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Semantic priming increases word frequency judgments: Evidence for the role of memory strength in frequency estimation

Dan J. Woltz *, Michael K. Gardner

University of Utah, United States

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ABSTRACT

Previous research has demonstrated a systematic, nonlinear relationship between word frequency judgments and values from word frequency norms. This relationship could reflect a perceptual process similar to that found in the psychophysics literature for a variety of sensory phenomena. Alternatively, it could reflect memory strength differences that are expected for words of varying levels of prior exposure. Two experiments tested the memory strength explanation by semantically priming words prior to frequency judgments. Exposure to related word meanings produced a small but measurable increase in target word frequency ratings. Repetition but not semantic priming had a greater impact on low compared to high frequency words. These findings are consistent with a memory strength view of frequency judgments that assumes a distributed network with lexical and semantic levels of representation.

1. Introduction

The representation and utilization of frequency information in memory has attracted considerable attention over previous decades for several reasons. On a practical level, the availability of stored frequency information likely has had survival benefits. Ready access to accurate representations of past event frequency related to food, safety and reproduction has obvious benefit to the species. Despite some maladaptive heuristics (e.g., Tversky & Kahneman, 1973), it presumably has utility in many modern decision processes. For example, implicit knowledge of the likelihood of traffic events on a regular driving route may reduce attention demands and enhance driving skill. Similarly, an implicit representation of the frequency of patient outcomes may facilitate medical decision making. On a theoretical rather than practical level, this topic has attracted attention because frequency judgments may be based on different processes in different situations. Perhaps most intriguing, some frequency encoding processes appear to be largely automatic and surprisingly accurate regardless of age, practice, and task manipulations (Zacks & Hasher, 2002).

Early evidence of the accuracy of individuals' frequency judgments came from laboratory experiments that varied the number of exposures to different stimuli (e.g., words or pictures). For example, the correlation between actual and estimated exposure of words in a list of 70 was as high as .80 (Hasher & Zacks, 1979). The form of this relationship generally was assumed to be linear, and with frequencies in laboratory tasks only presenting a few exposures, it was difficult to evaluate alternative relationships. Nevertheless, some early evidence suggested nonlinearity (e.g., Hintzman, 1969; Howell, 1973a). Hintzman and Howell both presented participants with long word lists and varied the number of repetitions up to 10. Both noted that subjects overestimated the frequency at lower repetition levels and underestimated frequency at higher repetition levels. Hintzman showed in one experiment that this resulted in a logarithmic relationship between estimated and actual repetition frequency.

Recent evidence supports both the accuracy of individuals' frequency estimation and a logarithmic relationship between perceived and actual frequency (Woltz, Gardner, Kircher, & Burrow-Sanchez, 2012). In one experiment, participants rated the frequency of 200 words representing 10 frequency categories. The mean of individual fits for the linear relationship between perceived and actual frequency taken from word frequency norms was modest ($R^2 = .60$). In contrast, the mean fit of a logarithmic function for individual participant data was $R^2 = .95$. Furthermore, logarithmic model fits and parameter values were equivalent across four different rating scale formats.

Support for a logarithmic relationship between perceived and actual word frequency resembles evidence for Fechner's Law relating perceptual judgments to stimulus intensity for sensory domains such as light, sound and weight (see Wolfe et al., 2006). The Woltz et al. (2012) data was fit almost as well by a power function which corresponds to another seminal psychophysics theory, Steven's Law (Stevens, 1957). Thus, although the specific form of the non-linear relationship observed with word frequency estimates was not resolved, the general form of the relationship corresponded to those observed in a large body of psychophysics research spanning more than a century.

This similarity in perceptual and frequency judgment data might suggest common underlying processes. For example, Attneave and Koch (1962) proposed that the nonlinear relationship in psychophysical experiments could partly reflect the process of matching subjective

* Corresponding author.
E-mail address: dan.woltz@utah.edu (D.J. Woltz).

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magnitude of sensory perception with a subjective number scale (also see Garner, 1954; Garner, Hake, & Eriksen, 1956 for similar ideas). Such a mechanism could be extended to the matching of perceived event frequency with a subjective number scale, and thus explain the nonlinear relationships by a common psychophysical transformation of perception. However, subjective decisions about the intensity of sound, light and weight depend on the evaluation of current sensations. In contrast, subjective decisions about the frequency of prior events such as word exposure depend on the evaluation of memories that span decades. This difference makes it plausible that the nonlinear relationship found with word frequency judgments could reflect memory processes rather than a perceptual transformation, memory processes that are not instrumental in producing the nonlinear relationship found with judgments of immediate perception. The current experiments evaluate the viability of a memory strength rather than a perceptual transformation explanation for the logarithmic relationship observed between judged and actual word frequency.

A number of current theorists acknowledge the variety of ways that frequency information can be represented and utilized in frequency judgments depending on various factors (Brown, 1995, 2002; Haberstroh & Betsch, 2002). That notwithstanding, there have been two longstanding views about the representation and processing of frequency information beyond simple enumeration or other strategic processes. One view is primarily found in earlier works and assumes that the frequency of like events is automatically recorded at encoding as an implicit tally, count or tag that is relatively independent of other memory representations for the events (e.g., Alba, Chromiak, Hasher, & Attig, 1980; Hasher & Zacks, 1984; Howell, 1973b; Jonides & Jones, 1992; Underwood, 1969). This form of memory is assumed to underlie accurate frequency judgments without explicit or strategic processing. The other view assumes that frequency judgments reflect a form of strength in general memory representations of prior experiences. This has taken the form of multiple instance representation (e.g., Dougherty & Franco-Watkins, 2002; Dougherty, Gettys, & Ogden, 1999; Hintzman, 1988) or strength accrual in unitary, associative or distributed representations (e.g., Sedlmeier, 2002). In this research, we assumed a distributed network representation for lexical and semantic features of words (e.g., Masson, 1995; McClelland & Rumelhart, 1985). With memory distributed across a large number of network units, the memory strength for words that vary in prior exposure frequency is represented by differing weights in network connections. As with the direct coding view, the memory strength accounts assume implicit rather than explicit retrieval processes during frequency judgments, but they assume judgments are based on perceptions that reflect memory strength (e.g., perceived familiarity) rather than the retrieval of uniquely stored frequency information.

More recently, a third view of memory processes underlying frequency judgments has been proposed to explain laboratory findings problematic for a memory strength account. Hintzman (2004) reported evidence contrary to the view that a single dimension of memory strength is responsible for both frequency judgments and recognition confidence, an assumption made in his MINERVA 2 model (Hintzman, 1988). Several forms of analysis were used to test the assumed equivalence of stimulus exposure on recognition confidence and frequency estimation data collected after participants viewed 0, 1, 2 or 3 repetitions of 60 names at either short or long exposure durations (500 versus 2000 ms). The results were inconsistent with the premise that a single memory strength dimension influenced by both number and duration of exposures could account for performance in frequency judgments and recognition confidence. Instead, Hintzman proposed that frequency judgments were uniquely influenced by an automatic recursive reminding process. That is, each repetition of a stimulus reminds the participant of a previous exposure, and memory for these reminding episodes forms the basis of subsequent frequency judgments. Frequency judgments are assumed in to reflect the perceived "depth" of these stored remindings.

In this article, we focus primarily on the contrast of memory strength and simple tally (direct coding) views of frequency representation as they offer distinguishable explanations for the nonlinear relationship between perceived and actual frequency. The recursive reminding account has empirical support when frequency judgments are made for a relatively small number of repeated events that occur within a single experimental session. However, for judgments of word frequency based on a large number of exposures spanning decades, it is difficult to distinguish judgment processes that reflect the perceived depth of recursive reminding versus the perceived strength of lexical and semantic memory representations. In addition, despite the better fit of the recursive reminding model compared to a single strength model in Hintzman's (2004) work, he acknowledged the possibility that frequency judgments could be influenced by perceived familiarity reflecting memory strength (also see Hintzman, 2010). This issue will be revisited in General Discussion with respect to the current findings.

Both the automatic frequency coding and the memory strength views of frequency representation are capable of explaining a logarithmic or power function relationship between perceived and actual frequency, but they do so with different mechanisms. The existence of direct coding of frequency could produce such a relationship if individuals' perception of count magnitude resembles their perception of the intensity of light or sound. That is, the observed relationship could result from a perceptual transformation when individuals map perceived frequency onto a subjective number scale. In contrast, a memory strength explanation assumes that, over time, each additional exposure to a stimulus adds systematically decreasing strength to the memory representations for that information. This assumption is based on the almost universal slowdown of learning over extended practice events (e.g., Newell & Rosenbloom, 1981). Thus the nonlinear relationship between perceived and actual frequency would not necessarily reflect a transformation of one's perception of memory strength, but a nonlinear relationship between the number of prior events and the magnitude of memory strength increments.

Given the ability of each view to explain the empirical evidence of a nonlinear relationship between perceived and actual word frequency, distinguishing among them is challenging. In the current experiments we attempted to do so by strengthening semantic memory representations for stimulus words without incrementing the number of exposures of those words. This was done with semantic priming prior to frequency ratings. Our logic was that exposure to words that share meaning with target words should produce a temporary increase in semantic memory strength of the target words without direct exposure. If words are judged as more frequent when they have been semantically primed, it would support a memory strength view. Such an interpretation assumes that there is no conscious recollection of prime events that might influence frequency judgments. This possibility requires careful consideration in both task design and data interpretation, both of which are discussed later.

A secondary test of the memory strength account of word frequency judgments is possible by comparing the semantic priming effects on frequency judgments for high and low frequency words. Priming of low frequency words might be expected to produce a larger increment in memory strength and thus produce a larger increase in frequency ratings compared to the priming of high frequency words. Some previous research has shown larger repetition priming effects for low compared to high frequency words (e.g., Jacoby & Dallas, 1981). However, these effects are typically small and appear to depend on task characteristics (Ostergaard, 1998; Scarborough, Cortese, & Scarborough, 1977; Scarborough, Gerard, & Cortese, 1979; Toth & Daniels, 2002). There is also evidence for this effect from semantic rather than repetition priming experiments, but the evidence is limited and comes from tasks that require simple word identification and produce only short-term facilitation (Becker, 1979; Stone & Van Orden, 1992). Although previous research is not definitive regarding the relationship of word frequency and priming magnitude, particularly with respect to semantic priming, more than a century of research supports the principle that the benefit of repeating a learning event systematically declines with