# Counting While Talking: Different Signatures for Verbal and Nonverbal Counting

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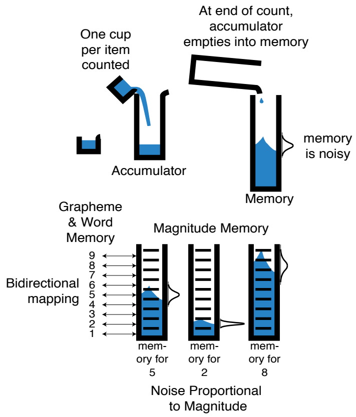
Humans appear to have a nonverbal counting process that generates mental magnitudes representing numerosities (Gallistel & Gelman, 1992, 2000; Gelman & Cordes, in press). This process is well-modeled by an accumulator system (Meck & Church, 1983).




**The Accumulator Model**

A magnitude representing a numerosity is formed through accumulation of 'cup fulls' of activation, one cup for each item enumerated. Accumulated magnitudes from an on-going count may be compared to a magnitude stored in memory or may be mapped to symbols for quantities. However, magnitudes read from memory have inherent scalar variability that may result in errors. The greater the magnitude, the more likely an error.

**Variability Signatures Should Differ for Verbal and Nonverbal Counting**

Magnitudes may also be accessed independent of the verbal counting system. We assume that verbal and nonverbal counting predict distinct variability distributions:

-Nonverbal counting should yield scalar variability due to noise in memory, evidenced by a constant coefficient of variation (or c.v. - the ratio of the standard deviation to the mean).

-The equal probability of a verbal counting error (skipping or double-counting items) at each step in a verbal count suggests binomial variability, evidenced by a negative correlation between the c.v. and the numerosity counted.

**The Small Number Debate**

We hold that all real numbers are represented on this same mental continuum. Scalar variability should be found continuous throughout the small (1-4 or 5) and large number ranges.

Others argue that small numbers are processed with perceptual mechanisms that do not employ a serial process and that yield discrete (as opposed to magnitude) representatives of numerosity (e.g., Spelke, 2000; Klahr & Wallace, 1973). If this is so, then scalar variability should not hold.

**Research Questions:**

(1) Do humans possess a magnitude-based nonverbal counting system modeled by an accumulator?

(2) Do data patterns from verbal counting differ from those from nonverbal counting? Does verbal counting indeed yield binomial variability?

(3) Are small numbers represented as magnitudes on the same mental continuum as larger numbers?

## Method

***Participants:*** 8 adult human subjects (2 male, 6 female)

***Procedure:*** Subjects rapidly pressed a button as many times as indicated by an Arabic numeral on the computer screen. There were 2 counting conditions:

*(1) Nonverbal Counting*: Subjects repeated "the" with each and every press, without verbally counting, just "doing it by feel".
*(2) Verbal Counting*: Subjects counted their presses aloud, by using the traditional count list (Full Count condition), or groups of ten (e.g., 1, 2, ... 9, 10, 1, 2, …) (Tens Count condition).

We collected 20 data points per target number per subject. Subjects were presented stimuli from one of the three sets of target numbers used in this study:
(set A) 7, 9, 11, 13, 15, 17, 19, 21, 23, 25
(set B) 3, 5, 8, 13, 20, 32
(set C) 2, 3, 4, 5, 8, 13, 20, 32

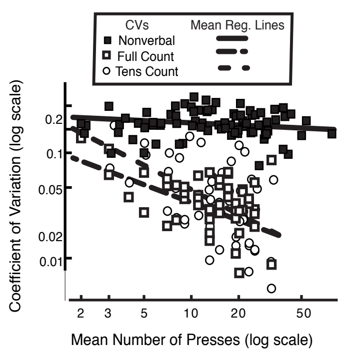
## Results

***Distinct Signatures:***
(a) Subject reports, experimenter observation, mean inter-response times, and data variability patterns all suggest that verbal counting did not play a role in the nonverbal counting condition.

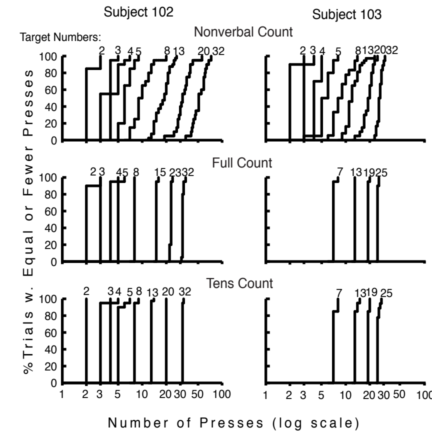
(b) In the nonverbal counting condition, the slope of the c. v. was not significantly different from zero (p>.05), indicating scalar variability. This slope did differ significantly from a binomial distribution (p<.05).

(c) In both verbal counting conditions, the slope of the c.v.. decreased in proportion to the inverse square root of the target numerosity, not differing significantly from binomial variability (p>.05). The difference between the slope of the c.v. and a zero value in the Full Count condition also approached significance (p=.07), while in the Tens Count condition this difference was statistically significant (p<.05).

**Thus, verbal counting and nonverbal counting are distinguished by the manner in which variability increases with the mean count: it increases in accord with the binomial law in the first case and in accord with the scalar law in the second. Humans are able to represent numbers both verbally (and/or symbolically) and nonverbally. Although these representations are mapped to each other, they can be accessed independently.**




*Coefficients of variation versus mean number of presses on double-log coordinates for all three conditions. The lines drawn have the mean slopes and intercepts of the population of slopes and intercepts obtained from the subject-by-subject*




*The cumulative normalized distributions of the number of presses made by two representative subjects for selected target numbers in the nonverbal counting and two verbal counting conditions.*

***It's Scalar All the Way Down:***
In the nonverbal counting condition, scalar variability was found all the way down the number line, in both the large and small number ranges. The slope of the c. v. in the small number range did not differ significantly from the slope for target numbers outside that range when:

(1) "small numbers" were considered to be 2-5 (p>.05).

(2) "small numbers" were considered to be 2-4 (p>.05).

(3) data from only those subjects tested using the full range of targets (set C) were included (p>.05).

**These results suggest small numerosities, like larger numerosities, are represented by mental magnitudes with scalar variability. Despite many arguments for discrete-valued representations of small numerosities, it appears that the mental number line is continuous.**

**In Sum…**

Our results lend support to the argument that humans have access to a nonverbal counting process that is independent from the verbal counting system. Nonverbal and verbal counting are distinguished by their signature variability - nonverbal magnitudes produce scalar variability, while use of the count words generates binomial variability. These mental magnitudes are continuous, as opposed to discrete, representing all real numbers, small and large, on the same continuum.

**References and Acknowledgements**

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