Intrusiveness, Annoyance and Sound Design

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We try to propose a series of practice-based guidelines for a low-intrusiveness / low-annoyance form of sound design. We describe a series of unwanted side-effects, resulting from the action of aural stimuli in different parts of the auditory system, which we partly observed in our sound design practices, and partly corroborated through scientific literature. We then argue which actions should be taken by sound designers in order to avoid these effects. We end up by devising a system of constraints that can be optimized but not solved.

Like a concert of Pavlov's bells (the signals used by I. Pavlov – russian physiologist, Nobel 1904 –, to elicit salivation in dogs trained to associate the sound of a bell and the delivering of food) –, today's soundscapes, rich in alerts, notifications, jingles and ubiquitous music, provoke unconscious responses in us. Behind the surface of this apparently jolly soundscape, quantities of orders, directions, injunctions, might be (unintentionally?) telling us how fast to move, where to look, when to pay attention. Part of the dystopian quality of today's soundscape could arise from an abuse of musical features in signals that communicate extremely simple, non life-threatening informations.
Sound elicits an extremely complex (and not yet fully understood) web of relations between automated physiological reactions, perceptual activities (attention direction, saliency evaluation, …) and cognitive systems (listening abilities, mental categories, layers of memories, emotional architectures).
When trying to communicate simple, factual notions such as "a call is coming" or "this device has successfully booted," sound designers should strive to activate only the minimum and sufficient number of mental activities to code the information. On the other hand, if we integrate Umberto Eco's idea that works of art allow vast numbers of interpretations, or the different hypotheses about the function of music in evolution, musicians – and not sound designers – should try to integrate the biggest possible number of mental systems, in order to maximize their work's reach.
We hypothesize that the partial confusion between simple, distilled sonic communication and elaborated, symbolic expression through musical features creates the risk of a profound distortion in the artificial sonic world around us. This paper is an attempt to give a clear vision of this risk, and to clarify the negative consequences of the use of musical cues in the world of sound design.
Far from outlining an exhaustive view of the problem (e.g., the conflict with the idea of earcons[2] – which makes great use of musical elements such as pitch structures), this paper aims at sketching out a series of intuitions that could be used as guidelines for a low-intrusiveness / low-annoyance form of sound design. These intuitions are built on empirical observations made by the authors during a long period of work in the automotive industry (several collaborations with Renault from the end of the 90's).

Our hypothesis

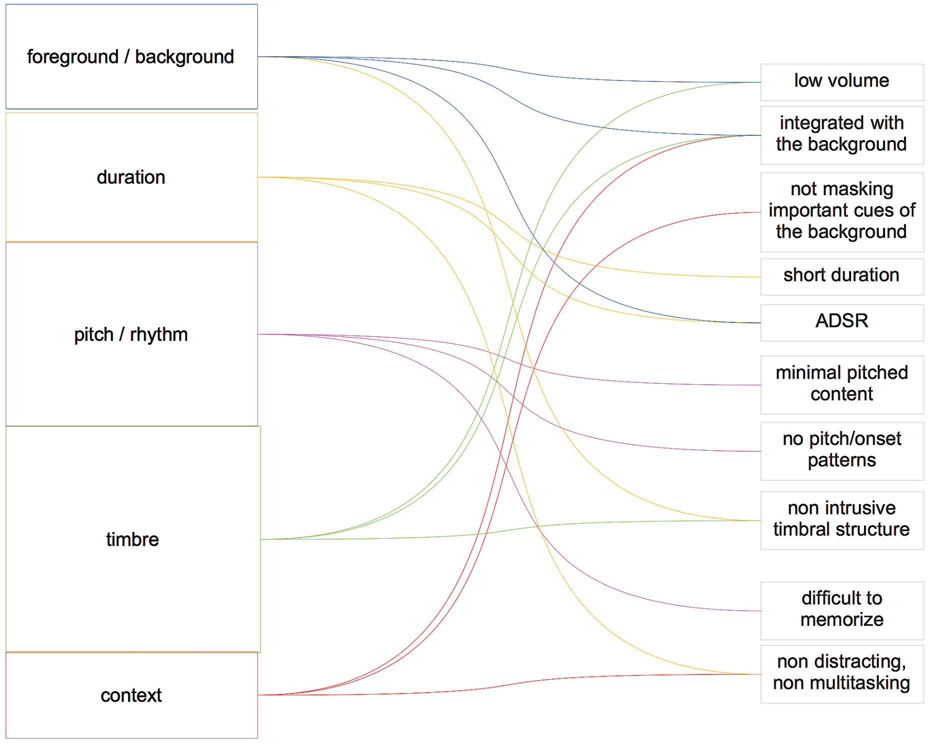
Intentional sounds – different from consequential sounds[3] – coming from the car's interior (blinkers, seatbelt alarms, welcome messages, reminders, *etc.*) might be heard several times during a trip. Usually, driver and passengers cannot switch these sounds off. While useful and sometimes mandatory for safety, these sounds might be potentially irritating and annoying for users. This consideration can be extended to other sound design cases, such as the creation of ringtones, or feedback sounds for medical equipment.
We call this situation "unwilling listening," inspired by the concept of "forced listening" – the highly controversial term which heated numerous debates in the US since the 40's, over the use of loudspeakers in the public space.[4]
We propose that the negative consequences arising from an insensitive use of sound in a context of unwilling listening could be ranged in 4 categories:

1) Startling effects (involving unintended automated primitive responses to auditory stimuli)[5]
2) Intrusiveness (proto-emotional reactions potentially related to threat)
3) Distraction (due to excessive attentional or memory load, in competition with other tasks)
4) Annoyance (long-term negative effect due to repetition of intrusive / distractive sounds).

Starting from the sonic elements and dimensions which elicit the most primitive, fast and unconscious reactions of the auditory system (and probably most basic evolutionary functions), and ending with the ones which interest the most complex, slow and possibly conscious ones (and probably most sophisticated evolutionary functions), we show a series of practical cases where artificial sound production can trigger unwanted side-effects. We offer some possible explanations, and propose a series of subsequent suggestions for sound designers.

Foreground / Background

Startling effects and intrusiveness of a foreground sound are related to its background.
The most basic activity of the auditory system is probably the analysis of differences in the soundscape, to find if there is a new sound, and where it is located. The emergence of a sound



Guidelines for low-intrusiveness sound design.

from a soundscape could reveal the presence of a salient or alerting event (a potential threat, a signal useful for orienting).

We observed that, in car user's terms, when a sound clearly emerges from a background it risks to be considered "loud": users often ask to "turn down the volume" of intrusive sounds. We could deduce that a low-intrusiveness / low-annoyance paradigm should include diffusion at the lowest possible amplitude. While this seems in general reasonable, there is another factor to be taken into account: the mechanisms that encourage fusion or segregation of sound events in a complex sound scene. During the 90's, the Auditory Scene Analysis (ASA) theory[6] shed light on psychoacoustic and cognitive mechanisms underpinning spectral emergence of a sound from its background.

From this perspective, a low-intrusiveness form of sound design emerges from the sense of proportion between timbral contrast with the background (non-integration) and amplitude settings.

Spectral / timbral analysis of the features of the background where a sound will be placed is an important pre-requisite. Given the volatility of contemporary soundscapes, real-time analysis of the sonic background should be an important future direction of investigation.

Sound movement in space can also create emergence from the background. Regarding this dimension, in the work for Renault Symbioz[7], we experimented with light random movements of virtual audio sources within the car's cockpit. A further reason to support these experiments is that a virtually moving sound interacts in different ways with the inner acoustics. This creates modulations in acoustical resonances, helping the sound to further emerge from the background noise at low amplitude levels.

In the future, the study of bioacoustics and acoustic ecology could also be particularly inspiring in order to extract guidelines of ecologic sonic behavior from natural observation.

Timbre

A few timbral features are directly linked to intrusiveness.

Once a sound has emerged from a background and has been identified as a meaningful unit, a more complex level of sound analysis might begin: the exploration of features such as the central spectroid or brightness (possibly related to energy and dimension of the sound source), roughness (possibly conveying information about intention), *etc.*

These mid-level forms of analysis could be linked to a primitive system of memory and categorization, which elicits arousing automations. If the sound falls in a certain category (*e.g.*, a "close, moving toward me, rough, big thing"), the system could initiate an alerting state activation. This hypothesis is corroborated by some initial research by Anna Preis (a psychologist and cognitive neuro-scientist who worked in the field of environmental sound analysis), which links intrusive timbres to quantity of partials beyond the masking threshold, roughness, and frequency of the most emergent spectral component.[8]

It is important to underline that these features, while potentially intrusive, could nonetheless be extremely useful to help the emergence of a specific sound from a complex background. Placing a potentially intrusive sound (*e.g.*, a sound with a spectral centroid around 3000 Hz. – the minimum of the ear sensitivity), at very low amplitude (just above the detectability threshold), could minimize its intrusiveness. Timbre definition, amplitude settings and background timbral features analysis should be parts of a holistic sound design methodology.

Back again to our work experience in the automotive industry, there is also a repertoire of rules for avoiding sounds that, while being intrusive, could also reveal badly functioning mechanical parts in the car's fabric (*e.g.*, clinking related to bad vibrations). At the same time, automotive sound technologies (small loudspeakers, resonating cavities of the cockpit, extremely simple embedded synthesis systems) can lead to timbral idiosyncrasies, like harsh timbres, high-pitched materials, harmonic distortion, *etc.*

In these two cases, we find the same constraints described above (*e.g.*, exaggerated prominence of a high pitched spectral component caused by a resonant cavity in the cockpit, leading to intrusiveness according to A. Preis).

Sound designers need to recognize these phenomena and learn how to deal with them. Typical specific actions could be in situ mastering, car's cockpit resonances modeling (with Impulse Response measurement) or realistic studio configuration (working on the dedicated loudspeaker).

Duration

Intrusiveness of a sound is linked to its duration.

The temporal dimension could be an important sonic cue[9], especially for the perception of danger.

Research shows that – other features being equal (amplitude, spatial position, timbre, *etc.*) – a long sound is likely to be more intrusive than a short one. A low-intrusiveness strategy should then probably aim at the shortest sounds, as long as the needed informations are properly communicated.

As a counterweight, we often noticed that very short sounds might create feelings of urgency. If not needed, this effect could to be neutralized by using other strategies. Intuitive use of reverbs, or particular attention to sound morphologies (attack, decay or release) can help in creating short audible duration and long, almost inaudible, tail which can dampen this "urgency" effect.

Considering especially the sound's attack, in our automotive experience, two extremes should be avoided: overly percussive sounds, with noisy attacks (better apply short fades-in and quick opening lowpass filters); and sounds with a too long fade in (which obviously contributes to the total duration).

Further research should be included about perceived sound duration[10]: is there a threshold between the clearly audible components and the ones that are more transparent? Are timbre and amplitude variations influencing the perceived duration of a sound?

Cognition, memory

Cognitive processes contribute to annoyance.

Listening is connected not only with primitive and unconscious responses, but also with cognitive processes, which may arise to consciousness and make use of complex memory systems. These processes can be relatively simple, such as the ones responsible for identification (of a sound's source), interpretation (of a phoneme), discrimination (between two tones), or more sophisticated, like the ones that allow for the comprehension of a speech, the ability to follow a musical form, the association between a sound and its source. This interaction between stimuli and cognitive activity could add a further level of negative appraisal to a sound source, by some kind of feedback (recognizing a source of intrusion leads to a higher focus on it, enhancing its intrusiveness). For instance, studies on urban soundscapes show that the recognizability of annoying sources (*i.e.* "a jackhammer in the street") augments the level of perceived annoyance, compared with the lack of recognition.[11]

We could assume that for the same reason, pitched and rhythmical events used in wrong contexts might create annoyance. Pitch and rhythm are ideal candidates for conveying symbolic information: tone sequences and rhythmic patterns are categorized and memorized more accurately than spatial movements, or loudness changes[12] (it is worth noticing that mood induction techniques select music using mainly pitch and rhythm related features). Then, pitched and rhythmic sound structures can become highly recognizable after a few listenings. This high recognizability can easily trigger annoyance.

In the case of automotive Human-Machine Interfaces (HMI), we empirically noticed that once the information / function has been learned, a bifurcation seems to happen. After a learning curve, the meaning of a highly recognizable signal (*e.g.*, the "welcome sound," indicating a correct boot of the car's computer) becomes clear. At this point, the auditive / cognitive system seems to split its activity into:

a) a quick recognition of the sound's meaning (even before the sound's playback is over),
b) a passive listening to the rest of the sound as a non-asked-for musical event. This can cause annoyance effects.

From these observations we propose that pitched and rhythmic content should be used with extreme prejudice when designing sounds for forced listening situations. An alternative solution could be to integrate generative systems that continuously vary the musical functional elements, in order to avoid the trap of memorization while maintaining some form of identity.

Context

Annoyance arises from a contradiction of context and function.

Listening to a klaxon can be an enjoyable activity if my soccer team has won the championship and everybody is in the street celebrating from his car. But if I am trapped in a traffic jam and I'm late, the same klaxon becomes highly annoying. Aside from this example, presence of competing sound signals, coexistence with activities that require different levels of attention[13], temporal disposition of events, information competition, visual noise, *etc.* together with audio / visual or audio / physical divergence (i.e. perceptual incompatibility between the sound and the object / icon it is related with) are factors to be taken into consideration.

These elements are not always in the hands of sound designers but should be accurately analyzed in any case, in order to quantify the danger of annoyance coming from social, ergonomic, informational and situational needs linked with a specific situation and the modes of listening potentially arising from it.

Note that the last two points appear to be of paramount importance since seminal research works in annoyance perception[14] point out that cognitive, emotional and social factors seem to overweight the purely acoustically intrusive factors (*i.e.* the three first points of the current reasoning) as constitutive elements of an annoying context.

Conclusion

Taken together, these observations uncover a system of sound design constraints that are not totally solvable. There is an intricacy of such a system. To catch the listener's attention, a minimal startle effect is unavoidable. This will forcedly create degrees of intrusiveness, distraction, and finally annoyance. These consequences can never be avoided completely when designing an effective audio communication.

But thoughtful sound design can minimize these consequences: working on the way a signal emerges from its background relations; curating its timbral qualities in order to avoid the intrusive features listed above; minimizing duration; controlling that attentional and memory systems are not unintentionally overloaded; avoiding disruption of the ergonomic context.

Sound designers must find good compromises between efficacy / expressiveness and minimization of intrusiveness / annoyance effects.

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Corporalité, corporéité et *embodiment* en modification au contact des technologies

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*Cet article souhaite examiner l'interrelation des notions de corporalité, de corporéité et d'*embodiment *dans une approche transdisciplinaire pour réfléchir au nouveau statut du corps contemporain dans le contexte technologique. Il prend notamment en compte les théories sur la complémentarité des intelligences d'Howard Gardner, psychologue en développement humain du Harward University, présentées dans son ouvrage* Frame of Minds : The theory of multiple intelligences *(1983)*[1]*, et examine plus spécifiquement la réintroduction de l'intelligence corporelle dans la réorganisation du savoir. Trois notions sont en particulier utilisées : la corporalité – telle que développée par Michel Bernard, professeur d'esthétique théâtrale et chorégraphique et co-fondateur du département de danse de l'Université Paris 8, dans son livre* De la création chorégraphique *(2001)*[2]*, indiquant qu'elle concerne le corps physique dans sa matérialité ; la corporéité, concept transdisciplinaire qui se définit selon Michel Bernard et sa collègue Julie Perrin comme un état du corps où ce dernier ne peut plus être réduit à sa réalité biologique – ce qui implique selon Perrin*[3] *de revoir toute la problématique du corps comme être plein de l'ontologie classique, le « carrefour » de la corporéité traduisant une réalité mouvante, mobile, en transformation continuelle, faite de réseaux d'intensités et de forces modifiant la sensorialité ; et enfin l'*embodiment*, en tant qu'acte d'intégration par le corps – ici dans un environnement désormais technologique.*