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Original article

Differential effects of stimulus context in sensory processing

Effets différentiels du contexte de présentation des stimuli sur les processus perceptifs

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Abstract

Stimulus contexts in which different intensity levels are presented to two sensory–perceptual channels can produce differential effects on perception: Perceived magnitudes are depressed in whichever channel received the stronger stimuli. Context differentially can affect loudness at different sound frequencies or perceived length of lines in different spatial orientations. Reported in hearing, vision, haptic touch, taste, and olfaction, differential context effects (DCEs) are a general property of perceptual processing. Characterizing their functional properties and determining their underlying mechanisms are essential both to fully understanding sensory and perceptual processes and to properly interpreting sensory measurements obtained in applied as well as basic research settings.

Résumé

Les contextes dans lesquels on présente des niveaux différents d'intensité de stimuli à deux canaux sensoriels/perceptuels, peuvent produire des effets différentiels sur la perception : les intensités perçues sont diminuées dans le canal recevant les stimuli les plus intenses. Le contexte peut affecter différentiellement la sonie de sons présentés à différentes fréquences ou la longueur perçue de lignes présentées dans différentes orientations spatiales. Démontrés en audition, vision, perception haptique, goût et olfaction, les effets différentiels de contexte sont une propriété générale du traitement perceptif. Caractériser ses propriétés fonctionnelles et déterminer ses mécanismes fondamentaux est essentiel pour comprendre les processus sensoriels et perceptifs, ainsi que pour interpréter correctement les mesures sensorielles réalisées dans le domaine de la recherche fondamentale comme appliquée.

Keywords: Contextual effects; Stimulus intensity; Perceptual magnitude; Sensory processes

Mots clés : Effets de contexte ; Intensité du stimulus ; Grandeur perceptive ; Processus sensoriels

1. Introduction

It has long been known that judgments of sensory magnitudes depend not only on the physical characteristics of each stimulus that is judged—on its intensity, duration, qualitative make-up, and so forth—but also on the physical characteristics and perceptual properties of other stimuli presented either recently or at the same time. Especially well-known in this regard is Helson's (1964) adaptation-level theory, developed in large measure to account for the ways that the judgments given to a test stimulus depend on the contextual ensemble of other stimuli that form its immediate background. A sound of fixed intensity and frequency, for example, may be rated as louder or softer in the context of other relatively weaker or stronger sounds—an example of sensory contrast.

Abbreviations: DCE, differential context effect; Hz, Hertz; RT, response time; SPL, sound pressure level.

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A line of investigation that began in the first author's laboratory nearly 20 years ago (Marks, 1988) led to the discovery of stimulus-specific context effects similar to, though far from identical to, those analyzed by Helson (1964) several decades earlier. These stimulus-specific or *differential contextual effects* are pervasive: They appear in virtually every sensory modality tested. Their functional characteristics suggest that they reflect sensory changes induced at an early stage in perceptual processing. Obviously, it is important, from a theoretical perspective, to understand these (and other) contextual effects if we are to understand fully the mechanisms of sensory information processing. Further, from a practical perspective, the omnipresence of differential contextual effects in perception and perceptual judgment also underscore their relevance to the proper interpretation of findings obtained in applied as well as basic research settings. Consequently, the present paper has three main goals: first, to review the main empirical findings on differential context effects (DCEs); second, to assess, given current understanding, the likely source or sources of the effects: whether they reflect relatively early sensory processes or later decisional ones; and third, to show how DCEs can affect experimental results obtained in studies assessing sensory or perceptual processes.

2. DCEs characterized

DCEs first appeared in a study that asked people to rate the perceived magnitude (loudness) of tones that varied multidimensionally, in their frequency as well as intensity (Marks, 1988). In the basic paradigm of that study, subjects were presented tones selected from an ensemble consisting of 12 possible intensity levels (sound pressure levels, or SPLs) at each of two sound frequencies, one low (500 Hertz, Hz) and another high (2500 Hz). In one contextual condition (A), subjects heard the eight lowest SPLs at 500 Hz and the eight highest SPLs at 2500 Hz, whereas in the second condition (B), the assignment of SPLs to frequency reversed, the subjects hearing the eight highest SPLs at 500 Hz and the eight lowest at 2500 Hz. Thus, four SPLs at each frequency were common to the two contextual conditions, and it is the responses to these common tones that are critical (Fig. 1).

A typical result is shown in Fig. 1, which plots the average numerical judgments (magnitude estimates) of loudness against SPL at 500 and 2500 Hz, separately in condition A (left side of figure) and condition B (right side of figure). Context clearly affected the relative (differential) responses at the two frequencies. Consider the responses to the 500 and 2500-Hz tones when both were presented at 60 dB SPL, as they were in both conditions. In condition A, the two tones were judged nearly equal in loudness, the 60-dB 2500-Hz tone receiving a very slightly greater judgment than the corresponding 500-Hz tone; but in condition B, the 2500-Hz tone was judged much louder than the 500-Hz tone. In general, considering just the four stimuli at each frequency common to the two contextual conditions, the 500-Hz tones were rated louder in condition A versus condition B, whereas the 2500-Hz tones were rated louder in condition B versus condition A. This is the prototypical pattern of DCEs.

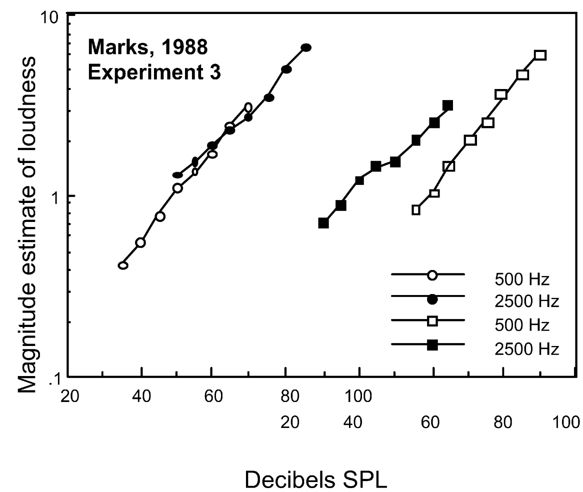

Fig. 1. Magnitude estimates of loudness of 500 and 2500-Hz tones. In contextual condition A (left), the SPLs at 500 Hz were low and those at 2500 Hz were high; in condition B (right), the SPLs at 500 Hz were high and those as 2500 Hz were low. Data from Marks (1988).

These contextual effects are not specific to the method of magnitude estimation. Similar contextual effects arise in tasks that use a variety of methods. For example, Schneider and Parker (1990) obtained similar findings when subjects compared loudness intervals. Importantly, DCEs appear even when the subject's task is simply one of direct comparison, that is, when the subject is presented on each trial with two stimuli in succession and simply indicates which of them is greater. Using ensembles of 500 and 2500-Hz tones constructed similarly to those in Fig. 1, direct loudness comparison also reveals DCEs (Marks, 1992a, 1994) (Fig. 2).

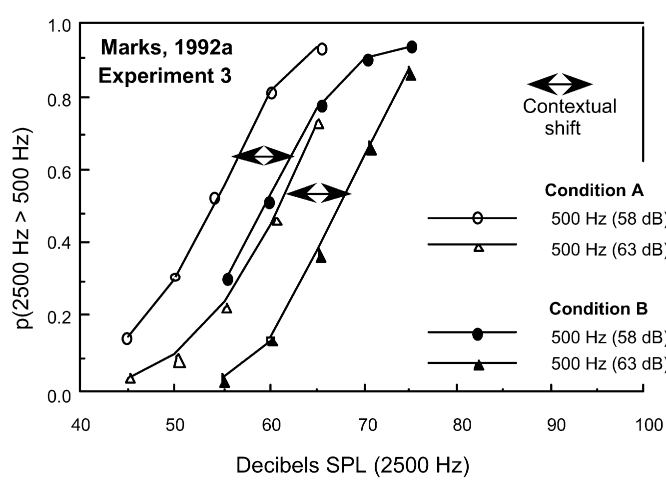

Fig. 2. Psychometric functions, showing how the probability that a 2500-Hz tone was judged louder than a 500-Hz tone, in two contextual conditions. In condition A (left-hand function in each successive pair, open symbols), the SPLs at 2500 Hz were 10 dB lower than they were in condition B (right-hand function in each successive pair, filled symbols), while the SPLs at 500 Hz were the same in both conditions. Changing the context displaces the functions as indicated, reflecting the changes in loudness. Data from Marks (1992a).