Proportional and cardinal comparatives: When variation in scale dimensions meets COVID

We report a study on quantity comparatives that are ambiguous between **cardinal** and **proportional** readings. In degree-based semantics, comparatives express relations between degrees on a scale [1,2,9]. (i) is true if we compare *cardinalities of people*. (Ithaca is smaller than NYC.) But the 'reverse' in (ii) is true if we compare *proportions*: a larger proportion of Ithacans know their neighbors [8]. Here the *scale* tracks 'proportions of a totality', not cardinalities [8].

(i) ***Cardinal*** More residents of New York City than Ithaca know their neighbors
$|NYC_{know\_neighbor}| > |ITH_{know\_neighbor}|$
(ii) ***Proportional*** More residents of Ithaca than New York City know their neighbors
$|\underline{ITH_{know\_neighbor}}| / |ITH_{population}| > |\underline{NYC_{know\_neighbor}}| / |NYC_{population}|$

Though both readings are available, questions remain about whether – in constructions of the type in (i-ii) – one reading is preferred and if so, what modulates this (see also [3,7]), and what this means for how to capture the existence of scales ranging of degrees of proportions [8]. Prior work largely assumes cardinality readings are preferred [8]. We test this experimentally, and suggest that a dispreference for proportional readings, if it exists, could be due to their greater complexity (depend on numerator, denominator). In addition, cardinal vs. proportional readings (at least with certain quantifiers) have been argued to be constrained by predicate type [6,8], in particular stage-level predicates (describing transient properties, e.g. *is feverish*) vs. individual-level predicates (describing stable/permanent properties, e.g. *has a college degree*).

Recently, the cardinal-proportional ambiguity has been highlighted by the COVID pandemic, as shown by confusion about public health information (ex.iii). This situation also provides a meaningful, naturalistic context for experiments. We test 2 hypotheses: **(a)** *Simplicity hypothesis:* Cardinality readings are preferred over proportional readings in quantity comparatives (Exp1) and superlatives (Exp2). **(b)** *Predicate hypothesis:* Availability of cardinality vs. proportional interpretations is modulated by predicates (in ways that seem related to individual-/stage-level).
(iii) *Naturalistic example of confusion between cardinal and proportional readings (www)*
A: Alaska has more COVID than California…riiiight. ***B***: No, the percentage goes by their population individually (…) Yeah California is bigger buuuut the percentages are only going off each states numbers. (…) They aren't counting people, only percentages of those people

We test both statements about COVID cases/infections (*stage-level*) vs. vaccinations/vaccinated people (*individual-level*) to assess the predicate hypothesis in a realistic context.

Exp1 Comparatives. 139 native English speakers saw pairs of COVID county dashboards (Fig.1, 8 different pairs) and typed words into blanks (Table 1) to indicate their interpretations. In a pair, one county had higher absolute numbers of COVID cases (or vaccinated people); one had a higher proportional COVID rate (or higher % of vaccinated people): The cardinal/proportional readings are truth-conditionally distinct. We tested 4 wording types (Table 1). More+*NP* conditions (2a,b) should allow cardinal *and* proportional readings (depending on predicates) and will shed light on our hypotheses. Two control conditions verify availability of cardinal (3a,b) and proportional readings (4a,b). The *'more COVID/vaccinated'* conditions (1a,b) are exploratory, testing if *eliminating direct reference to vaccinated people*/*countable cases* weakens the cardinality bias (which involves 'counting people'). To do this, (1a,b) use place-name meaning transfer (see [5]), e.g. *Lakehorne County has more COVID than Blue Oak County*.

Exp2 (Superlatives, n=129) used 3-dashboard displays and superlative wording (*the most*, Table 1), to see if the results extend to proportional superlatives [4]. On a trial, one county had the highest absolute number; one the highest proportional number; one was in-between.

Results. In both studies (Figs.2,3), comparisons involving *COVID cases (stage-level) receive*

more cardinal readings than comparisons involving vaccination (individual-level). All COVID /vax differences are significant (p's<.05, glmer), except Exp2 'number' conditions. These effects coexist with an overall ***cardinality bias*** in both Exp1,2: All conditions yield above-chance rates of cardinality readings (p's<.05), except for proportion controls (4a,b, as expected) and the 'more/most vaccinated' construction (1b). This fits our hunch that meaning transfer (place name use) disprefers cardinal scales – suggesting the cardinality bias is indeed a malleable bias and not hard-wired. The exp1-2 parallelism is compatible with decompositional analyses of *most* [3,4].

Table1 *(people type county names in blanks)*	**Exp 1: Comparatives**	**Exp 2: Superlatives**
1a. People/cases not directly ment'd COVID	_ has more COVID than _	_ has the most COVID.
1b. People/cases not directly mentioned vax	_ is more vaccinated than _	_ is the most vaccinated.
2a. more/most COVID cases	There are more COVID cases in _ than _	_ has the most COVID cases.
2b. more/most vax'd people	There are more fully vaccinated people in _ than _	_ has the most fully vaccinated people.
3a. number of COVID cases *(card)*	The number of COVID cases is higher in _ than in _	_ has the highest number of COVID cases.
3b. number of vax'd people *(card)*	The number of fully vaccinated people is higher in _ than in _	_ has the highest number of fully vaccinated people.
4a. COVID case rate *(prop)*	The rate of COVID cases is higher in _ than _	_ has the highest rate of COVID cases.
4b. vaccination rate *(prop)*	The vaccination rate is higher in _ than in _	_ has the highest vaccination rate.

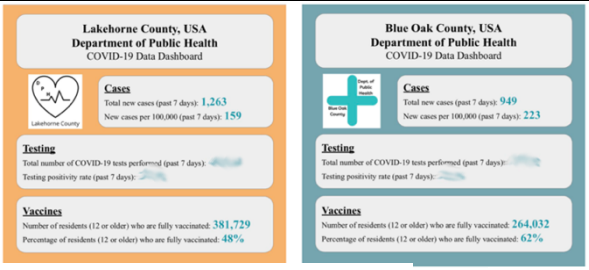


Fig 1. Exp1 example with two county dashboards, e.g. *Lakehorne County, Blue Oak County*. (Proportional COVID cases reported *out of 100,000*, vaccination rates as *%*, following common U.S. practice. Testing info was blurred out, it is irrelevant here.)

Fig2. *Exp1 Comparatives*: Cardinal vs. proportional interpretations

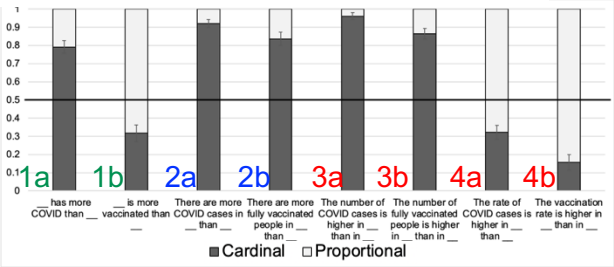
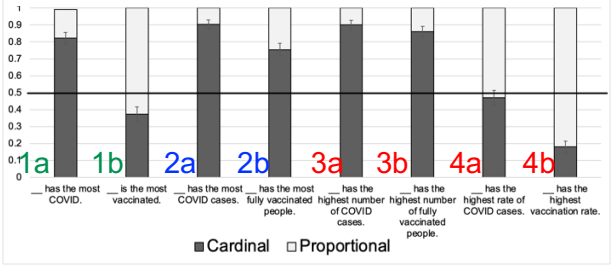


Fig3. *Exp2 Superlatives* (3rd county chosen on 1.48% of trials; excluded from analysis)



We provide new evidence that comparatives and superlatives refer to scales where the degrees *d* range over *degrees of proportion*. We identify a cardinal bias, but it is not rigid and can be weakened in favor of proportional readings by factors seemingly related to stage-/individual-level differences, and by certain linguistic forms (1b), suggesting specific syntactic and semantic factors impact scale interpretation (degrees of cardinality vs. proportion) in ambiguous contexts.

[1] Beck'11 *Comparison constructions* [2] Cresswell'77 *Semantics of degree* [3] Hackl'09 *On the grammar and processing of proportional quantifiers* [4] Kotek et al'12 *Many readings of most* [5] Nunberg'95 *Transfers of meaning* [6] Partee'89 *Many quantifiers* [7] Pietroski et al'09 *The meaning of 'most'* [8] Solt'18 *Proportional comparatives and relative scales* [9] von Stechow'84 *Comparing theories of comparison*