ALARM/WILL/SOUND: PERCEPTION, CHARACTERIZATION, ACOUSTIC MODELING, AND DESIGN OF MODIFIED CAR ALARMS

Ircam Composer in Research Report 2014

Alexander Sigman

Composer
lx.sigman@gmail.com

Nicolas Misdariis

Researcher, Perception and Sound Design Team
Ircam – UMR CNRS 9922.
nicolas.misdariis@ircam.fr

ABSTRACT

This article outlines the salient phases, goals, and results of *alarm/will/sound*, a multidisciplinary musical research project carried out in the context of the IRCAM IRC (*Interface Recherche-Création*) Musical Residency Research program. After the rationale for and motivations behind the project are presented, the following research and production milestones are described: 1) the elaboration and characterization of the sound corpus intended for the modified car alarm prototypes; 2) a sound perception experiment testing source typicality of a sub-category of sounds within the corpus; 3) an acoustic descriptor space in which a subset of the stimuli employed in the typicality experiment were situated; 4) the construction of synthetic auditory warnings from sound-sources within the descriptor space, prototypical environmental sound envelopes, and inter-onset intervals (IOI's) derived from extant car alarms; and 5) the design of a second experiment pertaining to levels of repulsion vs. attraction to the synthetic auditory warnings. Finally, short-, mid-, and long-term objectives and directions for the project are discussed.

1. INTRODUCTION

alarm/will/sound is a tripartite collaboration between composer Alexander Sigman, IRCAM Sound Perception and Design (SPD) team researcher Nicolas Misdariis, and Stuttgart based product designer/visual artist. This project was begun in January 2013 under the IRCAM IRC (*Interface Recherche-Création*) Musical Research Residency program, and is still in progress at present (March 2014).

Taking as a point of departure the proven ineffectiveness of current audible car alarm systems as deterrents [1] and the relative lack of research into and development of audible car alarm design compared to other sound-emitting components of vehicles (e.g., the audio system, engine, horn, turn signal, or door), we have sought to produce innovative modified car alarm prototypes. The design of these prototypes would be informed by musical, artistic, scientific, and industry expertise, as well as sound perception research and acoustic modeling.

As an often-ignored and predictable source of noise pollution, the car alarm as an auditory warning device raises a host of intriguing questions of a sociological nature. How may the essential functionality of the audible car alarm be defined? To whom is the alarm directed: the potential perpetrator, the car owner, or the public? Studies summarized in the report cited above have indicated that even the most high-end audible alarms require a maximum of ten minutes for professional car thieves to disable, and in most instances fail to prevent break-ins. The owner may or may not be within earshot of his/her respective car alarm when it is activated. However, given the homogeneity of car alarm emissions, the alarm may not be detected in time for the car owner to intervene. As a result of the sheer number of false alarms, as well as the aforementioned element of aural annoyance (among other factors), members of the more public have a greater documented tendency to flee from or simply ignore an activated alarm than to proceed towards the source.

In the presence of a car alarm, wherein lies the boundary between the public space of the vehicle's physical environment and the private territory of car? An audible alarm designates a boundary beyond the car's physical perimeter—a "grey zone" that is often creatively explored, as is made evident by the countless videos of car alarm dance routines posted to Youtube.[1]

Our approach to audible car alarm system design has been guided and constrained by a fundamental question: wherein lies the alarm's identity? Does it consist in the hardware components and context (i.e., embedded in the automobile), or in the sounds that it emits and the interaction protocol by which it operates? If the latter, is it possible to transform the alarm system from a mechanism of (ineffective) deterrence into one

[1] Here is a particularly well-choreographed example: http://www.youtube.com/watch?v=1Li3mNl2-EM (accessed 17 March 2014).

of engagement? That is to say: through the expansion and customization of its sonic vocabulary and potential modes of human-machine interaction, could this device be repurposed as a sort of virtual instrument that the passerby (or car owner) learns to manipulate, with the help of audio-visual feedback? By the same token: could the alarm gain sensitivity to more physical parameters than simply physical proximity? Could temporal variation in these physical parameters trigger time-varying sonic responses?

Indeed, it was not our intent purely to focus upon enhancing the car alarm's deterrence effectiveness. Non-audible devices such as the Lojack system[2] have been associated with a high documented vehicle recovery rate. Rather than entirely *replacing* an existing system in service of security enhancement, the focus has been placed on *expanding* and *enhancing* this system's functionality and sonic potential. Despite the seemingly unique nature of the project and the collaborative model underlying it, aspects of *alarm/will/sound* are in fact extensions of Matthias Megyeri's work on domestic security systems[3] and Alexander Sigman's compositional interests in the influence of sonic phenomena in physical environments on the aesthetics of the composer/sound artist and the impact that a composer/sound artist may have on transforming the physical environment (and by extension, the human behaviors therein).[4] The IRCAM Sound Design and Perception research team's involvement with the automobile industry has assumed the form of a partnership with Renault on sound design for electric vehicles (in collaboration with composer Andrea Cera), a follow-up study on electric vehicle detectabilty in urban environments [2], and an earlier study on car horn sound quality [3]. Research topics in the domain of human-machine interaction has included the influence of audio features on perceived urgency and its application to car interior Human-Machine Interfaces [4] and the influence of naturalness of auditory feedback of an interface on perceived usability and pleasantness [5]. In addition, Sigman's background in Cognitive Science and timbre perception has been relevant to the project's collaborative model. It is thus hoped that both the artistic and research outcomes *alarm/will/sound* will contribute not only to the understanding and development of vehicle alarm systems specifically, but also to the design and classification of auditory warnings in general.

2. PROJECT PHASES AND GOALS

For practical purposes, the project was divided into four primary phases: three research and production phases (see Figure 1) and one presentation and user experience documentation phase. The first phase was devoted to the production and characterization of a corpus of potential alarm sounds. Subsequently, a sound perception experiment in sound source identifiability was designed and conducted on a significant portion of the corpus, in order to focus on acoustic properties, rather than exclusively to sound causality. A subset of the stimuli used in this experiment was then placed within an acoustic features descriptor space. Phase III has consisted of constructing synthetic auditory warnings via the integration of the source-sounds within the descriptor space, prototypical auditory warning temporal morphologies, and the inter-onset intervals (IOI's) of real car alarm sounds. These synthetic warnings will then be tested for their respective capacities for repulsion vs. attraction in a second experiment. Concurrently, Matthias Megyeri is developing hardware designs for the eventual prototypes, which will be exhibited as interactive installations in public and gallery spaces during the final phase of the project.

Given the breadth of *alarm/will/sound,* we have decide to focus in the present article on the sound corpus elaboration and characterization process of Phase I, the source typicality experiment and acoustic feature modeling completed during Phase II, and the synthetic auditory warning construction and deterrence vs. engagement experiment of the third phase. All of these project achievements pertain to the creation of semantic and acoustic classification of the alarm prototype sounds. The classification methodologies employed will be critical to both subsequent research and to exhibiting the prototypes in an interactive art installation context.

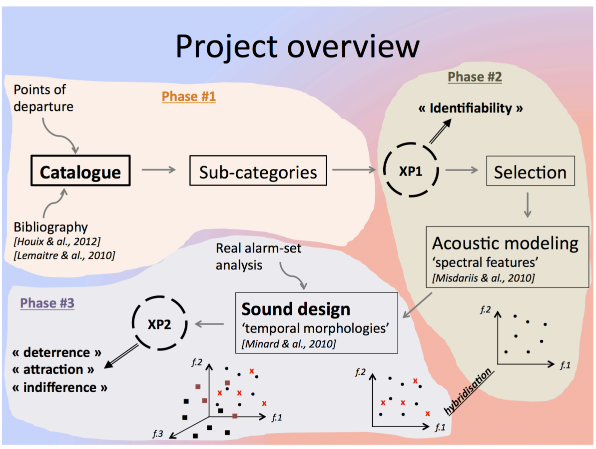

Figure 1. The three primary project phases. "XP1" and "XP2" refer to "Experiment 1" and "Experiment 2," respectively.

[2] http://www.lojack.com/Home (accessed 17 March 2014).

[3] E.g., *Sweet Dreams Security*, a commercial line of security products developed and distributed by Megyeri: http://www.sweetdreamssecurity.com/sweetdreamssecurity.html (accessed 17 March 2014).

[4] Sigman's *VURTRUVURT* (2011) for prepared violin and live electronics and *down the bottle* (2012) for bass flute, installation, and live electronics—both members of the *VURT* cycle—reflect these interests. Scores and recordings to both works may be found on the composer's website: http://lxsigman.com/media/audio.htm (accessed 17 March 2014).

3. BACKGROUND

Besides the IRCAM Sound Perception and Design team studies mentioned above, several important researches have informed each stage of the project. Initially, a survey of historical audible alarm patents and current standards was made. Sound corpus construction was guided both by classic twentieth century approaches to timbral classification (e.g., Pierre Schaeffer's *Traité des objets musicaux* [6]), as well as more recent studies in environmental sound categories (e.g., Houix et al, 2012 [7]). Formal components were also extracted from Olivier Claude's 2006 thesis *La recherche intelligente des sons* [8], where taxonomies of natural, animal, human, and object/machine sounds are proposed, such that sounds within these taxonomies are organized into limited sets of morphological, causal (physical), and semantic sub-categories.

In Ballas (1993) [9], acoustic, ecological, perceptual, and cognitive factors that influence the identification of current environmental sounds were evaluated. As is explained in Section 5.2, this study was particularly relevant to the sound causality confidence rating protocol utilized in Experiment 1.

The acoustic modeling step was largely informed by several studies done on the definition of an exhaustive set of acoustic features—at first dedicated to musical sounds (Peeters et al, 2002 [10]) and the identification of some of these features that are best suitable for describing similarities and differences of environmental sounds.

The auditory warning construction was grounded on the standard template defined by Patterson (1990) [12] and, among others, the direction taken by Edworthy (2011) [13] to extend the conception of the inner structure of such signals was considered. Moreover, our own auditory warning design process was also based on prototypes of morphological profiles found out by Minard et al. (2010) [14] from an environmental sound corpus.

Finally, existing auditory design in automobiles (Yamauchi et al, 2004 [15], Kuwano et al 2007 [16]), and approaches to the synthesis of new auditory warnings in military helicopters (Patterson 1999 [17]) and intensive care units (Stanton & Edworthy, 1998 [18]) were also taken into account in this process.

4. SOUND CORPUS TAXONOMY AND SOURCES

The first phase of the project entailed the elaboration and characterization of a sound corpus to apply to the modified car alarm prototypes. As is presented in Figure 2, the sound corpus taxonomy consists of three primary categories: individual sounds, "auditory scenes," or sound complexes, and real car alarm sounds (i.e., the standard repertoire of six auditory warnings typical of audible car alarm systems). The Individual Sound category is further divided into 1) Synthetic/Electroacoustic; 2) Vocal; 3) Film Danger Icons; and 4) Industrial/Mechanical Sounds. Further subdivisions were made along semantic/contextual and—particular at the lowest levels of the taxonomy—acoustic lines.

Among the non-synthetic sounds in all three primary categories, the majority were mined from existing sound databases (e.g., SoundIdeas, Blue Box, Auditory Lab[5], and freesound.org). Under the Auditory Scenes rubric, a series of field recordings of public spaces in Paris—streets, the Forum Les Halles shopping concourse, the Centre Pompidou, metro stations, and train car interiors—were compiled in February 2013 by Alexander Sigman and Matthias Megyeri. It is intended that the collection of field recordings be expanded over time to include further site-specific entries.

Synthetic individual sounds were generated and edited using such synthesis software as AudioSculpt[6], Pure Data (Pd)[7], SuperCollider[8], and the Python-based concatenative synthesis program Audioguide.[9]

5. EXPERIMENT 1: SOURCE IDENTIFIABILITY OF INDUSTRIAL/MECHANICAL SOUNDS

5.1 Experimental Objectives

The first sound perception experiment was designed in the interest of determining levels of source identifiability of sounds within the corpus. Based upon the results of the experiment, it would be possible to construct an abstractness-iconicity scale across the corpus, as well as to determine the salient semantic and acoustic attributes of the sounds using empirical data. However, given the size and scope of the catalogue, the selected stimuli were limited to a subset of the Industrial/Mechanical category. This category was chosen due to a) the number of sub-categories and entries; and b) the range of source abstractness and ecological context relative to other Individual Sound categories.

5.2 Methods and Materials

In order to obtain data from a broad range of subjects over a relatively short period of time (ca. one month), the experiment was conducted in an online, crowd-sourced format.[10] Subjects were asked to listen to each stimulus, provide a brief description of *sound causality*, and indicate a confidence rating of sound causality identification on a 1-5 Likert scale (see Figure 3).[11] The

[5] http://www.psy.cmu.edu/~auditorylab/website/index/home.html (accessed 17 March 2014).
[6] http://anasynth.ircam.fr/home/english/software/audiosculpt
[7] http://puredata.info/
[8] http://supercollider.sourceforge.net/
[9] AudioGuide was developed by composer Ben Hackbarth, and is obtainable from his website: http://www.benhackbarth.com/audioGuide/doc.html (accessed 15 March 2014).
[10] The experiment may be found at the following URL: http://recherche.ircam.fr/equipes/pds/projects/asigman/causality/src/EvaluationStartTrial.php (accessed 15 March 2014).
[11] This experimental protocol was based on Ballas (1993), who found a correlation between the measure of confidence of sound causality and the more laborious causal uncertainty measure (Heu). [9]

stimuli were presented via an embedded Dewplayer.[12] The stimuli could be played back any number of times, but could not be paused and resumed mid-file. Thirty-nine stimuli were presented in MPEG-3 format. Every sub-category of the Industrial/Mechanical category was represented by at least one stimulus.

All subjects were required to complete a trial session consisting of three practice trials prior to being directed to the experiment, in order to determine judgment

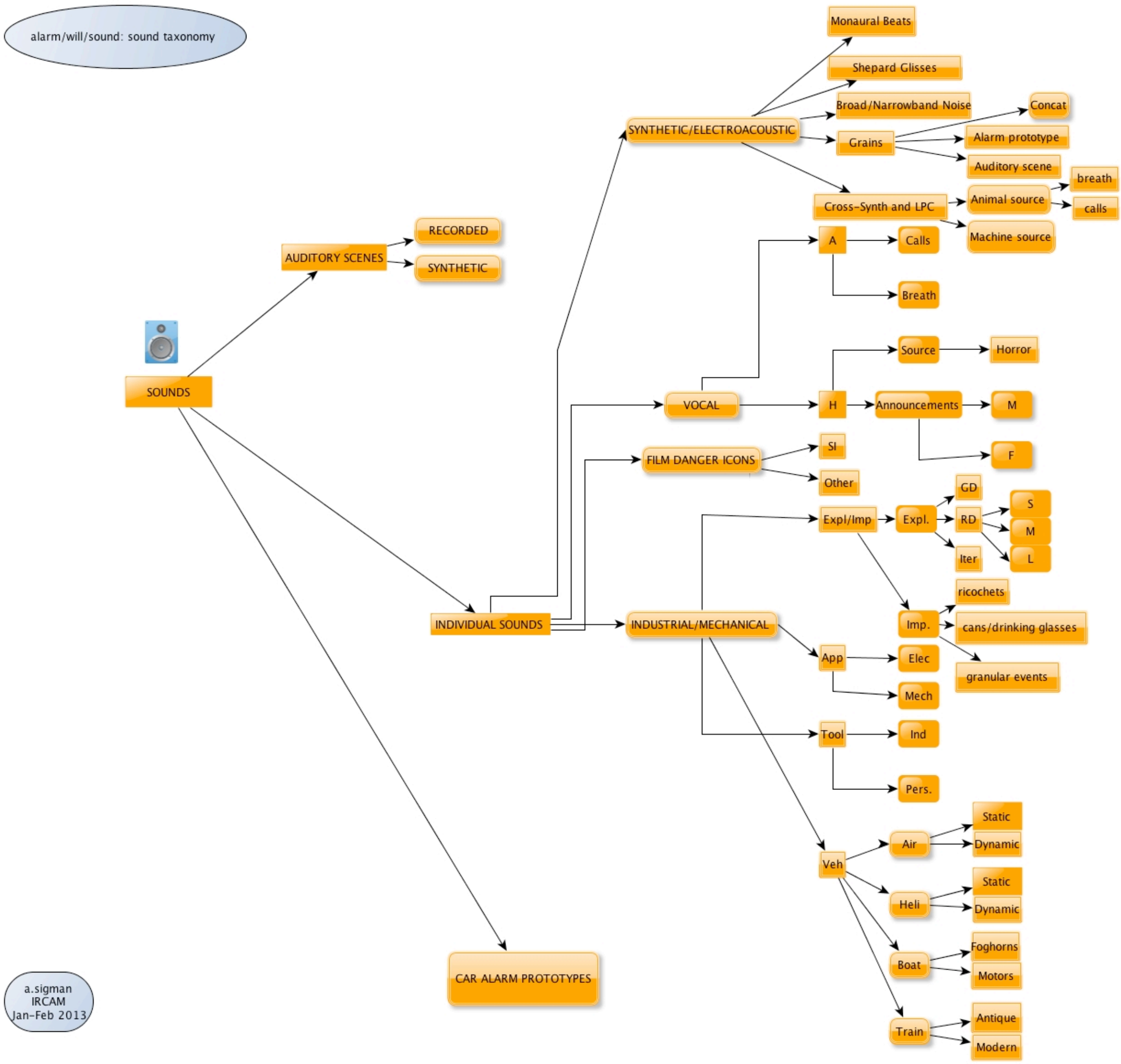

Figure 2. Sound corpus taxonomy, constructed in January-February 2014

[12] http://www.alsacreations.fr/dewplayer.html (accessed 15 March 2014).

stability for each participant. Subjects could not advance to the next trial until the "Sound Source Description" field was filled out. Once the experiment was completed, subjects were requested to submit a questionnaire pertaining to the subjects' professional and educational backgrounds, audio equipment used during the experiment, and acoustics of physical environment in which the subjects were located at the time of participating in the experiment. In addition, feedback regarding the experiment was solicited.

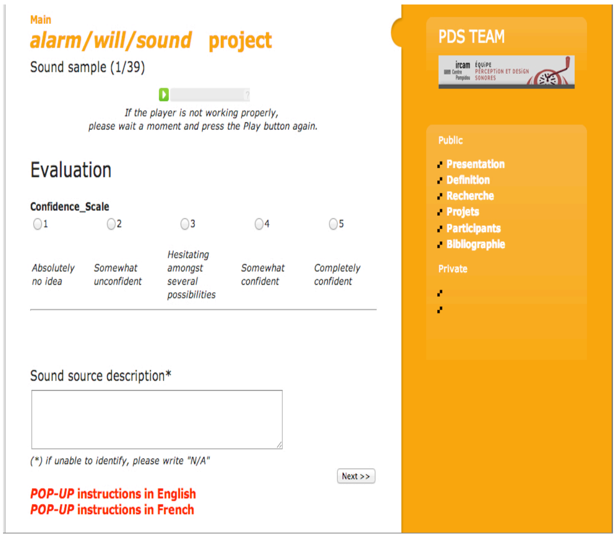

Figure 3. Experiment 1 user interface.

5.3 Results

Of the ca. 100 visitors to the experiment website, twenty-four subjects began the experiment. Of this subject pool, only fifteen subjects completed all trials.

Figure 4 indicates the confidence ratings of the fifteen subjects across the thirty-nine stimuli. The stimuli are indicated on the *x*-axis from left to right in order of confidence rating (from low to high). A significant difference t-test was applied to the lowest and highest mean confidence ratings in order to locate the threshold between iconic (strongly identifiable) and non-iconic sounds (represented by the thick vertical line in Figure 4). Stimuli and their respective mean confidence ratings are listed (alphabetically) in Figure 5.

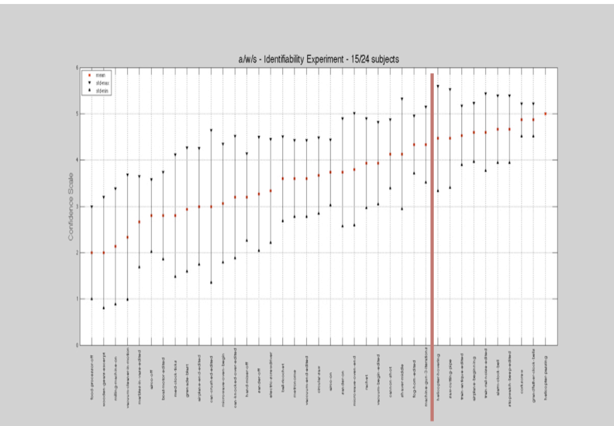

Figure 4. Confidence ratings for 39 stimuli with iconicity threshold indicated from low (left) to high (right).

Stimulus	Mean Confidence Rating
1 airco_off	2.80
2 airco_on	3.73
3 airplane_beginning	4.60
4 airplane_end	3.00
5 alarm_clock_bell	4.67
6 ball_ricochet	3.60
7 boat_motor_edited	2.80
8 can_crushed_edited	3.00
9 can_knocked_over	3.20
10 cannon_shot	4.13
11 circular_saw	3.67
12 corkscrew	4.87
13 electric_screwdriver	3.33
14 fog_horn	4.33
15 food_processor_off	2.00
16 grandfather_clock_bells	4.87
17 grenade_blast	2.93
18 hand_mixer_off	3.20
19 helicopter_hovering	4.47
20 helicopter_passing	5.00
21 machine_gun_3_iteration	4.33
22 marbles_in_vase	2.67
23 med_clock_ticks	2.83
24 metronome	3.60
25 microwave_oven_begin	3.07
26 microwave_oven_end	3.80
27 milling_machine_on	2.13
28 rachet	3.93
29 sander_off	3.27
30 sander_on	3.73
31 saw_cutting_pipe	4.47
32 shaver_middle	4.13
33 stopwatch_beep	4.67
34 train_antique	4.53
35 train_rail_noise	4.60
36 vaccuum_end	3.60
37 vacuum_begin	3.93
38 vacuum_cleaner_in_motion	2.33
39 wooden_gears_excerpt	2.00

Figure 5. The thirty-nine stimuli (listed alphabetically) and their respective mean confidence ratings.

Amongst the sound source descriptions provided by the subjects (in the field below the confidence scale on the experiment interface), the responses ranged in confidence and specificity. (In one case, for instance, a subject identified the brand of metronome of one of the stimuli.)

5.4. Discussion

The relatively high attrition rate amongst potential subjects (100 to twenty-four to fifteen) suggests two factors that discouraged participants from continuing with the experiment: 1) the duration required to complete the task (30-45 minutes) and 2) the fatiguing nature of the sounds presented. There was also no available "Save and Continue" option, so the experiment had to be conducted in one sitting. Experiment 2 will require a shorter completion time (ca. 15-20 minutes), and will consist of stimuli of shorter durations.

The individual differences in confidence ratings and specificity of responses may be attributed in part to differences in experience with mechanical/electrical tools and industrial equipment. The sounds that caused the most confusion either had contextually-obscure sources (e.g., wooden gears or milling machine), impulsive (e.g., grenade blast, marbles in vase, or a ball-ricochet) or were steady-state and drone-like in nature, with motor sources (e.g., air conditioner, microwave oven, boat motor, or food processor). The iconic sounds were quite context-specific (e.g., grandfather clock bells, antique train, or machine gun), time-varying (e.g. helicopter, airplane, or train passing), or common (e.g., corkscrew opening a bottle or alarm clock). Interestingly, a few sounds that were segmented into two stimuli produced different confidence scale ratings for each segment. The sound "airco-off" (air conditioner off) had a mean confidence rating of 2.8, while "airco-on" was correlated with a mean rating of 3.73. Similarly, "airplane-end" had a mean rating of 3.0, while the rating "airplane-beginning" fell to the right of the iconicity threshold, at 4.6. As otherwise drone-like, steady-state, motor-produced sounds, the onsets of "airco-on" and "airplane-beginning," as well as "sander-on," may have provided more spectral cues than the respective offsets. By contrast, the termination of "microwave-oven-end" (confidence rating = 3.8) seems to have given more cues than "microwave-oven-begin" (confidence rating = 3.07).

Despite the lower levels of participation than expected, these results did enable us to construct an abstraction-iconicity scale and to determine salient semantic characteristics of the sounds tested. It was concluded that the sounds falling to the right of the iconicity threshold would not function effectively in the car alarm context, as they were too closely associated with specific sources, which may very well exist within a vehicle's immediate environment (e.g., trains/airplanes/helicopters and clock chimes).

6. ACOUSTIC MODELING: PSC-HNR DESCRIPTOR SPACE

The next step in the corpus characterization process was to compute perceptually relevant acoustic descriptors. The objective was to construct an acoustic descriptor space in which to situate the corpus sounds, thereby enabling us to trace relative distances between constituent sounds, as well as between extant sounds and new entries.

Several approaches were considered, including Mel Frequency Cepstral Coefficient (MFCC) attached to a Gaussian Mixture Model (GMM) and a Multi-Dimensional Scaling (MDS) analysis. It was ultimately decided that weighted-mean Perceptual Spectral Centroid (PSC) and Harmonicity-to-Noise Ratio (HNR)—two acoustic parameters included in the IrcamDescriptor 2.7 toolbox [19]—would be employed based upon a 2010 study by Misdariis et al. on metadescription and modeling of environmental sounds such as interior car sounds, air conditioners, car horns, and car doors [11].

A two-dimensional PSC-HNR space was then calculated and populated by the thirty-one Industrial/Mechanical sounds tested in Experiment 1 that fell below the iconicity threshold. Moreover, in order to fill empty or underrepresented zones of the space, hybrid sounds were constructed via the constant cross-synthesis of pairs of one-second samples of extant sounds in AudioSculpt. The resulting acoustic features space is illustrated in Figure 6.

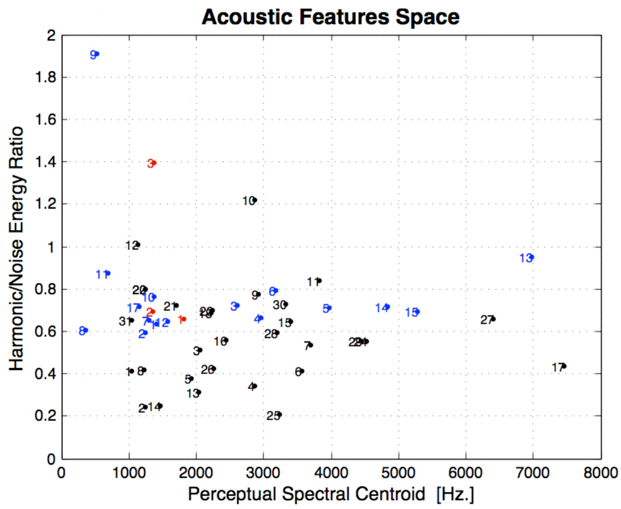

Figure 6. Perceptual Spectral Centroid (PSC)-Harmonicity-to-Noise Ratio (HNR) acoustic features space containing industrial/mechanical source sounds and hybrid sounds.

7. SYNTHETIC AUDITORY WARNING CONSTRUCTION

Synthetic auditory warnings were constructed by combining: a) selected industrial/mechanical source sounds and hybrids placed within the acoustic descriptor space described above; b) five typical environmental sound envelopes; and c) the inter-onset intervals (IOI's) of the six alarms comprising a standard car alarm repertoire.

Of the set of stimuli shown in Figure 6, six original sounds and three cross-synthesized hybrids that lie at the extremes and center of the descriptor space were selected. In the Minard, et al. study [14] mentioned previously, six perceptually distinct environmental sound morphologies were devised and tested: 1) stable; 2) decreasing; 3) increasing; 4) pulse-train; 5) single impulse; and 6) rolling (see Figure 7). Given the iterative nature of these alarms, the "stable" category was excluded, as this inhibits recognition of new iterations in an ecological or experimental context.

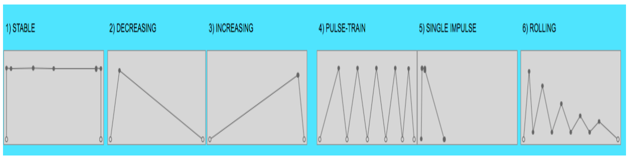

Figure 7. Six environmental sound envelopes, rendered as breakpoint functions (BPF's) in Max/MSP.

As is presented in Figure 8, the inter-onset intervals of six standard car alarms were calculated (in Matlab[13]). Given the similarity in IOI of alarms 1 and 2, 3 and 5, and 4 and 6 (respectively) to each other, each pair of IOI's was averaged, producing three distinct IOI durations: 300 ms. (short), 536 ms. (medium), and 2082 ms. (long).

Since the combination of nine sources times five envelopes times three IOI's would still produce too many stimuli to be realistically tested in a sound perception experiment, and several combinations would create contradictions among the parameters (and by extension, lose perceptual salience in an auditory warning context), further exclusions were made on an intuitive (but empirical) basis. For instance, new onsets of sounds with a decreasing envelope and a short IOI were deemed imperceptible. On the opposite end of the scale, single-impulse envelopes with long IOI's would lose the qualities of an auditory warning, given the latency between onsets. Similarly, impulsive and granular source-sounds (e.g., wooden gears, or a toppled tin can) would not effectively be paired with long IOI's.

Once these restrictions were applied, it was possible to generate an array of contrasting stimuli to be employed in Experiment 2. This was achieved via the Max 6 patch illustrated in Figure 9. In the patch, the six environmental sound envelopes are rendered as breakpoint functions (BPF's), as is indicated in Figure 7. The user first chooses from amongst the nine possible source sounds mentioned above. This sound is modulated with one of the six BPF's, selected from a drop-down menu. The BPF's duration and triggering/looping rate may be altered by clicking on one of nine IOI durations: six corresponding to the IOI's of the standard car alarms, and the three aforementioned averaged inter-onset intervals (300, 536, and 2082 ms., respectively). In addition, it is possible to trigger a Morphology Sequencer, which cycles through the six BPF's at the current IOI rate. The Morphology Sequencer loops until it is deactivated.

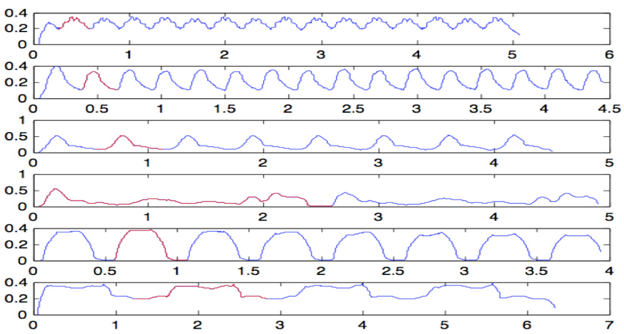

Figure 8. Six car alarm inter-onset intervals (IOI's).

[13] http://www.mathworks.com/products/matlab/

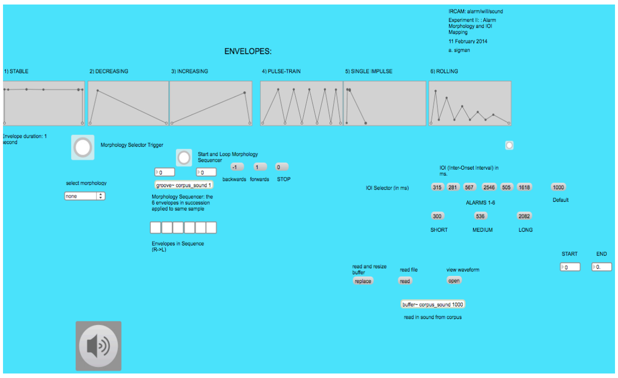

Figure 9. Synthetic auditory warning Max patch. The six environmental sound envelope BPF's are positioned at the top of the patch, the car alarm IOI selector towards the right. (The user may select one of the six original IOI's, or one of the three averaged IOI's—short, medium, and long—used in Experiment 2.) The Morphology Sequencer is placed below the third BPF, to the right of the morphology drop-down menu.

8. EXPERIMENT 2: ATTRACTION VS. REPULSION TO SYNTHETIC AUDITORY WARNINGS

As was the case for Experiment 1, Experiment 2 will be conducted via an online, crowd-sourced format on the IRCAM Sound Perception and Design research team site. Subjects will be presented with synthetic auditory warning stimuli, and asked to rate the level of attraction or repulsion to the sound on a three-point scale (attraction/indifference/repulsion). In order to facilitate this task, the instructions to the experiment will include metaphors to other sensory modalities (e.g., attraction vs. repulsion to odors). In addition, the subjects will be presented with the following ecological scenario, described verbally and through images: one is confronted with a box emitting a given synthetic auditory warning. Does one feel compelled to pick up and open the box, ignore it, or to run away? With this scenario in mind, subjects will complete three practice trials prior to being directed to the experiment.

In the interest of limited the required completion time for the experiment to 15-20 minutes, a subset of the synthetic auditory warnings described above will be employed as stimuli. These stimuli will be selected on the basis of contrast of spectral and temporal characteristics. It is hoped that the results of this experiment will enable us to determine which synthetic auditory warnings would be more effective as deterrents, and which could be utilized as auditory feedback in the context of user interaction with the alarm prototypes.

9. FUTURE WORK

Goals for the short-term include completing Experiment 2 and analyzing the results. Thereafter, we will focus on the interactivity component of the project, and determine the optimal hardware and software development environments in which to pursue this. Once our alarm prototypes have reached a sufficient stage of development, they will be exhibited primarily in site-specific public-space contexts, but also in gallery spaces. The establishment of collaborative relationships with industry partners is in progress, and should be confirmed within the next year or so.

When the prototypes are presented to the public, the interaction models described previously will be featured. Exhibition visitors will be able to trigger alarm sounds remotely via control stations or mobile devices, in a searchable catalog organized and characterized based upon the results obtained from the two experiments and the constructed acoustic descriptor space. User experiences with the various modes of interaction will be documented via video/camera images, data collected from user input at control stations, and survey responses. Ultimately, it is intended that users will be able to upload their own recordings, which may then be edited and indexed according to criteria derived from the experiments.

10. REFERENCES

[1] F. Friedman, A. Naparstek, and M. Taussig-Rubbio, "Alarmingly Useless: The Case for Banning Car Alarms in New York City," *Transportation Alternatives*, 2003. Retrieved from http://www.transalt.org/files/newsroom/reports/caralarms/ on 08 February 2013.

[2] N. Misdariis, A. Gruson, and P. Susini, "Detectability study of warning signals in urban background noises: a first step for designing the sound of electric vehicles," in *Proceedings of Meetings on Acoustics (POMA)-ICA 2013*, Montreal, 2013**,** pp. 1-9.

[3] G. Lemaitre, P. Susini, S. Winsberg, B. Letinturier, and S., McAdams, "The sound quality of car horns: Designing new representative sound," *Acta acustica united with Acustica*, vol. 95, no. 2, pp. 356-372, 2009.

[4] C. Suied, P. Susini, and S. McAdams, "Evaluating Warning Sound Urgency With Reaction Times," *Journal of Experimental Psychology: Applied*, vol. 14, no. 3, pp. 201-212, 2008.

[5] P. Susini, N. Misdariis, G. Lemaitre, and O. Houix, "Naturalness influences the perceived usability and pleasantness of a user interface's sonic feedback," *Journal on Multimodal User Interfaces*, vol. 5, no. 3, pp. 52-80, 2012.

[6] P. Schaeffer, *Traité des objets musicaux*. Paris, France: Seuil, 2002.

[7] O. Houix, G. Lemaitre, N. Misdariis, P. Susini, and I. Urdapilleta, "A Lexical Analysis of Environmental Sound Categories," *Journal of Experimental Psychology: Applied*, vol. 18, no. 1, pp. 52-80, 2012.

[8] O. Claude, *La recherche intelligente des sons*. (Masters Thesis.) Université de Provence, Aubagne, France, 2006.

[9] J.A. Ballas, "Common Factors in the Identification of an Assortment of Everyday Sounds," *Journal of Experimental Psychology: Human Perception and Performance,* vol. 19, no. 2, pp. 250-267, 1993.

[10] G. Peeters and X. Rodet, "Automatically selecting signal descriptors for Sound Classification," *International Computer Music Conference Proceedings,* Göteborg, Sweden, 2002, pp. 455-458.

[11] N. Misdariis, A. Minard, P. Susini, G.Lemaitre, S. McAdams, and E. Parizet, "Environmental Sound Perception: Metadescription and Modeling Based on Independent Primary Studies," *EURASIP Journal on Audio, Speech, and Music Processing*, January 2010, Article No. 6.

[12] R.D. Patterson, "Auditory warning sounds in the work environment," in *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 1990, pp. 485-492.

[13] J. Edworthy, E. Hellier, K. Titschener, A. Naweed, and R. Roels, "Heterogeneity in auditory alarm sets make them easier to learn," *International Journal of Industrial Economics*, vol. 41, no. 2, pp. 135-146, 2011.

[14] A. Minard, N. Misdariis, O. Houix, and P. Susini, "Catégorisation des sons environnementaux sur la base de profiles morphologiques," *10ème Congrès Français d'Acoustique*, Lyon, France, 2010, pp.1-6**.**

[15] K. Yamauchi, J. Choi, R. Maiguma, M. Takada, and S. Iwamiya, "A Basic Study on Universal Design of Auditory Signals in Automobiles," *Journal of Physiological Anthopology and Applied Human Science*, vol. 23, no. 6, pp. 295-298, 2004.

[16] S. Kuwano, S. Namba, A. Schick, H. Höge, H. Fastl, T. Filippou, and M.Florentine, "Subjective impression of auditory danger signals in different countries," *Acoustical Science and Technology*, vol. 28, no. 5, pp. 360-362, 2007.

[17] R.D. Patterson and A.J. Datta, "Extending the Domain of Auditory Warning Sounds: Creative Use of High Frequencies and Temporal Asymmetry," in *Human Factors in Auditory Warnings*, N. Stanton and J. Edworthy (Eds.), Brookfield, VT, USA: Ashgate, 1999, pp. 73-88.

[18] N. Stanton and J. Edworthy, "Auditory affordances in the intensive treatment unit," *Applied Ergonomics*, vol 29, no. 5, pp. 389-394, 1998.

[19] G. Peeters, “A large set of audio features for sound description (similarity and classification),” CUIDADO project Ircam technical report, 2004, http://www.ircam.fr/anasyn/peeters/ARTICLES/Peeters_2003_cuidadoaudiofeatures.pdf