CLARIFYING AMPLITUDE ENVELOPE'S CRUCIAL ROLE IN AUDITORY PERCEPTION

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Résumé

La plus grande partie de la recherche du laboratoire MAPLE explore le rôle de l'enveloppe d'amplitude - la «forme» d'un son au fil du temps. Le système de perception est sensible aux changements dynamiques dans les enveloppes d'amplitude des sons naturels, lesquels transmettent des informations importantes sur les événements et les sources. Toutefois l'étude de la perception auditive utilise souvent des tonalités d'amplitudes fixes dépourvus de telles informations. Nos études ont documentés des cas dans lesquels la recherche fondée fortement sur de tels sons néglige certain des aspects principaux et des capacités du système de perception. Ici, je résume certains de ces travaux et les lignes directrices des orientations futures.

Mots-clés: enveloppe d'amplitude, perception auditive, timbre, intégration audio-visuel, alarmes auditives

Abstract

Much of the MAPLE Lab's research explores the role of amplitude envelope – the "shape" of a sound over time. The perceptual system is sensitive to the dynamic changes in the amplitude envelopes of natural sounds, which convey important information about events and sources. However auditory perception research often uses amplitude invariant tones lacking such information. Our studies have documented instances in which research based heavily on such sounds overlooks key aspects and abilities of the perceptual system. Here I summarize some of this work and outline future directions.

Keywords: amplitude envelope, auditory perception, timbre, audio-visual integration, auditory alarms

1 The MAPLE Lab

Founded in 2009, the MAPLE Lab researches Music, Acoustics, Perception & LEarning (www.maplelab.net). This interdisciplinary team explores topics of relevance to psychologists, musicians, neuroscientists, and educators at the graduate and undergraduate levels in a recently renovated, CFI-Funded facility. Our work ranges from audio-visual and sensorimotor integration to the design of auditory alarms and the communication of emotion in music. As Canada's first research facility with a percussion focus, we are proud to house several professional level percussion instruments affording new research possibilities. Our interest in percussion led to novel insights on the importance of the amplitude envelopes of percussive sounds, and we are now working to explore implications of these insights for general theories of auditory processing.

1.1 Natural sounds vs. "tone beeps"

Natural sounds such as those produced by musical instruments, speech, and/or real world events generally exhibit dynamically changing amplitude envelopes. For example, notes produced by the piano or marimba decay rapidly, similar to non-musical objects excited by impacts. The perceptual system uses this decay to understand the types of materials involved in the impact. Sustained events such as notes played on a clarinet or French horn do not decay immediately, but still exhibit dynamic changes.

In contrast to these natural amplitude envelopes, sounds synthesized for auditory perception research often trapezoidal shapes with a rapid onset/offset surrounding a sustain period. These "flat" tones hold many advantages for scientific research. They are easy to quantify, facilitating re-generation for replications. Their crisp offsets also afford clear quantification of duration. However, auditory researchers have noted that the natural world is "[not] replete with examples of naturally occurring auditory pedestals [i.e., flat amplitude envelopes]" (Phillips et al., 2002) and even issued explicit calls for increased research with tones "closer to real-world tasks faced by the auditory system" (Joris et al., 2004).

1.2 The prevalence of amplitude invariant tones

Although sounds with flat envelopes hold certain methodological advantages, they can lead to theories of auditory perception failing to generalize to our perception of natural events. For example, although vision does not typically affect auditory judgments of event duration [3], this widely replicated finding does not generalize to impacts produced by a marimba [4] or piano [5]. This complements other demonstrations that dynamic changes in envelope serve as important cues for perceptual organization [6]. Overlooking the role of amplitude envelope can lead to inaccurate conclusions. Past claims that the "unity assumption" is specific to speech [7] overlooked the crucial role of amplitude envelope in this important process [8]. Flat tones suggest conclusions about multisensory

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integration [9] and audio-visual association [10] that do not apply to natural sounds.

To empirically explore flat tones in auditory researsch, we classified the amplitude envelopes of sounds from 222 experiments published in the journal *Music Perception.* Our surprising results reveal that 35% of the sounds encountered lacked definition of amplitude envelope! Many undefined sounds used tones that were "500ms in duration" – presumably flat (although this description could apply to other shapes). Therefore the key outcome from this and subsequent [11] surveys is that the majority of auditory stimuli used in perceptual assessments lack the dynamic variation characteristic of natural sounds [12]. We are currently exploring the degree to which theories derived from these experiments generalize to natural sounds.

1.3 Impact events differ from receding sources

Research on amplitude varying sounds has often focused on asymmetries in the perception of rising vs. falling tones. Although impact sounds with decaying envelopes may appear similar to previously used "falling" tones (Fig 1), they hold some important differences. Those tones simulate sustained sources decaying in volume as they move away from the listener. Consequently they are much longer in duration than impact sounds – from around two seconds [13] to over a minute in duration [14].

In contrast, sounds originating from impact events and tones synthesized to simulate such sounds [6], [15] involve stationary, singular events. Consequently they mimic fundamentally different sources. This distinction is crucial if the auditory system processes sounds as "events" rather than mere "stimulus properties" [16], as sustained vs. decaying sources may be processed using different underlying strategies [17].

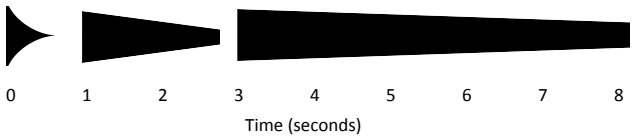

Figure 1: A sample percussive tone mimicking an impact occurring at a fixed location (left). This contrasts Nuehoff's (middle) or Teghtsoonian's (right) "receding tones" mimicking moving, sustained sources.

1.4 Future research directions

Flat tones often serve as the "default" stimulus for both research and applied purposes. For example, the International Electrotechnic Commission has previously recommended they be used exclusively for auditory alarms in certain medical devices – which may be one factor contributing to current problems with their design and usability. In the future we hope to clarify the important albeit underappreciated role of amplitude envelope in auditory perception. For more information on this work visit http://maplelab.net/overview/amplitude-envelope. We have also created software for synthesizing flat and percussive tones at maplelab.net/software to aid others interested in exploring this important acoustic property.

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