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► **To cite this version:**

| Sabine Meunier. Tribute to Bertram Scharf. Acoustics 2012, Apr 2012, Nantes, France. hal-00811386

**HAL Id: hal-00811386**

**<https://hal.science/hal-00811386>**

Submitted on 23 Apr 2012

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# ACOUSTICS 2012

## Tribute to Bertram Scharf

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This paper is a tribute, which the Groupe Perception Sonore of the SFA wishes to pay to Professeur Bertram Scharf who died on 30 November 2011. Since 1978, Professor Scharf divided his time between the USA and France. He was a professor in psychology at Northeastern University. In France, he was a visiting scientist until the mid-1990s in the "Laboratoire de Mécanique et d'Acoustique" in Marseille and collaborated with the University of Marseille (Faculté de Médecine) until now. Professor Scharf's major contributions to the field of psychoacoustics concern the perception of intensity. His major works focused on loudness, loudness adaptation and detection. He was among the first who studied, during the auditory efferent system using psychoacoustical paradigms. This paper focuses primarily on his collaboration with his French colleagues.

## Introduction

Professor Bertram Scharf was born on 3 March 1931 in the Bronx (New-York, USA) and died in France on 30 November 2011 (Cassis). He graduated *cum laude* from City College of New-York in 1953. He obtained his Experimental psychology "Diplôme" at the "Université de Paris" in 1955. He returned to the USA and received a Ph.D. in psychology at Harvard University in 1958. He worked at Northeastern University (Department of Psychology) as Assistant Professor, Associate Professor, and Professor from 1958 until 1994, after which he became Research Professor. He traveled a lot as a Visiting Scientist in Germany, Finland and France. France became his second home and, since 1978, he split his time between Boston and Marseille (or Cassis). In Marseille, he worked at the "Laboratoire de Mécanique et d'Acoustique" (Mechanics and Acoustics Laboratory) with Georges Canévet who has created the psychoacoustics team in the laboratory. Bertram Scharf was part of this "adventure". Afterward, he worked at the "Université d'Aix-Marseille, Faculté de Médecine" where he started his work on the role of the olivocochlear bundle in hearing. He served as an associate editor of the Journal of the Acoustical Society of America. He was a founding member of the International Society for Psychophysics (ISP). He received several honors, among them, in 1995, the Fechner Medal from ISP.

Most of Bertram Scharf's contributions in psychoacoustics concerned loudness: spectral loudness summation (among his first publications), binaural summation of loudness, loudness adaptation, induced loudness reduction.

Bertram Scharf also orientated his work on frequency selectivity and the role of attention in frequency selectivity.

He had several contributions on binaural hearing and auditory localization, especially when working in Marseille with Georges Canévet and Jens Blauert from Bochum (Germany).

In Marseille, he collaborated with physicians on the role of the olivocochlear bundle in hearing. A pioneer study that could be developed because of the cooperation between Bertram Scharf and surgeons in Marseille that used vestibular neurotomies in the surgical management of incapacitating Meniere's disease, during which the olivocochlear bundle is severed

In this paper, I will focus on two of Bertram Scharf's contributions to the field of psychoacoustics: spectral loudness summation and loudness adaptation

Scharf (1978 [18], p. 227) defined loudness in the following manner:

*"Loudness is the subjective intensity of a sound. Subjective means a sentient listener, human or animal,*

*must respond to the sound. Intensity is normally a physical term, but the modifier "subjective" puts intensity in the observer and brings along all the other senses where subjective intensity seems to be part and parcel of every sensation."*

## Spectral loudness summation

When a sound is broadened in frequency, its loudness stays constant (with overall level constant) until a critical bandwidth is reached, above which the loudness increases. The increase in loudness is called spectral loudness summation (it had been known as loudness summation, but this expression can be confusing because of binaural loudness summation which is another kind of loudness summation).

Bertram Scharf contributed to the study of spectral loudness summation from the early beginning as can be found in one of the first paper on that topic by Zwicker *et al.* (1957 [25]): *"The experiments with pure tones were begun by Stevens early in 1956, with the assistance of Bertram Scharf."*

Bertram Scharf published several papers on this topic. He worked on spectral loudness summation near threshold (Scharf, 1959a [13]). He found that spectral loudness summation depends on level. While above 10 dB SL (Sensation Level, i.e. level above individual threshold), the loudness of a complex sound increases for bandwidths larger than a critical band, at 5 dB SL, no increase in loudness was found. He even found, at some frequencies, a decrease of loudness. The same results were found under masking, showing that the amount of spectral loudness summation *"varies more closely with the Sensation Level than with the Sound Pressure Level"* (Scharf, 1961b [16]). The width of critical bands does not depend on intensity while the amount of the increase in loudness by spectral summation depends upon the intensity of the sound.

Bertram Scharf also studied the effect on spectral loudness summation of the number of components in a complex sound (Scharf, 1959b [14]). The complexes were composed of two, three, four and eight pure tones equally intense, with constant overall widths. Loudness was found to be independent of the number of components within the complex.

In 1961, Bertram Scharf [15] published an interesting review of critical bands. He described four ways to measure critical bands: absolute threshold of complex sounds, masking of a band of noise by two tones, sensitivity to phase differences and loudness. The end of the paper opens the door to the next 50 years (or more) of researches on hearing:

*"With the experimental basis for the critical band reasonably well established, investigators are beginning to consider the relevance of the critical band to the loudness of pure tones, to temporal integration, to deafness, to speech perception and to other auditory process"*

He started this work with Zwicker in 1965 by the publication of the article: "A model of loudness summation" [24]. In this article, the bases of the model developed by Zwicker are given. It is nowadays often known as "Zwicker's model", and has been standardized in DIN 45 631 and ISO 532.

## Loudness adaptation

A sensory system adapts when the sensation decreases over time while the physical stimulus is constant. A lot of sensations adapt: brightness, odor intensity, taste. For example, when exiting from a dark room, the brightness of the sun seems very strong while it decreases after a certain time of adaptation. For a long time, "the question of: does loudness adapt?" was asked. Bertram Scharf and his colleagues [9] gave a first answer: *"Loudness may adapt, after all"*. But *"Loudness resembles pain in that it decreases as a function of time only under special stimulus conditions."* (Scharf, 1983 [19]).

Different studies showed a decrease in the loudness of a steady stimulus over the first 2 or 3 minutes of exposure. However, in most of the experiments, an interaural matching procedure was used (Hood, 1950 [11]; Egan, 1955 [8] for example). A continuous sound, with constant level and frequency, was presented to one ear; the task of the listener was to adjust the level of a brief sound, played intermittently to the other ear, in order to make it equal in loudness to the continuous sound. After some minutes of exposure to the continuous sound, the level of the intermittent sound was decreased, showing a decrease in the loudness of the continuous sound. However, when no contralateral signal was used, very little adaptation was found (Canévet et al., 1981 [3]; Scharf, 1983 [19]); when it appears, it is called simple loudness adaptation, in contrast to induced loudness adaptation when loudness adaptation is induced by a second sound, such as in measurements using matching procedures.

## Simple loudness adaptation

In order to measure simple loudness adaptation, procedures are required that do not involve matching between two sounds. Scharf (1983 [19]) reviewed some of those procedures: absolute judgments, cross-modality matching and tracking. Among the absolute judgment procedures, Bertram Scharf proposed the method of successive magnitude estimation *"whereby the observer assigns numbers to express the loudness of a sound at successive time intervals"*.

Simple loudness adaptation occurs in very few cases. It has been observed only for pure tones (Scharf, 1995 [20]). Simple loudness adaptation is very strong, sometimes complete, at the lowest sensation levels (< 20 dB SL). Complete adaptation means that the sounds become inaudible. For levels above 20 dB SL, adaptation decreases rapidly, and disappears for levels above 40 dB SL (Canévet et al., 1981 [3], Scharf, 1983 [19]). Adaptation increases

with frequency (Canévet et al., 1981 [3], Scharf, 1983 [19]). High-frequency pure-tones produce more adaptation than low-frequency pure-tones: Bertram Scharf and his colleagues (Miskiewicz et al., 1993 [12]) showed that, at a high frequency, simple loudness adaptation can take place at relatively high sensation levels (40 dB SL). Bertram Scharf and his colleagues (Hellman et al., 1997 [10]; Miskiewicz et al., 1993 [12]) assumed that adaptation takes place when excitation is restricted to a narrow region of the cochlea. This hypothesis is supported by the strong adaptation observed for high frequencies as well as for low-level sounds that both provide a restricted spread of excitation.

Modulated sounds produce less adaptation than continuous sounds (Scharf, 1983 [19]) and there are large inter-individual differences in the magnitude of adaptation. Most listeners show a decrease in loudness of about 50% after one minute of exposure to a high-frequency pure tone at a low level; but some listeners may report no change in the loudness, whereas for other listeners the sound becomes inaudible (Scharf, 1983 [19]).

## Contralaterally induced loudness adaptation

As described previously, the loudness of a steady sound at high levels also decreases over time when played simultaneously with an intermittent sound in the contralateral ear (contralaterally induced loudness adaptation). Many papers co-authored by Bertram Scharf have reported this effect (for example Scharf, 1983 [19]; Botte et al., 1982 [2]; Canévet et al. 1983 [4], 1985 [5], 1989 [6]).

Contralaterally induced loudness adaptation was observed as well at high levels as at low levels of the continuous sounds. It increases with frequency but not as much as simple adaptation (Botte et al., 1982 [2], 1986 [1]). It is observed even when the inducer and the continuous tones frequencies differ (Botte et al., 1982 [2], 1986 [1]). But, contralaterally induced loudness adaptation is selective in frequency; a stronger effect was found for inducer frequencies close to the continuous tone frequencies (Charron and Botte, 1988 [7]). An inducer at the same level, louder or lower than the continuous tone, may induce loudness adaptation (Botte et al., 1982 [2]).

Bertram Scharf studied the recovery from loudness adaptation induced by a contralateral tone (Scharf et al., 1983 [22]). When the inducer is turned off (after 3 minutes of listening to the continuous tone plus the contralateral inducer) the recovery from loudness adaptation is small. In the presence of the inducer, the loudness of the continuous tone decreased by 60% within three minutes. Five minutes after the end of the inducer, loudness was still 50% below its initial value (at the beginning of the test, before any adaptation). After a long silence (30 s), and without any contralateral inducer, if the continuous tone is turned on, its loudness is still lower than it was initially. This partial recovery has not been found in simple adaptation.

## Ipsilaterally induced loudness adaptation

Loudness adaptation may also be induced by an intermittent sound presented to the same ear (ipsilaterally induced loudness adaptation). Bertram Scharf's contribution to ipsilaterally induced loudness adaptation can be found for example in Scharf, 1983 [19]; Canévet et al., 1983 [4], 1985 [5], 1989 [6]; Scharf et al., 1986 [23].

Ipsilaterally induced loudness adaptation does not depend on the frequency of the continuous tone (Charron and Botte, 1988 [7]). It depends on the level of the inducer. The increment in level produced to the continuous tone by the addition of the ipsilateral inducer must be 5 dB or more (Canévet et al., 1983 [4]). The greater the increment, the greater is the loudness adaptation (Canévet et al., 1983 [4]). Ipsilaterally loudness adaptation is stronger for pure tones than for noises (Scharf and Canévet, 1989 [21]). Below 40 dB SPL, the lower the base level (the continuous tone), the greater is the adaptation (Scharf and Canévet, 1989 [21]).

## Acknowledgments

I would like to thank Mary Florentine and Georges Canévet for their precious help in writing this paper.

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