PROCEEDINGS of the
23rd International Congress on Acoustics

9 to 13 September 2019 in Aachen, Germany

Parametric measurement of the effects of relative loudness on the relative weights

Alexander Fischenich[1]; Jan Hots[2], Jesko Verhey[2]; Daniel Oberfeld[1]

[1] Johannes Gutenberg-Universität Mainz, Germany

[2] Otto von Guericke Universität Magdeburg, Germany

Keywords: Sound, Loudness, Temporal weights

ABSTRACT

As many experiments have shown (Namba, Kuwano, & Kato, 1976; Oberfeld, Heeren, Rennies, & Verhey, 2012; Oberfeld, Jung, Verhey, & Hots, 2018; Pedersen & Ellermeier, 2008), the beginning of a sound is of greater importance for the judgement of loudness than later temporal parts. This pattern known as the *primacy effect* is largely independent of the sound duration (Oberfeld, Hots, & Verhey, 2018). Furthermore, it occurs both when the sound is presented in quiet and in the presence of continuous background noise and is not altered by the average sound pressure level of the temporal segments (Fischenich, Hots, Verhey, & Oberfeld, submitted). The primacy effect is well described by an exponential decay function with a time-constant of about 200-300 ms (Oberfeld, Hots, et al., 2018; Oberfeld, Jung, et al., 2018), where the temporal weight at the beginning of the sound is 4-5 times higher than the asymptotic weight, and where the weight assigned to a temporal portion of a sound is the integral of this function over the segment duration (Oberfeld, Jung, et al., 2018).

Another effect altering perceptual weights in loudness judgements is *loudness dominance*, which describes the phenomenon that temporal components of a sound that are systematically louder relative to other components within the stimulus receive increased weight and thus tend to dominate the global loudness judgement of a sound (Berg, 1990; Lutfi & Jesteadt, 2006; Oberfeld, 2015; Oberfeld, Kuta, & Jesteadt, 2013; Oberfeld & Plank, 2011; Ponsot, Susini, Saint Pierre, & Meunier, 2013; Richards, Shen, & Chubb, 2013; Turner & Berg, 2007). The aim of the present study was to gain insight into the parameters that modulate the size of the loudness dominance effect. How does loudness dominance interact with the temporal weighting? Do effects of forward or backward masking on intensity resolution (Oberfeld, 2008; Zeng, Turner, & Relkin, 1991) play an important role for the occurrence of loudness dominance? And is the effect of relative component level symmetric in the sense that amplifying the level of a stimulus component by, e.g., 15 dB relative to the remaining temporal stimulus components increases the weight on the amplified segment by a given factor, while an attenuation by 15 dB decreases the weight on the attenuated segment by a comparable factor?

In two experiments, we measured temporal weights in loudness judgments for level fluctuating sounds. All sounds consisted of 100-ms Gaussian wideband-noise-segments (20-20,000 Hz). In Experiment 1, the sounds contained of four such segments which were separated by 500-ms silent gaps, which should reduce the effect of non-simultaneous masking between adjacent segments (Zeng & Turner, 1992). In Experiment 2, the sounds consisted of either four or ten contiguous segments. Level fluctuations were created by assigning each segment a sound pressure level drawn independently and at random from a normal distribution on each trial. The task of the listeners was to judge whether the sound presented on a given trial was "louder" or "softer" compared to the sounds they had encountered on previous trials. To investigate the effect of relative segment level within a sound (loudness dominance), in some experimental conditions the mean of the level distribution of certain segments was attenuated or amplified relative to the remaining segments. In Experiment 1 (four-segment sounds with silent gaps), either segment 1 or segment 3 received an amplification of 5 or 15 or an attenuation of 5 or 15 dB SPL. In Experiment 2 (sounds with 4 or 10 contiguous segments), either segment 1 or segment 7 in case of the ten-segment sounds or segment 1 or segment 3 in case of the four-segment sounds received an amplification or attenuation of 15 dB SPL. The variation of the position of the

amplified or attenuated segment was realized in order to investigate whether the effect of relative component level varies as a function of the temporal position of the amplified/attenuated component within the sound. Such an effect would occur if the temporal weighting (primacy effect) and loudness dominance interacted.

The temporal weights assigned to each segment were estimated using multiple logistic regression, separately for each listener and each experimental condition. The sound pressure levels of the segments served as the predictors and the response of the participants was the criterion variable.

For the sounds with segments separated by 500-ms silent gaps in Experiment 1, no primacy effect was observed. This can be attributed to a "reset" of the primacy effect during the silent gap (Fischenich, Hots, Verhey, & Oberfeld, 2019; Hots, Verhey, & Oberfeld, 2018). As expected, the weights assigned to amplified segments were increased and the weights assigned to attenuated segments were decreased, compatible with loudness dominance. Thus, the loudness dominance effect does occur even when non-simultaneous masking between adjacent components is reduced by 500-ms silent gaps. For the sounds with contiguous segments in Experiment 2, a primacy effect as well as effects of relative segment level (in the same direction as in Experiment 1) were found. The effects of relative level were stronger for the contiguous segments of Experiment 2, compared to those found in Experiment 1. Additionally, segments next to the amplified segments received slightly lower weights compared to the control condition where all segments had the same average level. A potential explanation of this pattern is that backward and forward masking of intensity processing played a role in the conditions with contiguous segments (Oberfeld et al., 2013). The effects of relative level on the weights of the amplified segment did not differ substantially between an amplification of the first and the third or the first and the seventh segment. This indicates that there is no substantial interaction between loudness dominance and the primacy effect. However, attenuation of the first segment resulted in a greater decrease of the weight assigned to the attenuated segment, compared to an attenuation of the third or seventh segment.

The effects of amplification and attenuation were rather symmetric for the middle segments in both experiments in the sense that amplification increased the weight on the amplified segment by a given factor and attenuation by the same amount decreased the weight on the attenuated segment by a comparable factor. As mentioned above, attenuation of the first segment had a stronger effect on the weight than amplification by the same factor.

Taken together, the data show that the loudness dominance effect cannot be attributed to forward or backward masking, that there is no substantial interaction between loudness dominance and the temporal weighting, and that in many conditions the effect of relative component level is approximately symmetric for amplification and attenuation by the same factor. Additional data are needed to confirm these findings and to gain insight into the exceptions from these rules and the mechanisms underlying the loudness dominance effect.

REFERENCES

Berg, B. G. (1990). Observer efficiency and weights in a multiple observation task. *Journal of the Acoustical Society of America, 88*(1), 149-158. doi: 10.1121/1.399962

Fischenich, A., Hots, J., Verhey, J., & Oberfeld, D. (2019). *Frequency-channel specific reset of the primacy effect in temporal loudness weights*. Paper presented at the DAGA 2019, Rostock, Germany.

Fischenich, A., Hots, J., Verhey, J., & Oberfeld, D. (submitted). Temporal weights in loudness: Investigation of the effects of background noise and sound level.

Hots, J., Verhey, J., & Oberfeld, D. (2018). *Der Einfluss von Signalpausen auf die zeitliche Gewichtung bei der Lautheitswahrnehmung*. Paper presented at the DAGA 2018, München, Germany.

Lutfi, R. A., & Jesteadt, W. (2006). Molecular analysis of the effect of relative tone level on multitone pattern discrimination. *Journal of the Acoustical Society of America, 120*(6), 3853-3860.

Namba, S., Kuwano, S., & Kato, T. (1976). Loudness of sound with intensity increment. *Japanese Psychological Research, 18*(2), 63-72.

Oberfeld, D. (2008). The mid-difference hump in forward-masked intensity discrimination. *Journal of the Acoustical Society of America, 123*(3), 1571-1581. doi: 10.1121/1.2837284

Oberfeld, D. (2015). Are temporal loudness weights under top-down control? Effects of trial-by-trial feedback. *Acta Acustica United with Acustica, 101*(6), 1105-1115. doi: 10.3813/aaa.918904

Oberfeld, D., Heeren, W., Rennies, J., & Verhey, J. (2012). Spectro-temporal weighting of loudness. *PLOS One, 7*(11), e50184. doi: 10.1371/journal.pone.0050184

Oberfeld, D., Hots, J., & Verhey, J. L. (2018). Temporal weights in the perception of sound intensity: Effects of sound duration and number of temporal segments. *Journal of the Acoustical Society of America, 143*(2), 943-953. doi: 10.1121/1.5023686

Oberfeld, D., Jung, L., Verhey, J. L., & Hots, J. (2018). Evaluation of a model of temporal weights in loudness judgments. *Journal of the Acoustical Society of America, 144*(2), EL119-EL124. doi: 10.1121/1.5049895

Oberfeld, D., Kuta, M., & Jesteadt, W. (2013). Factors limiting performance in a multitone intensity-discrimination task: Disentangling non-optimal decision weights and increased internal noise. *PLOS One, 8*(11), e79830. doi: 10.1371/journal.pone.0097209

Oberfeld, D., & Plank, T. (2011). The temporal weighting of loudness: Effects of the level profile. *Attention, Perception, & Psychophysics, 73*(1), 189-208. doi: 10.3758/s13414-010-0011-8

Pedersen, B., & Ellermeier, W. (2008). Temporal weights in the level discrimination of time-varying sounds. *Journal of the Acoustical Society of America, 123*(2), 963-972. doi: 10.1121/1.2822883

Ponsot, E., Susini, P., Saint Pierre, G., & Meunier, S. (2013). Temporal loudness weights for sounds with increasing and decreasing intensity profiles. *Journal of the Acoustical Society of America, 134*(4), EL321-EL326. doi: 10.1121/1.4819184

Richards, V. M., Shen, Y., & Chubb, C. (2013). Level dominance for the detection of changes in level distribution in sound streams. *Journal of the Acoustical Society of America, 134*(2), EL237-EL243. doi: 10.1121/1.4813591

Turner, M. D., & Berg, B. G. (2007). Temporal limits of level dominance in a sample discrimination task. *Journal of the Acoustical Society of America, 121*(4), 1848-1851. doi: 10.1121/1.2710345

Zeng, F. G., & Turner, C. W. (1992). Intensity discrimination in forward masking. *Journal of the Acoustical Society of America, 92*(2), 782-787.

Zeng, F. G., Turner, C. W., & Relkin, E. M. (1991). Recovery from prior stimulation II: Effects upon intensity discrimination. *Hearing Research, 55*(2), 223-230.