ABUNDANT PRIMACY EFFECTS IN MAGNITUDE ESTIMATION OF LOUDNESS WITH INVARIANT STIMULUS RANGE

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Abstract

Since the seminal work by Stevens (1956, 1975) on establishing the psychophysical law, sensory attributes of stimuli such as loudness of tones, have commonly been assessed by magnitude estimation, in which participants directly assign a number to their current sensation (Gescheider, 1997). Magnitude estimation has been argued to largely resist the context effects, although the stimulus range was shown to modulate the loudness estimation of tones presented within the context of a low or a high intensity range (Gescheider & Hughson, 1991). Here, we examine if magnitude estimation of loudness varies as a function of the frequency of occurrence (base rate) and serial order of tones taken from the same intensity range. Fifty six healthy adults assigned to seven separate groups estimated - without a modulus - a set of five tones (60, 65, 70, 75, and 80 dB SPL, sound pressure level) that were equally frequent (base rate, 10-10-10-10-10, soft tones come on the left) and randomized (i) in a standard computer-assisted way or with a bias such that either mainly (ii) soft or (iii) loud tones occurred on the initial trials, i.e., at the series outset. With different-frequent tones, the four randomization conditions were as follows: (iv, v) on overall frequent soft tones (20-14-8-4-4) and (vi, vii) on overall frequent loud tones (4-4-8-14-20) with either mainly soft or loud tones presented at the series outset. The results indicate abundant primacy effects on magnitude estimation of loudness: Regardless of the overall base rate, higher estimations occurred with mainly soft rather than loud tones presented at the series outset. For the first time, we show the context effects in absolute magnitude estimation of loudness without varying the intensity range. The outcome questions the context invariance of psychophysical scales derived from absolute magnitude estimation. Further research is required to determine if the primacy effects observed are response-bias or sensory dependent.

Since the seminal work by Stevens (1956, 1975) on establishing the psychophysical law, sensory attributes of stimuli such as loudness of tones, have commonly been assessed by magnitude estimation. In this procedure, the participant is presented with a single stimulus and required to directly assign a number to the current sensory impression (Gescheider, 1997). Typically, the task is readily comprehensible and accessible for the participant, brief in administration, and therefore widely used both in basic and applied psychophysics. The task's

additional important feature is that magnitude estimations of sensations have been viewed to be, with some exceptions, largely robust and resistant to context effects.

An original version of the task employs a standard stimulus (modulus) assigned an arbitrary score (e.g., 10) by the experimenter prior to accomplishing the scaling procedure; the participant has to assign numbers to his or her sensations of other stimuli with respect to the modulus. The original procedure turned to be vulnerable to the context effects of modulus magnitude: a small modulus (e.g., 40 dB) resulted in much higher judgments than a large one (e.g., 90 dB; Hellman & Zwislocki, 1961; Zwislocki & Goodman, 1980; see also Gescheider, Bolanowski, & Verrillo, 1992). Gescheider (1997) therefore suggests using instead absolute magnitude estimation without a modulus as the task appears to be fairly free from the context effects. One exception is the work by Gescheider & Hughson (1991), showing that the stimulus range still can modulate absolute magnitude estimation of loudness of tones presented within the context of a low or a high intensity range.

Two mechanisms have been proposed to account for the context effects in psychophysical scaling: one suggesting that the context alters solely perception of stimuli (Algom & Marks, 1990; Helson, 1964; Marks, 1992; Parker & Schneider, 1994; Schneider & Parker, 1990; Ward, 1990), and the other suggesting that the response bias, and hence judgment itself, is altered (Foley et al., 1990; Mellers, 1983; Poulton, 1979). While the perception account does not pose a problem for the validity of psychophysical scales obtained, the response bias account does as it implies the resulting scales fail to reflect the true magnitude of sensation (Gescheider, 1997).

Category judgments of visual stimuli have been shown to exhibit the frequency and primacy (serial presentation order) effects of context: For example, for identical ranges of stimulus speeds, greater judgments of visual speed occur with on overall frequent low compared to high speeds, and with mainly low compared to mainly high speeds presented on the initial trials, that is, at the series outset (Sokolov, Pavlova, & Ehrenstein, 2000). Here we examined if absolute (i.e., without a modulus) magnitude estimation of loudness would vary as a function of the frequency of occurrence (base rate) and serial order of distinct tones taken from the same intensity range. We expected to observe at least primacy effects as the initial stimuli of a series (i.e., either mainly soft or loud tones) might provide the participant with a kind of modulus relative to which to judge the remainder of the stimuli.

Method

Participants

Fifty six healthy male and female young adult volunteer participants assigned randomly to seven separate groups of eight (see below), took part in the study. They had normal hearing and vision, were right-handed, unaware of the aim of the research, and run individually.

Stimuli and procedure

We used the same five distinct tones of 1 kHz taken from a fixed intensity range throughout (60, 65, 70, 75, and 80 dB SPL, sound pressure level above threshold). In each group, however, the tones in a presentation series varied in their presentation order (that is, which – mainly soft or loud – tones occurred at the beginning, or outset, of the series) and overall frequency of occurrence (base rate; i.e., which tones on overall were more frequent in the series; Figure 1). Note that merely for statistical reasons (Johnson & Kotz, 1977), standard randomization of different-frequent stimuli for presentation makes on overall frequent stimuli

more likely to occur at the very beginning of the presentation series. In an earlier work (Sokolov et al., 2000), we proposed an algorithm of biased randomization that makes on overall *in*frequent rather than on overall frequent stimuli more likely to occur on the initial trials. The manipulation allows for separately assessing the primacy (presentation order) and frequency effects of stimulus context on judgment. The present between-subject study design therefore comprised the following seven conditions, each administered to a separate group of participants: equally frequent soft and loud tones (base rate, 10-10-10-10-10; soft tones come on the left) (1) randomized for presentation in a standard computer-assisted way or randomized with a bias such that either (2) mainly soft or (3) mainly loud tones occurred at the series outset. The two latter presentation series were similar except for the content of their initial trials, that is, except for their presentation order to assess a pure primacy effect.

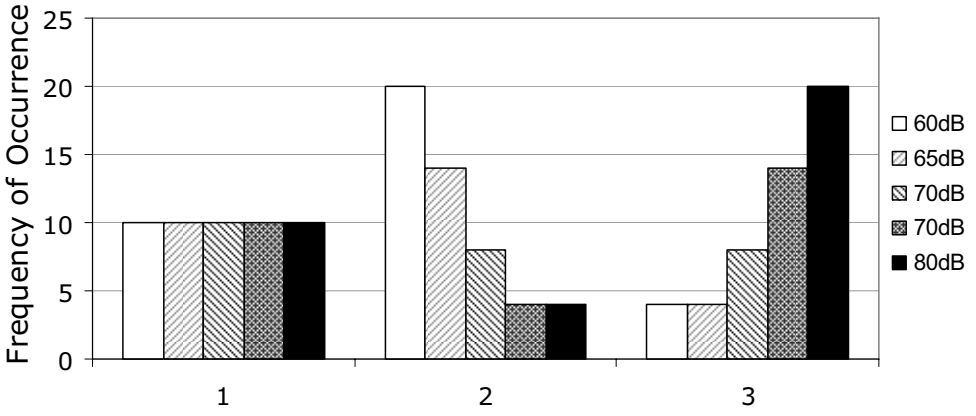


Figure 1. Three frequency distributions of five tones taken from a fixed intensity range (60, 65, 70, 75, and 80 dB SPL) used in the study. *1*, Equally frequent tones; *2*, on overall frequent soft tones; *3*, on overall frequent loud tones. With different-frequent tones (*2* and *3*), standard randomization yields more frequent, either soft or loud, stimuli more likely to occur at the beginning of the series, and biased randomization mainly *in*frequent stimuli to occur earlier. Biased randomization of equally frequent tones (*1*) yields either mainly soft or mainly loud ones to occur at the outset.

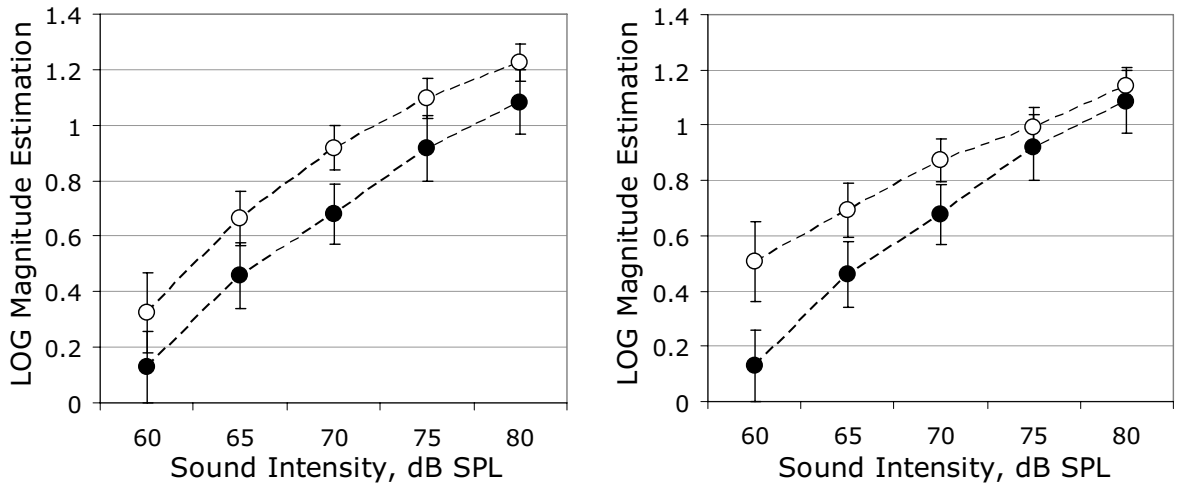
For series of different-frequent tones, the randomization conditions were as follows: on overall frequent soft tones (base rate, 20-14-8-4-4; soft tones on the left) with either (4) mainly soft tones (standard randomization) or (5) mainly loud tones (biased randomization) presented at the series outset, and on overall frequent loud tones (4-4-8-14-20) with either (6) mainly loud tones (standard randomization) or (7) mainly soft tones (biased randomization) presented at the series outset. These series therefore differed both in the frequency of occurrence and presentation order of stimuli to allow exploring both frequency and primacy effects.

The participant was seated in a sound-protected and dimly lit chamber in front of a computer screen, which automatically displayed written instructions and provided a window for manually entering from the keyboard by the participant his or her magnitude estimations. The experiments started automatically after the participant's entering gender and age information and confirming the understanding of on-screen instructions. The tones were presented one per trial through the stereo earphones; the individual SPL thresholds were determined prior to the experiment. The experiment was controlled by the MATLAB Psychophysics Toolbox, PsychToolbox, extensions for Microsoft Windows (Brainard, 1997)

running on a Pentium-4 PC workstation with a high-quality sound board. The participants received a standard instruction for absolute magnitude estimation of loudness, asking "not to worry about the numbers assigned to preceding stimuli" (Zwislocki & Goodman, 1980; Gescheider, 1997, p. 254). No information about stimulus probabilities was given to the participants prior to the experiment, and no immediate feedback was provided regarding performance.

Results

We used a series of two-way Group (Condition) by Sound repeated measures analyses of variance (ANOVA) on log-transformed individual medians of magnitude estimations as a dependent measure to accomplish comparisons between the distinct groups (conditions).



A B

Figure 2. The primacy effects for series of different-frequent tones: higher magnitude estimations occur with mainly soft rather than loud tones presented at the series outset ($p < 0.01$). *A*, On overall frequent soft tones with either mainly soft, *open* symbols, or loud tones, *closed* symbols, judged at the outset. *B*, On overall frequent loud tones with mainly soft tones judged at the outset, *open* symbols, *vs.* on overall frequent soft tones with mainly loud tones judged at the outset, *closed* symbols. A data point shows log-transformed averaged individual median magnitude estimations; vertical bars, ±1 *SEM*.

For the series of different-frequent tones regardless of the overall frequency of occurrence, much higher magnitude estimations occurred with mainly soft rather than mainly loud tones presented at the series outset (the primacy effect). This was seen when comparing the conditions with frequent soft tones, but either mainly soft or mainly loud tones presented at the outset (main effect of condition, $F(1;14) = 6.222$, $p < 0.015$; Figure 2A), and the condition with frequent loud tones, but mainly soft tones judged at the outset, *versus* the condition with frequent soft tones, but mainly loud tones judged at the outset (main effect of condition, $F(1;14) = 6.697$, $p < 0.012$; Figure 2B). No difference (i.e., no primacy effect) was observed in magnitude estimations for the series of frequent loud tones regardless of whether mainly soft or mainly loud tones occurred at the outset (main effect of condition, $p > 0.05$).

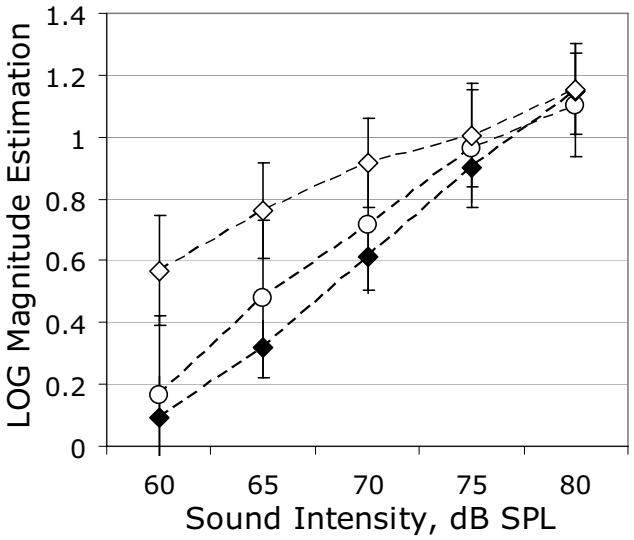


Figure 3. The primacy effect for series of equal-frequent tones ($p < 0.01$). The series with standard randomization of tones for presentation, *open* circles; the series randomized with a bias such that either mainly soft tones, *open* diamonds, or mainly loud tones, *closed* diamonds, were presented at the series outset.

Most important, the effect of the content of initial trials observed with the series of tones differing in their overall frequency, was further supported by a finding of the primacy effect for the series of equal-frequent tones that were randomized for presentation with a bias such that either mainly soft or mainly loud tones occurred at the outset: Magnitude estimations of loudness were higher with mainly soft tones judged on the initial trials (main effect of condition: $F(1;14) = 6.902$, $p < 0.011$; Figure 3).

In the conditions with different-frequent tones, no any frequency effects were found whatsoever. For pairwise comparisons of the experimental conditions, the outcome indicated main effects of sound (all $p < 0.01$) and no any sound by condition interactions.

Discussion and Conclusions

In this study, we for the first time demonstrate the existence of primacy effects of stimulus context on absolute (i.e., without a modulus) magnitude estimation of loudness of tones taken from a fixed intensity range. Much higher magnitude estimations of the same tones occurred when the initial trials of a presentation series comprised mainly soft rather than mainly loud tones. The findings extend previous evidence on context effects in absolute magnitude estimation obtained with variable stimulus range (Gescheider & Hughson, 1991) as in the present study, the intensity range remained unchanged and the tones in the series varied in their frequency of occurrence (base rate). One possible account of the primacy effects obtained is that the initial stimuli establish a kind of *internal modulus* relative to which the remainder of the stimuli in the series is judged. However, as no any effects of base rate of stimuli were found, it is conceivable that it is loudness itself (i.e., sensation) rather that the loudness judgment that is affected (cf. Schneider, & Parker, 1990).

Previous research has held that unlike conventional magnitude estimation with a modulus, absolute magnitude estimation is fairly prone to the effects of stimulus context. The

present findings question this proposal as does some earlier evidence. Further research is required to determine the precise mechanisms and locus of the context effects on magnitude estimation, in particular, whether they are response bias or sensory dependent. This is essential for the issue of validity of psychophysical scales obtained by means of magnitude estimation.

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