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ALARM SOUNDS FOR MEDICAL EQUIPMENT IN INTENSIVE CARE AREAS AND OPERATING THEATRES

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CONTENTS PAGE NO

0.0 SUMMARY

This report summarises work carried out under a grant from the Department of Trade and Industry to the Institute of Sound and Vibration Research, in conjunction with the MRC Applied Psychology Unit, for the production of a demonstration set of advanced auditory warnings for the intensive care areas and operating theatres of hospitals.

The demonstration warnings were made to support standards work undertaken by the Alarms Working Group of the British Standards Institute (BSI), Health Care Committee 16 (HCC 16), formerly Breathing Machines (SGC 46). This committee has a mandate to rationalise the auditory warnings found in the intensive care units and operating theatres of hospitals. To this end it has designed a set of seven pairs of auditory warnings using principles developed by the Medical Research Council's Applied Psychology Unit for the production of advanced warnings for aircraft flight decks. The warnings so designed were produced on a computer and recorded as a demonstration tape so that the relevant committees could actually hear and assess the products of the design.

This document describes the background to the design and production of these demonstration auditory warnings.

1.0 INTRODUCTION

Hospitals are employing an ever increasing amount of medical equipment with auditory warnings to signal potentially dangerous conditions or equipment malfunction. As a result there has been a rapid proliferation of auditory warnings particularly in intensive care areas and operating theatres. Generally the warning sounds are too loud, many are high-pitch tones that are difficult to localise and most are confusing because they have been introduced without consideration of other sounds in the environment. Currently, auditory signals provided on medical equipment may both resemble other signals with entirely different meanings, yet differ from signals with a similar meaning. In practice, staff have to learn a fresh set of warning sounds each time they move to a new environment and confusion can be caused when a new piece of equipment is added to the existing stock. There is, in short, a need to rationalise warning signals for use in hospitals and this has been set out in an editorial entitled "An 'Alarming' situation in the Intensive Therapy Unit" (Kerr and Hayes, 1983).

The problems of existing hospital warnings were recognised by the anaesthetists on a BSI committee for breathing machines (SGC 46) in 1982. This committee works in conjunction with Medical Committee TC 121/SC 3/WG1 of the International Organization for Standardization (ISO), which has the mandate to standardise auditory warnings in the operating theatres and intensive care units of hospitals around the world. The BSI Committee, now known as Health Care Committee 16 (HCC 16), was given the task of designing the warnings and drafting an initial standards paper because of expertise available through the Medical Research Council in Cambridge and the Institute of Sound and Vibration Research in Southampton. In conjunction with the Civil Aviation Authority this team had previously designed a set of advanced auditory warnings for the flight deck of a civil aircraft, and in conjunction with the MOD(PE) and the Royal Aircraft Establishment, Farnborough, had designed a set of advanced warning sounds for a military helicopter.

Dr. Patterson from the MRC was drafted onto HCC 16 and during the next two years HCC 16 designed a set of seven pairs of auditory warnings and prepared a working paper for ISO SG 3/WG1. Twice yearly HCC 16 met the ISO representatives to discuss the work, its direction and purpose, and a Draft International Standard was prepared which specified advanced auditory warnings for use in patient-monitoring equipment.

The new alarm sounds proposed in the standard are each composed of a sequence of notes in a distinctive rhythm somewhat analogous to a bird call or short melody. The notes are ‘rounded’ to minimise the potential of causing a startle reaction and there are silent intervals of a few seconds between repetitions of the ‘call’ to allow the staff time for thinking and action before they feel impelled to silence the alarm sound. The new sounds will be easier to localise because both high- and low-frequency harmonics will be included. Higher priority signals will be faster rather than louder.

Unfortunately these advanced warning sounds are difficult to imagine. The few examples from the aircraft industry prepared previously by the MRC were of some help but the committee felt that it was essential to prepare a full demonstration set to support the Standards work both in Britain and abroad. Apart from simply enabling the committee members to hear what they had designed, the demonstration warning set had another very important purpose; namely, to provide a test set which, when approved by the committee, could be evaluated in operating theatres and intensive care wards. Accordingly HCC 16 applied to the Department of Trade and Industry for a grant to produce the demonstration warning set. The grant was awarded and work began officially in July 1985.

2.0 CURRENT HOSPITAL WARNINGS

The first step in the project was to review hospital warnings currently in use. The warning sounds were reviewed in three hospitals: Addenbrooke's District Hospital in Cambridge, the Radcliffe Infirmary in Oxford, and the Royal Hampshire County Hospital in Winchester. The sounds are largely high-frequency tones or buzzers that go on and off at one rate or another. They are essentially the same in the different hospitals, although their usage may differ from hospital to hospital. Accordingly, the warning sounds were recorded at Winchester where the largest set was available. The set consists of 33 warning sounds which are listed with their manufacturer and function in Table 1. A cassette recording of the existing warning sounds is available and has been used to provide HCC 16 and SC 3/WG1 with a proper review of the current situation.

For reasons that will become clearer later in the report, none of the warning sounds was judged suitable to form the basis of a new warning sound, primarily because the spectra of the existing warnings were inappropriate for the hospital environment. When analysed they typically showed one main spectral peak whereas the guidelines for auditory warnings (Patterson, 1982) and the Draft International Standard for medical equipment (unpublished) require the sound to have at least four of the first ten harmonics of a relatively low fundamental, and these four harmonics have to fall in the frequency region 0.5 to 4.0 kHz. The temporal patterns of the warning sounds were completely inadequate, consisting typically of a simple continuous tone or a simple on-off pattern. Previous research on the confusability of aircraft warnings showed that warning sounds with similar temporal patterns were more likely to be confused (Patterson, 1982). In general, existing warning sounds come on abruptly at their full level which increases the probability of causing an unnecessary startle reaction both in the staff and the patients. The existing warnings, then, were judged to be wholly inadequate.

3.0 PROTOTYPE ADVANCED WARNINGS

3.1 An Overview of Warning Sounds and their Construction

Auditory warnings, like horns, bells and sirens, cut through speech and background noise and command people's attention. It does not matter whether one is concentrating on an important visual task or relaxing with one's eyes closed, the warning sound is automatically detected by the auditory system and routed through to the brain. As a result sounds are used throughout industry and the medical world to signal danger, or potential danger. Unfortunately, they are often installed with a 'better safe than sorry' approach that results in warnings that are too loud, too strident, and too insistent. Flooding an area with sound is certain to get people's attention but it will also prevent communication just at the time when it is essential. The annoying, and potentially dangerous, side effects of auditory warnings are largely avoidable, and a set of guidelines for the production of proper auditory warnings is now available (Patterson, 1982).

The guidelines explain the spectral characteristics required to make a pulsive sound that is distinctive and resistant to masking by unexpected noise sources. The generation of a sound pulse for a warning sound is described in Section 3.2. The guidelines then explain how to make a distinctive burst of pulses with its own melody and rhythm to produce a warning sound that will not be confused with other members of the set. The production of a burst of pulses and the assembly of a complete warning sound are described in Section 3.3. The remainder of this section consists of a general introduction to the new style of auditory warnings.

The time course of a warning sound designed for use in hospitals is presented in the bottom row of Figure 1. The 'houses', designated by Roman numerals, represent different versions of a burst of sound pulses. The height of the houses indicates the relative intensity of the bursts. The spectral and temporal characteristics of the pulse (upper row) and the burst (middle row) give the warning sound its distinctive character. The pitch, intensity, and speed of the burst are used to vary the perceived urgency of the warning sound. For present purposes a burst can be thought of as a brief, atonal melody with a syncopated rhythm.

When the situation indicates, the warning sound comes on and the first burst is played at a pitch and speed that indicate moderate urgency, and at a level that is clearly audible but not excessive, as determined by the background noise in the environment. This first burst (I) will attract the attention of staff in the vicinity and, in most cases, it will immediately convey the message of the warning sound. Occasionally when a person is deeply engrossed in a task he or she will detect the burst but not switch his or her full attention to it instantly, and so not be completely confident of the message. As a result, the burst is repeated after a 1–2 second gap (burst II) just at the time when the person might be inclined to say to themselves ‘What was that?’

At this point, after two bursts, it is highly likely that the warning has conveyed its message, and that further repetition of the burst form would be needlessly irritating. At this point, then, the pitch, sound level, and speed of the burst are lowered to reduce its perceived urgency, and it is played every 4 seconds or so in this non-urgent form (III and IV). With the level reduced and the time between bursts extended, one can communicate verbally in the presence of the warning without difficulty – an important advantage in an emergency.

If the condition that initiated the warning sound is not attended to within a reasonable length of time, the warning returns in its most urgent form – conveyed by a pair of bursts (V and VI) with a relatively high pitch, a fast pulse rate, and a sound level that overrides any ongoing speech and commands attention. Then the warning returns to the background level to permit communication. In the case of the hospital warning, bursts III–VI repeat until the condition that initiated the warning is corrected, or until someone indicates their attendance.

In summary, one can now design and build civilised warning sounds that present their message with reasonable urgency and promptly fall back to permit vital communication, returning to interrupt forcefully only if there is reason to believe that the condition has not received sufficient attention.

3.2 Warning Pulse Generation

The auditory warnings described in this report are made up from brief pulses which vary in duration from 75 to 200 ms in accordance with the guidelines set down by Patterson (1982). The pulses are synthesized in a computer program that initially requests values for the discrete frequencies and amplitudes of all spectral components to be used in a pulse;

alternate components are assigned cosine or sine phase in order to avoid excessive peak factors in the pulse waveform. The frequencies and amplitudes of the components are tailored to the environment. This spectral information undergoes an inverse Fourier transformation after which both the resulting waveform and the original spectrum can be refined further.

One of the major determinants of perceived urgency in pulses is their spectral content; the wider the range of frequency components, the wider the range of available urgencies. The urgency of the pulse also varies with the fundamental frequency, the degree of inharmonicity, and the relative weight of the high and low frequencies. Greater urgency appears to be signalled by higher fundamentals, by some degree of inharmonicity, and by relatively more high-frequency energy.

Temporal characteristics of pulses are constrained in their ability to signal urgency by the time/frequency Uncertainty Relation, i.e. as the overall duration of a pulse is made shorter, it sounds progressively more like a click owing to the increasing spread of energy. To avoid startling transients, all pulses are gated with raised-cosine ramps at their start and finish. The 'standard' ramp is 25 ms in duration, but 'slow onset' or 'slow decay' ramps can also be used. A slow onset pulse of 200 ms, for example, would have a raised-cosine ramp of 175 ms followed by a 35 ms decay ramp, giving a characteristic asymmetric envelope. Qualitatively, the slow onset is perceived as similar to a bowed-string instrument or a woodwind; the reverse – a slow decay – resembles a plucked string. The slow onset is generally perceived as less urgent that the slow decay.

Amplitude modulation and other forms of envelope shaping have little effect with pulses less than 100 ms in duration. The longer the pulse, the more important is the contribution from temporal parameters. Modulation in particular requires long pulses in order to be effective. This is because the temporal information imparted by the modulation takes a few cycles to take effect. In a similar way, but to a lesser extent, the asymmetric envelopes need longer durations for their asymmetry to become noticeable. One way of manipulating both spectral and temporal parameters to achieve a distinctive sound is to shift the whole spectrum upwards in frequency halfway through the pulse. An alternative approach, offering more flexibility, is to create separately brief pulses, each at a different frequency, and add them together in an overlapping sequence. This method enables one to mimic a frequency glide.

The design for hospital warnings includes six pairs of specific warning sounds to specify problems in six different functions (listed in Section 4.0 below) together with one pair of general purpose sounds. The spectral and temporal parameters that affect the urgency of a sound were used to create pulses that are more or less urgent, as appropriate to any action required by the staff.

3.3 Warning Burst Construction and Warning Sound Assembly

A burst is constructed by making 3–9 copies of the basic pulse and specifying three sets of parameter values for the burst. One set specifies the pitch of the pulses, thus producing a unique pitch-contour or melody; the second set specifies the elapsed time between the start of one pulse, and the start of the next, thus producing a distinctive temporal pattern or rhythm; the third set determines the attenuation of the pulses, thus producing the amplitude envelope. These parameters affect the perceived urgency of the burst, and thereby enable us to construct warnings where the perceived urgency is commensurate with the priority of the situation (whether it requires immediate action, immediate awareness, or is simply information). A burst constructed within this framework becomes the template for the complete warning. Three forms of the burst are generated: an initial form, a background form, and an urgent form. They are generated by varying the overall pitch, speed and attenuation of the burst. The effects of the burst parameters on perceived urgency, and the construction of new auditory warnings in which the urgency is appropriate to the priority of the situation, are described below.

In general, the shorter the time between pulses, the more urgent the burst. Or in rate terms, a burst with a high pulse rate will convey greater urgency than a burst with a low pulse rate. A regular temporal pattern, where the ratios of the times between the pulses are simple, sounds less urgent than an irregular pattern where the ratios are more complex (the rhythm is syncopated or non-metric). A rising pitch-contour (melody) produces a more urgent burst than a falling pitch-contour, and the difference is striking. The difference remains even if the progression is non-monotonic as long as the general trend, from the first pulse to the last, is upward (urgent) or downward (non-urgent). The pitch-contour also helps make warnings distinctive.

In situations requiring a careful response, startle reactions are undesirable. Startle reactions can be avoided in bursts of sound by attenuating the first two, or three, pulses. The amplitude envelope also affects burst urgency; an urgent burst should remain at, or near, the maximum level while a less urgent burst should decrease in level towards the end of the burst.

Thus, a burst designed to convey a high level of urgency has a fast, irregular pattern, a rising pitch contour and an amplitude envelope which ends at its maximum sound level. A burst designed to convey a low level of urgency has a slow tempo and is fairly regular; there is some syncopation in order to make the burst distinctive. It has a falling pitch contour, and an amplitude envelope which ends below the maximum sound level.

Once a burst appropriate to the priority of the situation has been designed, three forms of the burst are generated. As shown in Figure 1, the initial form of the burst is used at the beginning of the warning. The urgent form is created by raising the pitch and speeding up the entire burst (like transposing a melody up several semitones, and playing it faster). The loudness level is also increased. The background form is created by lowering the pitch and, where appropriate, by slowing down the burst. A complete warning is then assembled from the three forms of burst. The initial burst is played twice as shown in the bottom row of Figure 1. A time interval then elapses, allowing communication to take place. Depending upon the urgency of the situation, the next burst is either the urgent or the background form. In a high-priority situation, the urgent form of the burst will follow soon after the initial form; in a lower priority situation a number of background bursts follow the initial form before the urgent form appears.

4.0 DEMONSTRATION TAPE AND DOCUMENTATION

In the initial demonstration set prepared for HCC 16 in September of 1985, there were seven pairs of emergency and cautionary warning sounds to cover the categories:

1) general;
2) oxygenation;
3) ventilation;
4) cardiovascular;
5) artificial perfusion;
6) drug administration;
7) temperature.

A summary of the seven warnings is presented in Figure 2. Each subfigure shows the pitch contour, the temporal pattern, and the amplitude envelope for the emergency version of each pair of warning sounds. The abscissa in each case is time in seconds and the ordinate is pitch in semitones; each of the rectangles in the subfigure represents a single pulse of sound and the height of the rectangle indicates the amplitude of the pulse. Thus, the general emergency sound in the subfigure at the top is a set of four pulses that are simultaneously rising in pitch and amplitude followed by two syncopated pulses for which the amplitude remains high but the pitch drops. The warning sounds, then, are like short, one-bar melodies and the burst subfigure can be read rather like a piece of music. The pulses occur at a fairly rapid rate, around 6 per second, which gives an urgent impression.

The full documentation of each warning sound as originally designed is contained in Annex A. For each warning sound there is a burst summary figure like those in Figure 2. It is accompanied by a table of parameter values that specify the pitch, amplitude, and pulse spacing for each pulse in the burst, and for each form of burst, that is, the initial, urgent, and background forms of the burst. Then there is a table for the pulse used to make the basic burst. It gives the characteristics of the pulse, a pulse-waveform subfigure and a table of the frequencies in the pulse.

A meeting of HCC 16 was held in Cambridge in September 1985 to review the demonstration tape and its documentation. There was considerable discussion about the demonstration format which was revised and then approved.

The revisions made to the warnings included changing the emergency and cautionary general warning sounds to have a greater pitch range and a shorter duration, and the final two pulses were pushed together and left at the top of the pitch contour to make the sound a little more urgent. In the cautionary version of the general warning sound the final pair of pulses was dropped to make it sound less urgent. It was also decided to add an information sound for doctor's paging "bleepers". None of the warning pulses were changed.

The final demonstration tape and its documentation constitutes the final product of this project. The documentation is presented in Annex B. It consists of a transcript of the demonstration tape, a summary sheet of burst patterns for the seven pairs of warnings, and individual burst-pattern subfigures with tables giving the pitch, amplitude, and spacing of the pulses in the burst.

5.0 RECOMMENDATIONS

The demonstration warnings designed by the standards working group and produced under this project are under consideration for testing in hospitals in Japan, America and the U.K.

If equipment with the new warning sounds is installed alongside existing equipment the potential benefits of the new sounds may not be realised and the warnings not properly assessed. The underlying philosophy of the new warnings is to reduce the total number of warnings to a manageable number, make these warnings distinct from each other, and then assign meanings to each warning. To test this philosophy, all the equipment in a particular ward or ICU should be fitted with the new sounds, and no equipment should use any other sound. Adding to the number of existing sounds, rather than replacing existing sounds, may merely compound existing problems.

In practice, if and when the new sounds are accepted, there is likely to be a changeover period of several years when new and existing sounds are used side by side. This problem should be addressed separately from testing the new sounds.

Consideration must also be given at this stage to the technology required to install auditory warnings in medical equipment and to the costs of the manufacturer, ultimately borne by the customer.

6.0 REFERENCES

Kerr, J.H., and Hayes, B. (1983). An ‘Alarming’ Situation in the Intensive Therapy Unit. Intensive Care Med. 9, 103-104.

Patterson, R.D. (1982). Guidelines for auditory warning systems on civil aircraft. Civil Aviation Authority, London, Paper 82017.

ACKNOWLEDGEMENTS

The authors would like to thank the members of HCC 16 and in particular the Chairman, Dr. J. Kerr, for their assistance in specifying the warnings and reviewing the demonstration tapes and documentation. They would also like to thank the staff at the three hospitals mentioned for their time and assistance in demonstrating the existing warning sounds.

TABLE 1

CASSETTE COPY OF EXISTING AUDITORY WARNING SOUNDS RECORDED IN WINCHESTER HOSPITAL

No.	FUNCTION	MANUFACTURER/TYPE	SOUND
1	Blood pressure	Dynamat Vital Signs Monitor 1846	(Two tones alternating)
2	Servoventilator	Siemens Clema 900B	(Rapid pips)
3	Servoventilator – power	Siemens Clema 900B	(Slow pips pitch changes)
4	Ventilator	Cape	(Impure tone)
5	Volumetric infusion pump	Imed 960	(Pips grouped in fives)
6	Syringe pump	Vickers Trionic IP3	(Tone)
7	Ventilator	Cape	(Beeps)
8	Oxygen cylinder empty		(Whistle)
9	Cardiac Monitor	Hewlett-Packard	(Tone)
10	Oxygen analyser	Beckman	(Beeps)
11	Blood warmer	Grant	(Quiet hum/buzz)
12	Infusion pump	Ivac	(Slow peep)
13	General ward warning sound		
14	Incubator – overheat	Vickers 77	(Screech/fast warble)
15	Paging bleep		(Rapid pips)
16	Paging bleep		(Pips grouped in threes)
17	Oxygen failure		(Whistle)
18	Ventilator	Blease	(Slow pips)
19	?	?	(Beep)
20	Peripheral perfusion	Hewlett-Packard	(Repeated ping)
21	Incubator – overheat	Vickers 77	(Screech/fast warble)
22	Incubator – ventilator	Vickers 77	(Tone)
23	Incubator – overheat	Vickers 59	(Tone)
24	Apnoea	.	(Tone)
25	Apnoea	Graseby	(Pips)
26	Apnoea — (power)	Vickers	(Fast pips – (pitch change))
27	Partial oxygen – overlimit		(Tone)
28	Partial oxygen – malfunction	(Grasshopper/warble)	
29	ECG Triscope	S&W (Simonson & Weel?)	(Beep)
30	Transcutaneous partial 02	S&W	(Tone, pitch as above)
31	Syringe pump – end of infusion	Graseby MS2000	(Two pips, 10s cycle)
32	Syringe pump – blocked line	Graseby MS2000	(Three pips, pitch as above)
33	Syringe pump – power failure	Graseby MS2000	(Tone, pitch as above)

The recording was made with the assistance of Roger Clunie, Consultant Anaesthetist, and the staff of the Intensive Care, Maternity, and Special Care Baby Units on August 12, 1985. The original recording was made on a Sony PCM-F1 system by Mike Lower, ISVR, Southampton, and Mike Shailer, MRC Applied Psychology Unit, Cambridge, as part of a project funded by the Department of Trade and Industry to improve and standardise warning and information sounds in hospitals.

M.C. Lower
5/9/85

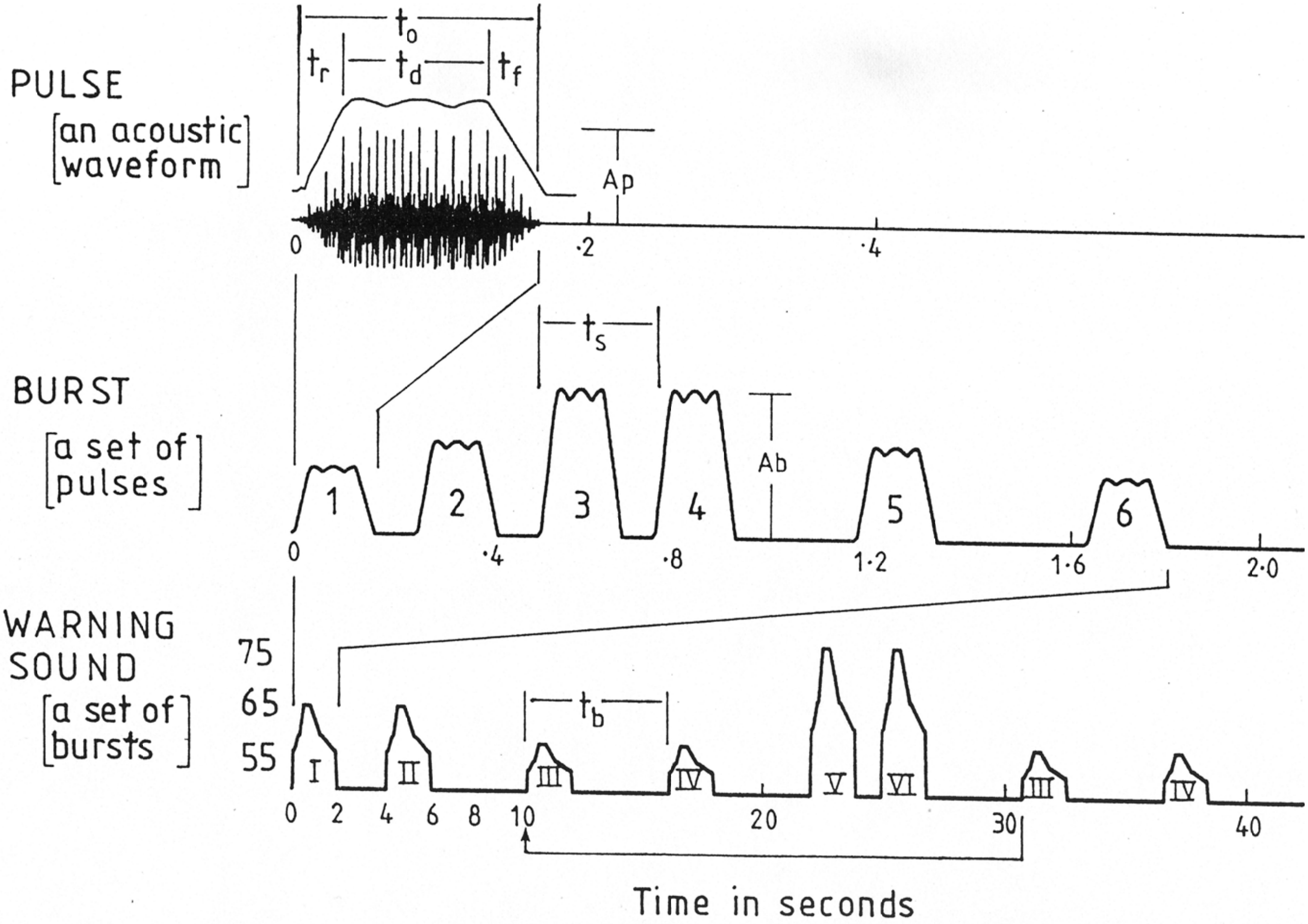


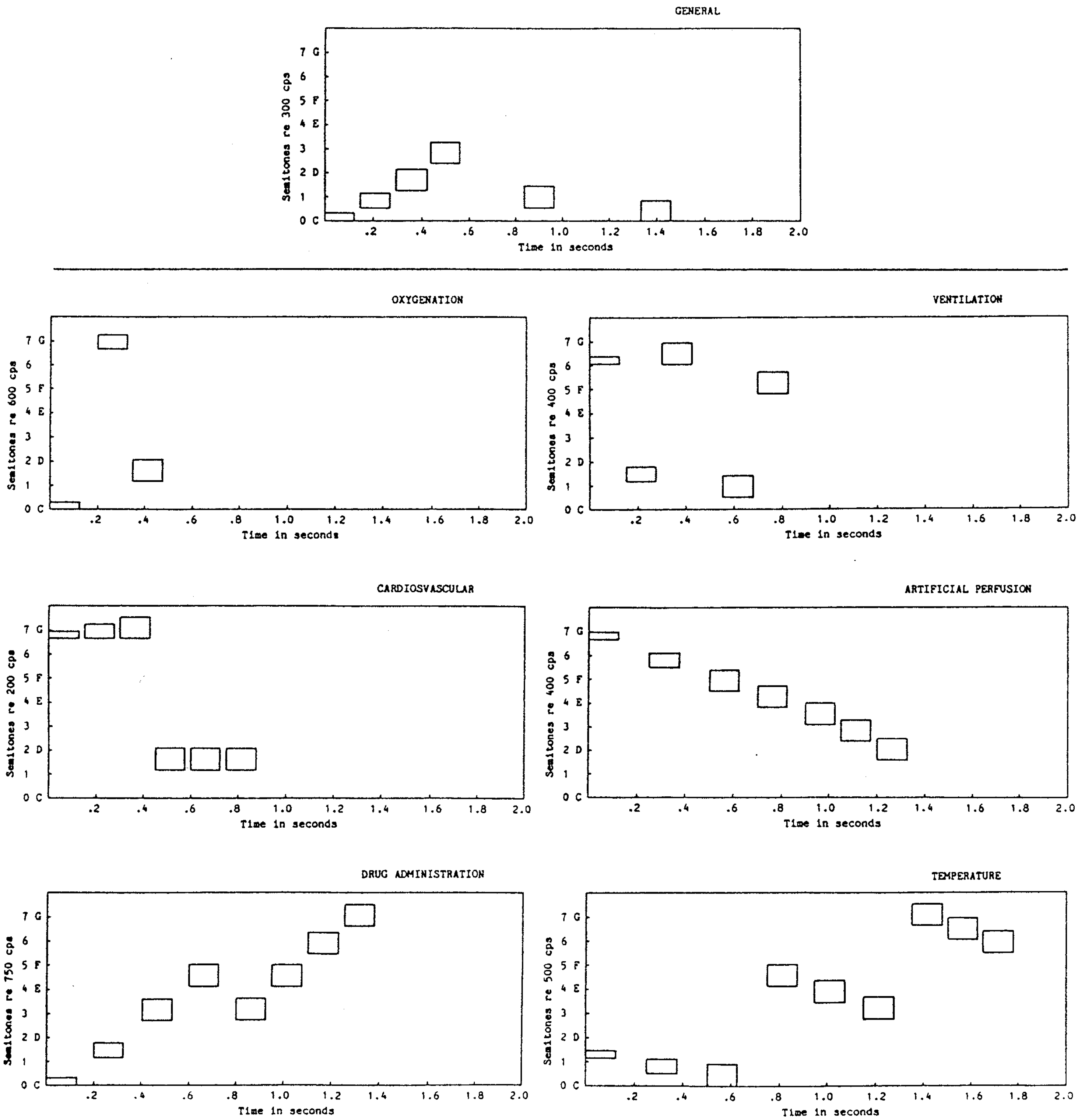
Figure 1

AUDITORY WARNING SOUND COMPONENTS

Figure 2 <u>HOSPITAL WARNING DEMONSTRATION SET</u>

APU Cambridge 5 September 1985

ISVR Southampton



ANNEX A

HOSPITAL WARNING DEMONSTRATION SET

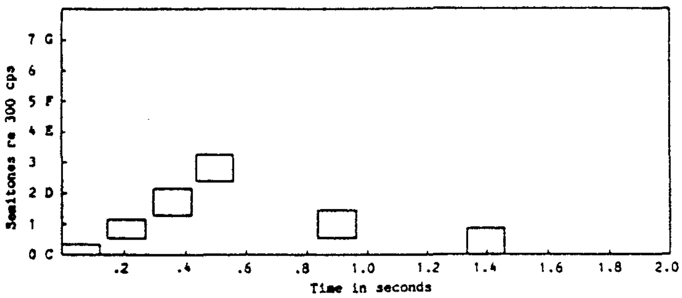
5th SEPTEMBER 1985

HOSPITAL WARNING DEMONSTRATION SET

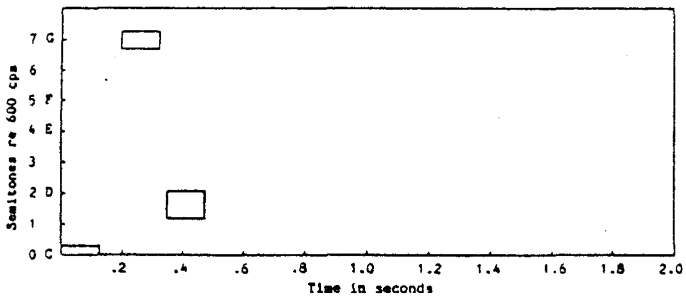
APU Cambridge
ISVR Southampton

5 September 1985

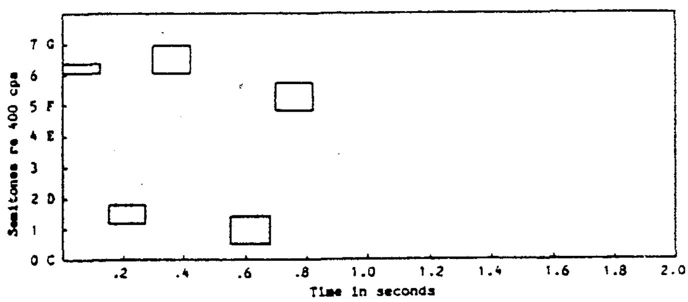
GENERAL



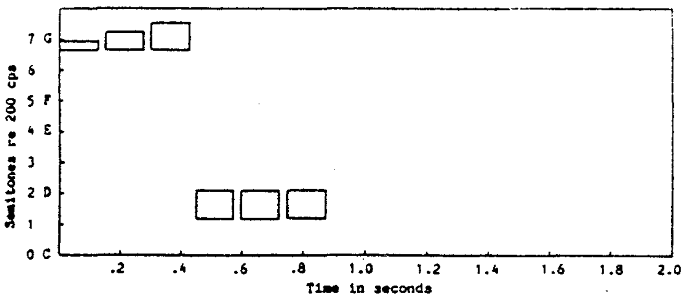
OXYGENATION



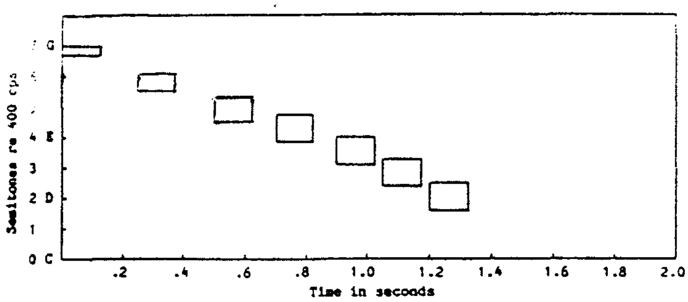
VENTILATION



CARDIOSVASCULAR



AR[illegible]CIAL PERFUSION



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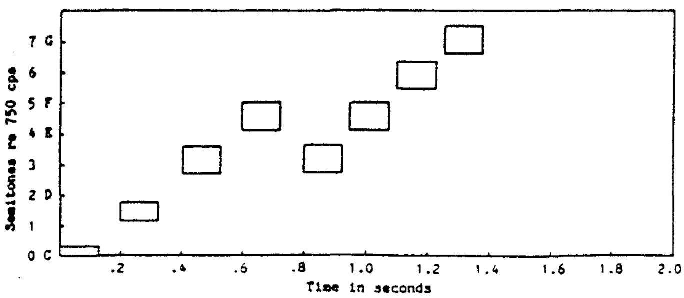
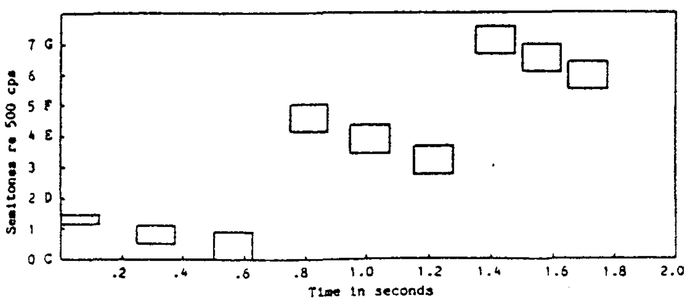
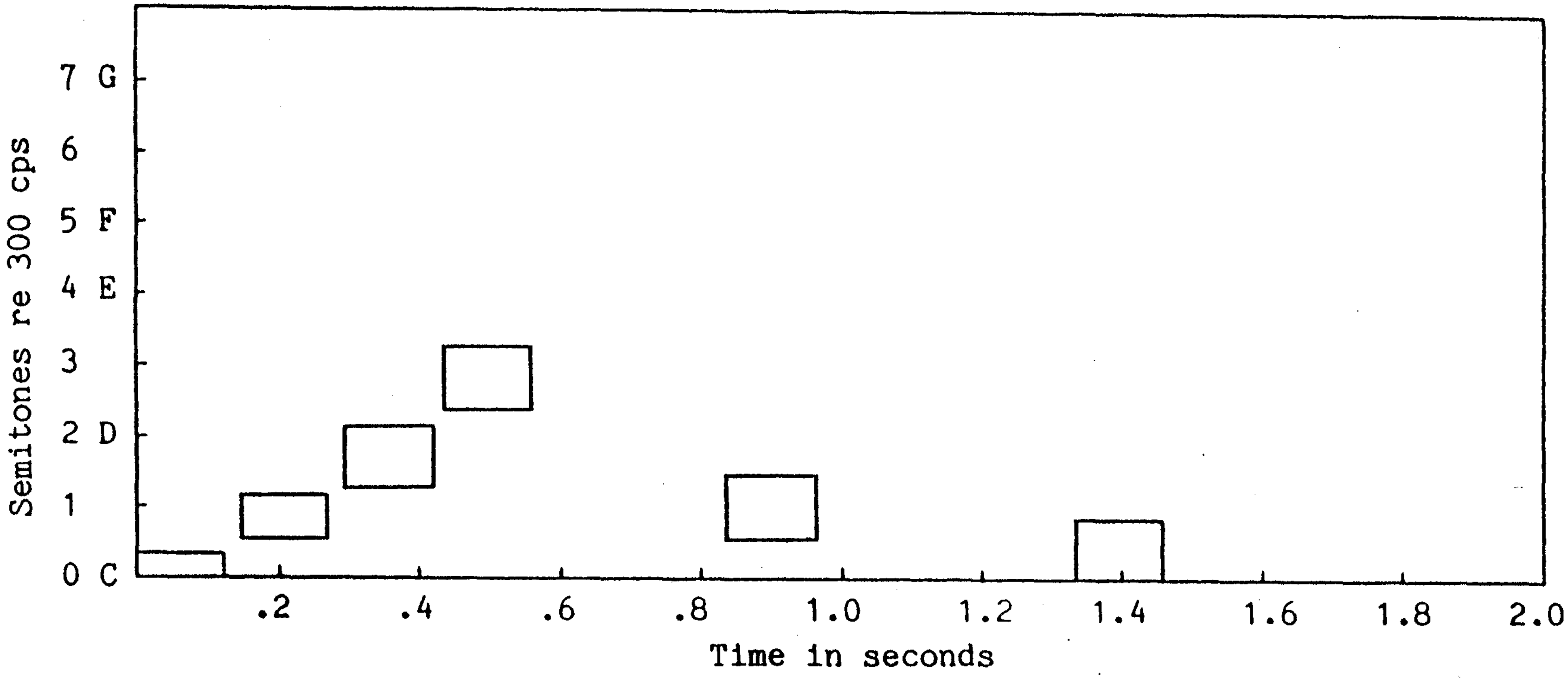


TEMPERATURE

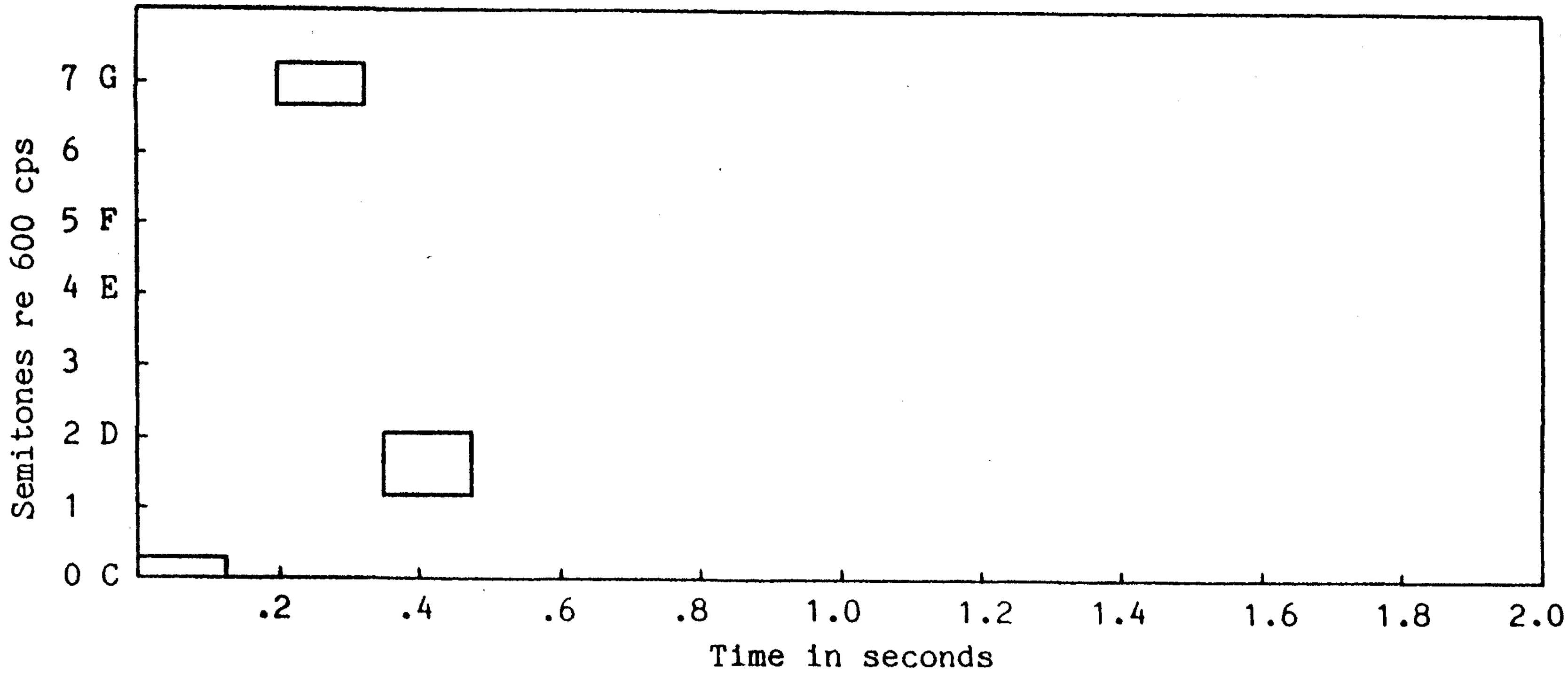


HOSPITAL AUDITORY WARNING EMERGENCY BURST: GENERAL



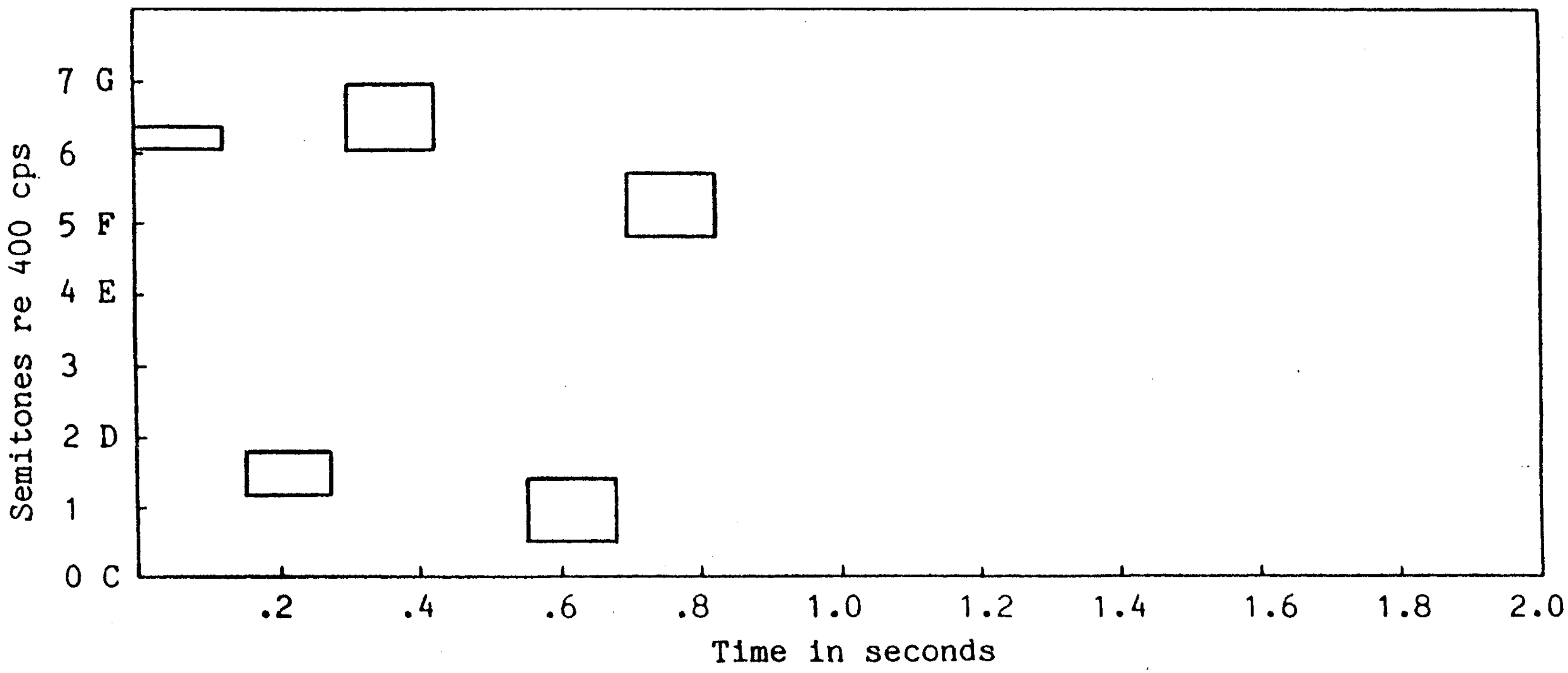
Pulse Number			1	2	3	4	5	6
Initial Burst	P	(Hz)	300	312	324	344	312	300
	A	(dB)	18	14	10	10	10	10
	PS	(ms)	150	150	137	400	500	
Urgent Burst	P	(Hz)	329	341	353	373	341	392
	A	(dB)	8	4	0	0	0	0
	PS	(ms)	135	135	123	360	450	
Background Burst	P	(Hz)	264	276	288	308	276	264
	A	(dB)	20	20	20	20	20	20
	PS	(ms)	180	180	168	480	600	

HOSPITAL AUDITORY WARNING EMERGENCY BURST: OXYGENATION



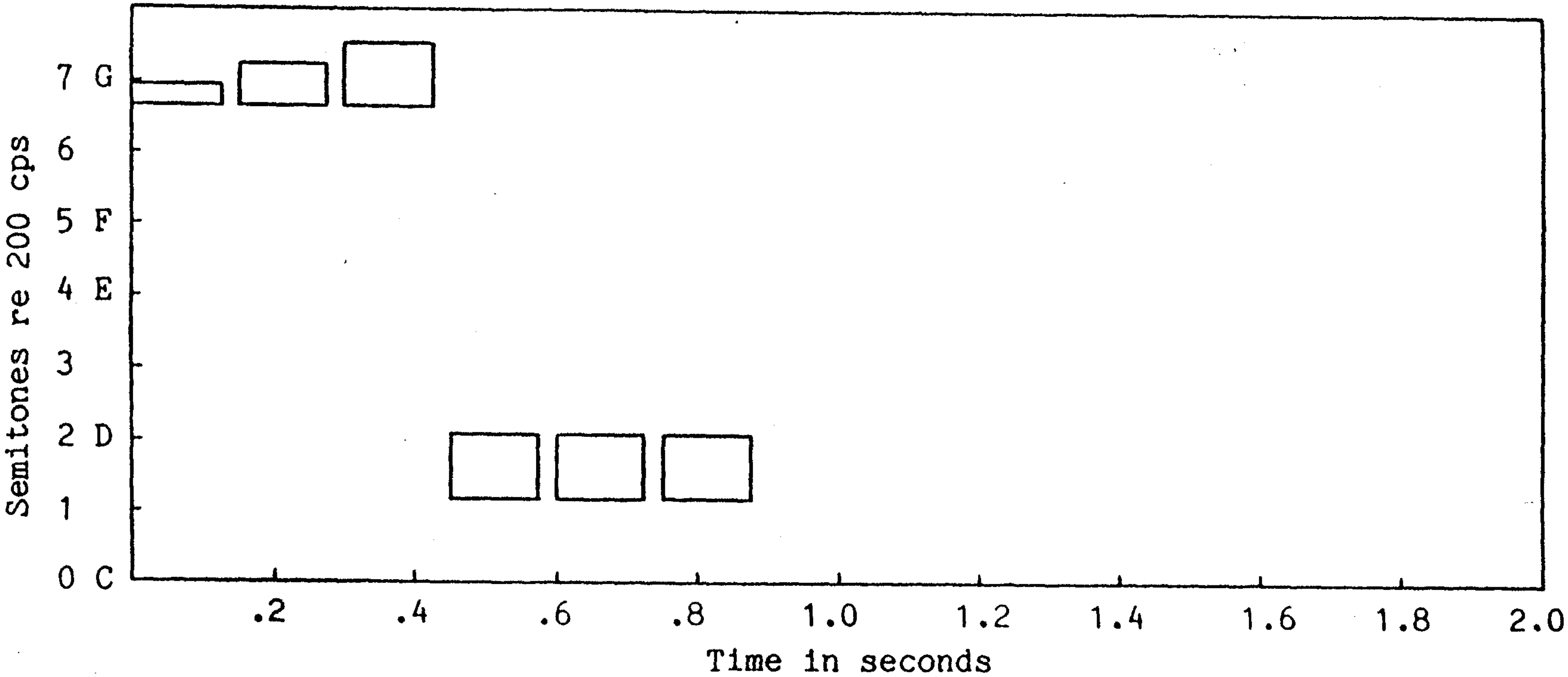
Pulse Number			1		2		3
Initial Burst	P	(Hz)	600		879		644
	A	(dB)	18		14		10
	PS	(ms)		200		150	
Urgent Burst	P	(Hz)	659		938		703
	A	(dB)	8		4		0
	PS	(ms)		180		135	
Background Burst	P	(Hz)	529		806		573
	A	(dB)	20		20		20
	PS	(ms)		240		180	

HOSPITAL AUDITORY WARNING EMERGENCY BURST: VENTILATION



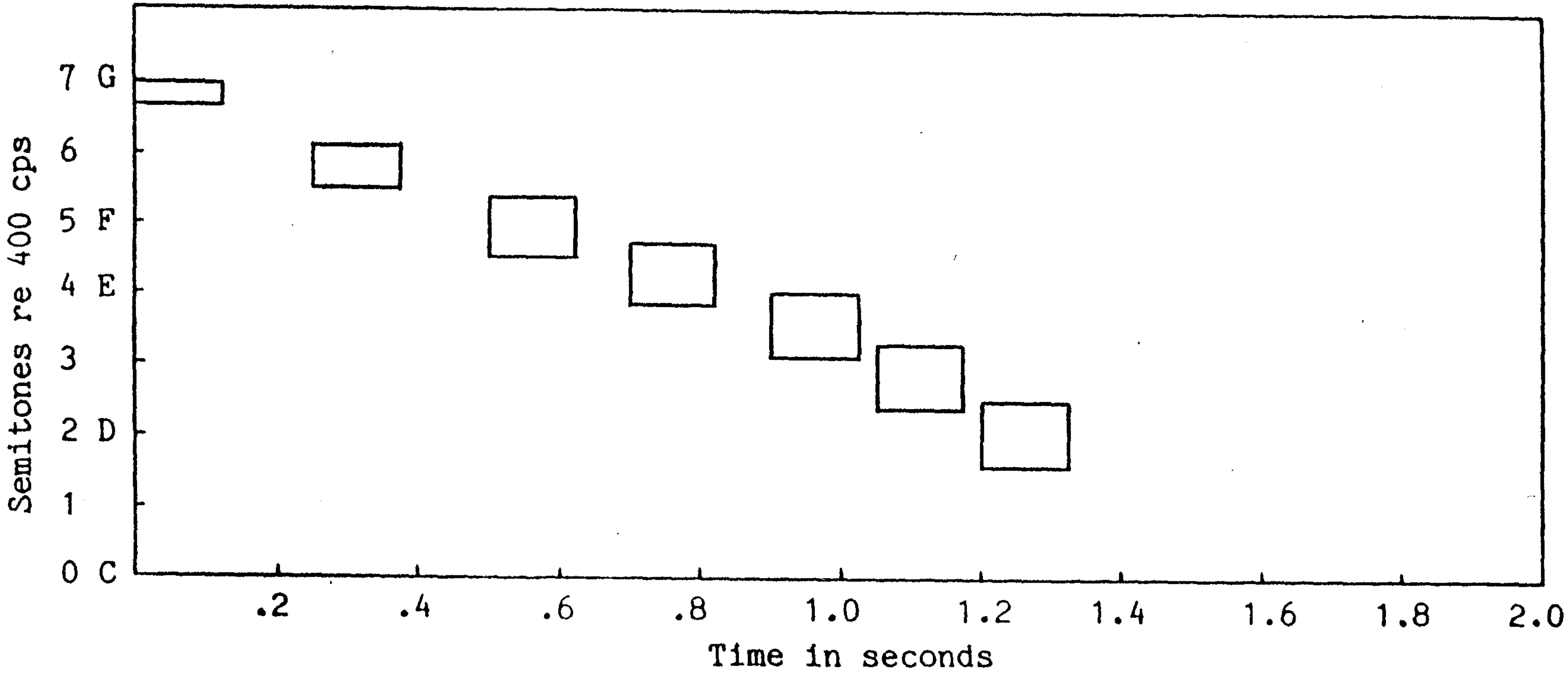
Pulse Number		1		2		3		4		5
Initial Burst	P (Hz)	566		430		566		410		527
	A (dB)	18		14		10		10		10
	PS (ms)		150		150		250		150	
Urgent Burst	P (Hz)	605		469		605		449		566
	A (dB)	8		4		0		0		0
	PS (ms)		135		135		225		135	
Background Burst	P (Hz)	527		391		527		371		488
	A (dB)	20		20		20		20		20
	PS (ms)		180		180		300		180	

HOSPITAL AUDITORY WARNING EMERGENCY BURST: CARDIOVASCULAR



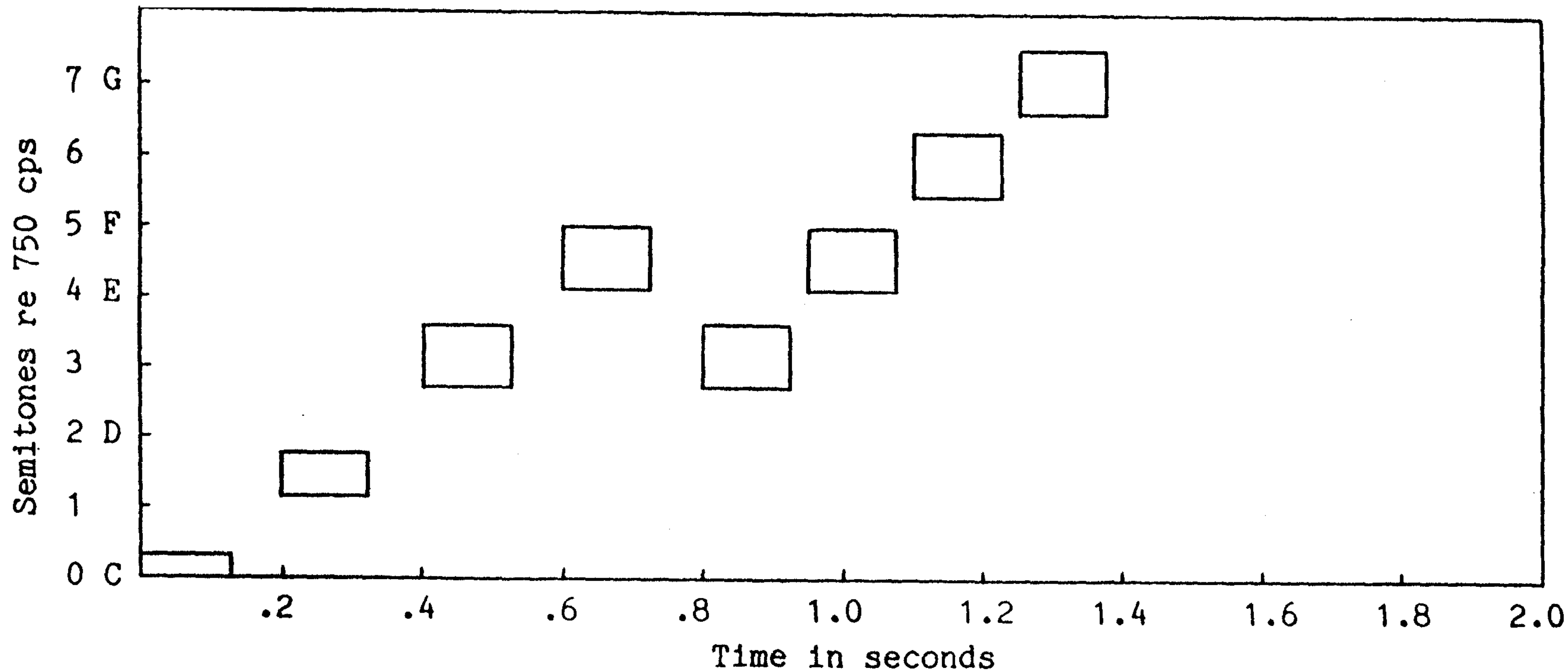
Pulse Number			1		2		3		4		5		6
Initial Burst	P	(Hz)	293		293		293		215		215		215
	A	(dB)	18		14		10		10		10		10
	PS	(ms)		150		150		150		150		150	
Urgent Burst	P	(Hz)	313		313		313		235		235		235
	A	(dB)	8		4		0		0		0		0
	PS	(ms)		135		135		135		135		135	
Background Burst	P	(Hz)	273		273		273		195		195		195
	A	(dB)	20		20		20		20		20		20
	PS	(ms)		180		180		180		180		180	

HOSPITAL AUDITORY WARNING EMERGENCY BURST: ARTIFICIAL PERFUSION



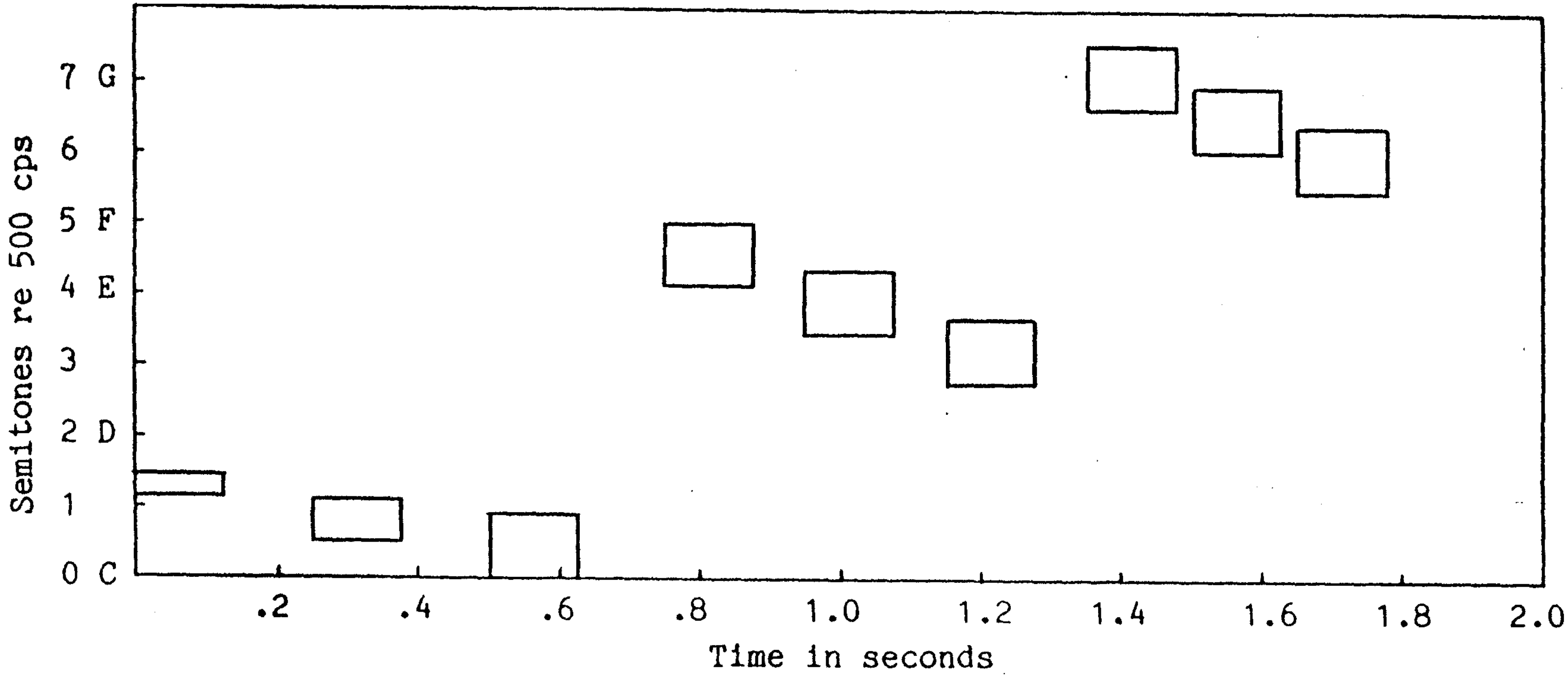
Pulse Number			1	2	3	4	5	6	7
Initial Burst	P	(Hz)	589	547	518	498	479	459	439
	A	(dB)	18	14	10	10	10	10	10
	PS	(ms)	250	250	200	200	150	150	
Urgent Burst	P	(Hz)	625	583	554	534	515	495	475
	A	(dB)	8	4	0	0	0	0	0
	PS	(ms)	225	225	180	180	135	135	
Background Burst	P	(Hz)	547	505	476	456	437	417	397
	A	(dB)	20	20	20	20	20	20	20
	PS	(ms)	300	300	240	240	180	180	

HOSPITAL AUDITORY WARNING EMERGENCY BURST: DRUG ADMINISTRATION



Pulse Number			1	2	3	4	5	6	7	8
Initial Burst	P	(Hz)	750	806	879	952	879	952	1025	1099
	A	(dB)	18	14	10	10	10	10	10	10
	PS	(ms)	200	200	200	200	150	150	150	
Urgent Burst	P	(Hz)	823	879	952	1025	952	1025	1099	1172
	A	(dB)	8	4	0	0	0	0	0	0
	PS	(ms)	180	180	180	180	135	135	135	
Background Burst	P	(Hz)	661	717	790	863	790	863	936	1010
	A	(dB)	20	20	20	20	20	20	20	20
	PS	(ms)	240	240	240	240	180	180	180	

HOSPITAL AUDITORY WARNING EMERGENCY BURST: TEMPERATURE



Pulse Number			1	2	3	4	5	6	7	8	9
Initial Burst	P	(Hz)	537	513	488	635	610	586	732	708	683
	A	(dB)	18	14	10	10	10	10	10	10	10
	PS	(ms)	250	250	250	200	200	200	150	150	
Urgent Burst	P	(Hz)	586	562	537	684	659	635	781	757	732
	A	(dB)	8	4	0	0	0	0	0	0	0
	PS	(ms)	225	225	225	180	180	180	135	135	
Background Burst	P	(Hz)	488	464	439	586	561	537	685	659	634
	A	(dB)	20	20	20	20	20	20	20	20	20
	PS	(ms)	300	300	300	240	240	240	180	180	

PROJECT: HOSPITAL WARNINGS

AUDITORY WARNING PULSE: GENERAL

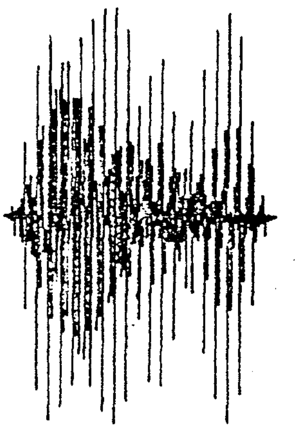
Priority: Emergency

Voice messages: None

Pulse characteristics:

Pitch: 300 Hz
Harmonicity: Harmonic
Duration: 150 ms
Delayed Harmonics: 75 ms
Envelope: Standard

Pulse waveform:



Pulse spectrum:

Frequency (Hz)	Weighting
300	5000
600	5000
900	5000
1200	5000
1500	5000
1800	5000
2100	5000
2400	5000
2700	5000
3000	5000
3300	5000
3600	5000

PROJECT: HOSPITAL WARNINGS

AUDITORY WARNING PULSE: GENERAL

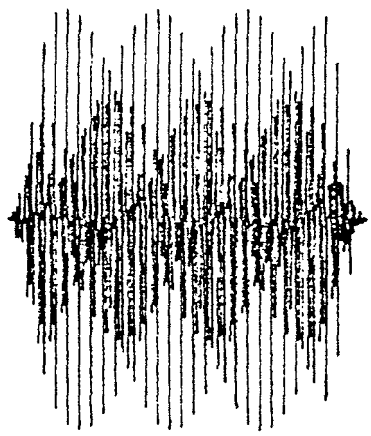
Priority: Cautionary

Voice messages: None

Pulse characteristics:

Pitch: 300 Hz
Harmonicity: Harmonic
Duration: 200 ms
Delayed Harmonics: None
Envelope: Standard

Pulse waveform:



Pulse spectrum:

Frequency (Hz)	Weighting
300	5000
600	5000
900	5000
1200	5000
1500	5000
1800	5000
2100	5000

PROJECT: HOSPITAL WARNINGS

AUDITORY WARNING PULSE: OXYGENATION

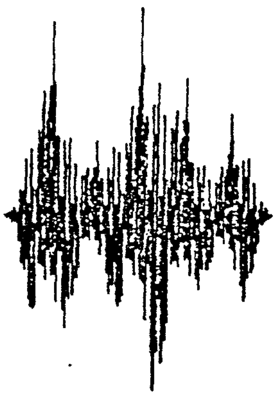
Priority: Emergency

Voice messages: None

Pulse characteristics:

Pitch: 600 Hz
Harmonicity: Inharmonic. Alternate component ± 20% of fundamental.
Duration: 150 ms
Delayed Harmonics: None
Envelope: Standard, with 15 Hz amplitude modulation

Pulse waveform:



Pulse spectrum:

Frequency (Hz)	Weighting
600	5000
1320	5000
1680	5000
2520	5000
2880	5000
3720	5000
4120	5000
4480	5000

PROJECT: HOSPITAL WARNINGS

AUDITORY WARNING PULSE: OXYGENATION

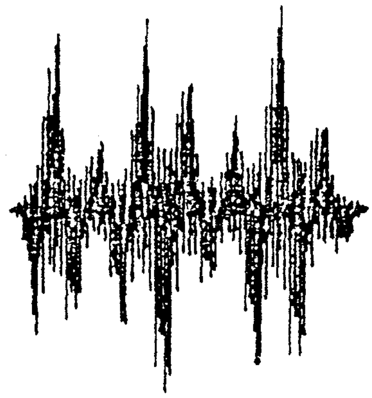
Priority: Cautionary

Voice messages: None

Pulse characteristics:

Pitch: 600 Hz
Harmonicity: Inharmonic. Alternate component ± 20% of fundamental.
Duration: 200 ms
Delayed Harmonics: None
Envelope: Standard, with 15 Hz amplitude modulation

Pulse waveform:



Pulse spectrum:

Frequency (Hz)	Weighting
600	5000
1320	5000
1680	5000
2520	5000
2880	5000
3720	5000

PROJECT: HOSPITAL WARNINGS

AUDITORY WARNING PULSE: VENTILATION

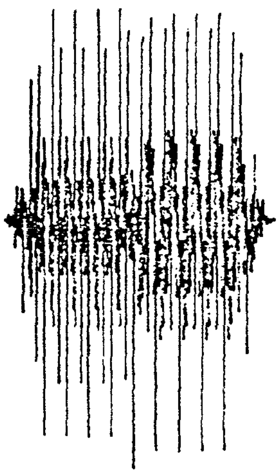
Priority: Emergency

Voice messages: None

Pulse characteristics:

Pitch: 400 Hz
Harmonicity: Inharmonic. Alternate component ± 20% of fundamental.
Duration: 150 ms
Delayed Harmonics: 75 ms
Envelope: Standard

Pulse waveform:



Pulse spectrum:

Frequency (Hz)	Weighting
400	5000
880	5000
1120	5000
1680	5000
1920	5000
2480	5000
2720	5000
3280	5000
3520	5000

PROJECT: HOSPITAL WARNINGS

AUDITORY WARNING PULSE: VENTILATION

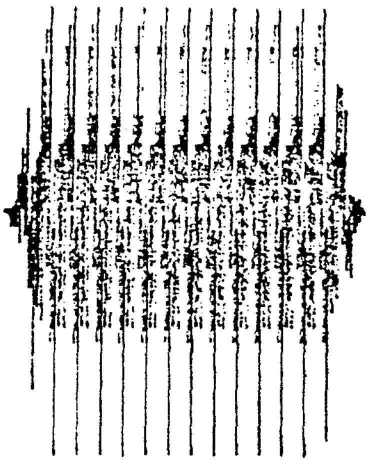
Priority: Cautionary

Voice messages: None

Pulse characteristics:

Pitch: 400 Hz
Harmonicity: Inharmonic. Alternate component ± 20% of fundamental.
Duration: 200 ms
Delayed Harmonics: None
Envelope: Standard

Pulse waveform:



Pulse spectrum:

Frequency (Hz)	Weighting
400	5000
880	5000
1120	5000
1680	5000
1920	5000
2480	5000

PROJECT: HOSPITAL WARNINGS

AUDITORY WARNING PULSE: CARDIOVASCULAR

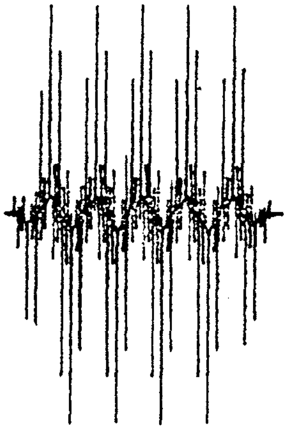
Priority: Emergency

Voice messages: None

Pulse characteristics:

Pitch: 200 Hz
Harmonicity: Harmonic
Duration: 150 ms
Delayed Harmonics: None
Envelope: Standard

Pulse waveform:



Pulse spectrum:

Frequency (Hz)	Weighting
200	10,000
400	1,000
600	10,000
800	1,000
1000	10,000
1200	1,000
1400	10,000
1600	1,000
1800	10,000
2000	1,000
2200	10,000
2400	1,000
2600	10,000
2800	1,000

PROJECT: HOSPITAL WARNINGS

AUDITORY WARNING PULSE: CARDIOVASCULAR

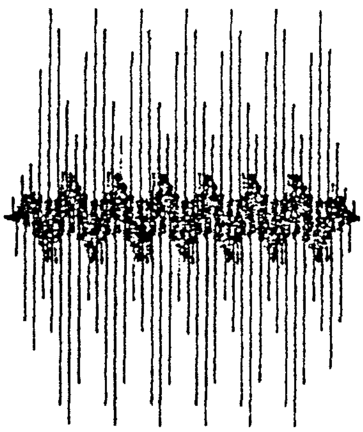
Priority: Cautionary

Voice messages: None

Pulse characteristics:

Pitch: 200 Hz
Harmonicity: Harmonic
Duration: 200 ms
Delayed Harmonics: None
Envelope: Standard

Pulse waveform:



Pulse spectrum:

Frequency (Hz)	Weighting
200	10,000
400	1,000
600	10,000
800	1,000
1000	10,000
1200	1,000
1400	10,000
1600	1,000
1800	10,000
2000	1,000

PROJECT: HOSPITAL WARNINGS

AUDITORY WARNING PULSE: ARTIFICIAL PERFUSION

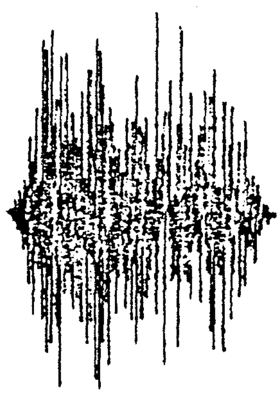
Priority: Emergency

Voice messages: None

Pulse characteristics:

Pitch: 400 Hz
Harmonicity: Inharmonic, with added components.
Duration: 150 ms
Delayed Harmonics: 75 ms
Envelope: Standard

Pulse waveform:



Pulse spectrum:

Frequency (Hz)	Weighting
400	5000
800	5000
1000	5000
1100	5000
1150	5000
1600	5000
2000	5000
2200	5000
2300	5000
2350	5000
2800	5000
3200	5000
3400	5000
3500	5000
3550	5000

PROJECT: HOSPITAL WARNINGS

AUDITORY WARNING PULSE: ARTIFICIAL PERFUSION

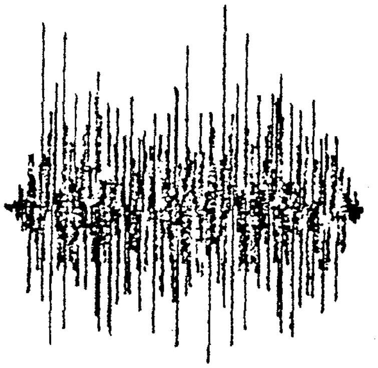
Priority: Cautionary

Voice messages: None

Pulse characteristics:

Pitch: 400 Hz
Harmonicity: Inharmonic, with added component.
Duration: 200 ms
Delayed Harmonics: None
Envelope: Standard

Pulse waveform:



Pulse spectrum:

Frequency (Hz)	Weighting
400	5000
800	5000
1000	5000
1100	5000
1150	5000
1600	5000
2000	5000
2200	5000
2300	5000
2350	5000
2800	5000
3200	5000
3400	5000
3500	5000
3550	5000

PROJECT: HOSPITAL WARNINGS

AUDITORY WARNING PULSE: DRUG ADMINISTRATION

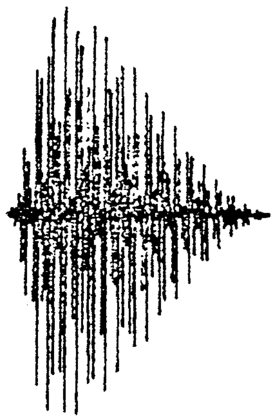
Priority: Emergency

Voice messages: None

Pulse characteristics:

Pitch: 750 Hz
Harmonicity: Harmonic
Duration: 150 ms
Delayed Harmonics: None
Envelope: Slow offset

Pulse waveform:



Pulse spectrum:

Frequency (Hz)	Weighting
750	5000
1500	5000
2250	5000
3000	5000
3750	5000

PROJECT: HOSPITAL WARNINGS

AUDITORY WARNING PULSE: DRUG ADMINISTRATION

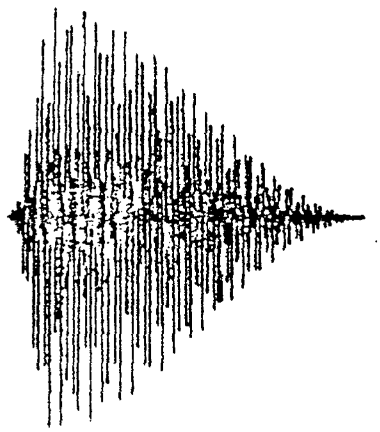
Priority: Cautionary

Voice messages: None

Pulse characteristics:

Pitch: 750 Hz
Harmonicity: Harmonic
Duration: 200 ms
Delayed Harmonics: None
Envelope: Slow offset

Pulse waveform:



Pulse spectrum:

Frequency (Hz)	Weighting
750	5000
1500	5000
2250	5000
3000	5000

PROJECT: HOSPITAL WARNINGS

AUDITORY WARNING PULSE: TEMPERATURE

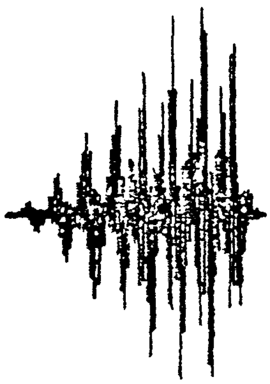
Priority: Emergency

Voice messages: None

Pulse characteristics:

Pitch: 500 Hz
Harmonicity: Harmonic
Duration: 150 ms
Delayed Harmonics: 75 ms
Envelope: Slow onset

Pulse waveform:



Pulse spectrum:

Frequency (Hz)	Weighting
500	5000
1000	5000
1500	5000
2000	5000
2500	5000
3000	5000
3500	5000
4000	5000
4500	5000
5000	5000

PROJECT: HOSPITAL WARNINGS

AUDITORY WARNING PULSE: TEMPERATURE

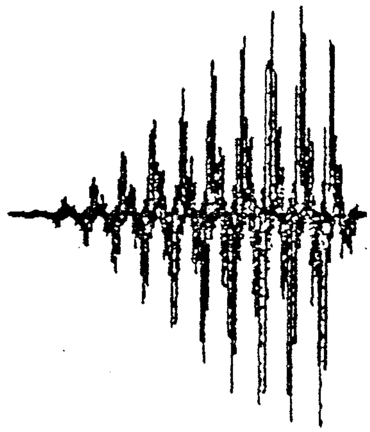
Priority: Cautionary

Voice messages: None

Pulse characteristics:

Pitch: 500 Hz
Harmonicity: Harmonic
Duration: 200 ms
Delayed Harmonics: None
Envelope: Slow onset

Pulse waveform:



Pulse spectrum:

Frequency (Hz)	Weighting
500	5000
1000	5000
1500	5000
2000	5000
2500	5000
3000	5000
3500	5000
4000	5000

ANNEX B

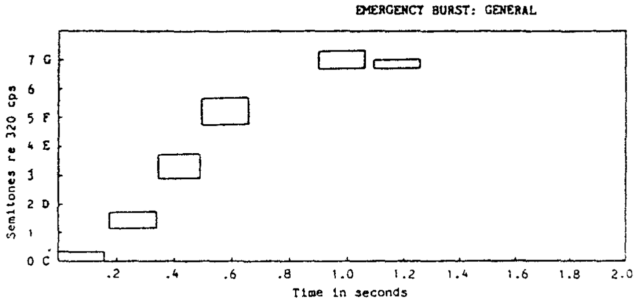
HOSPITAL WARNING DEMONSTRATION SET

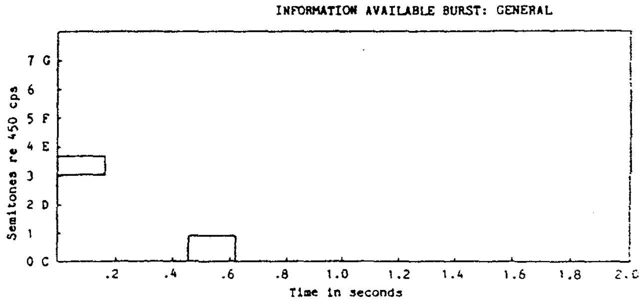
20th DECEMBER 1985

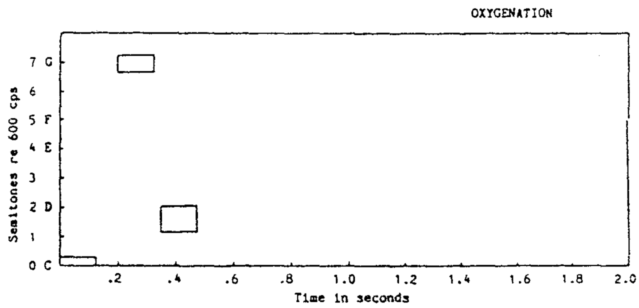
HOSPITAL WARNING DEMONSTRATION SET

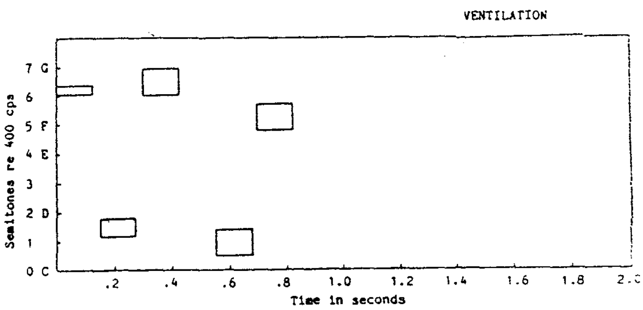
APU Cambridge — 20 December 1985

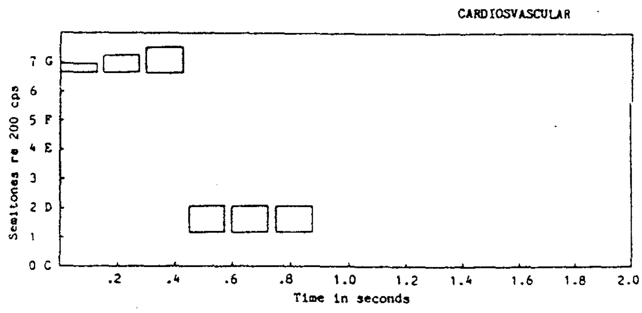
ISVR Southampton

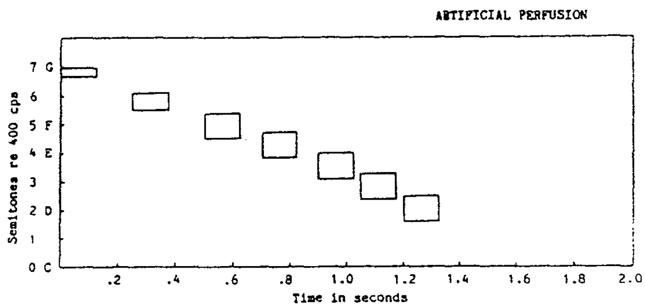


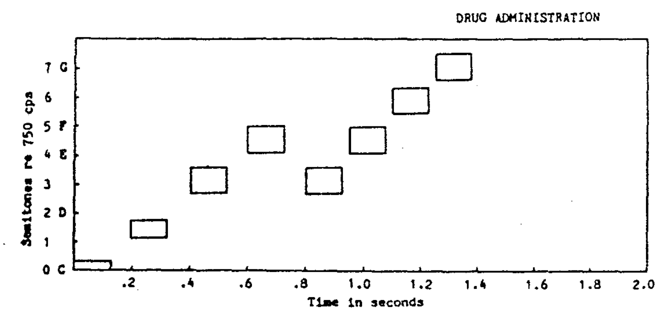


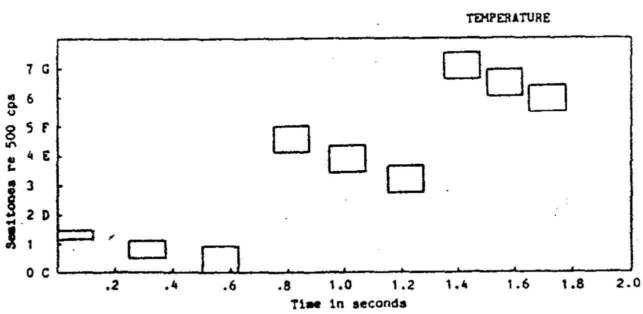




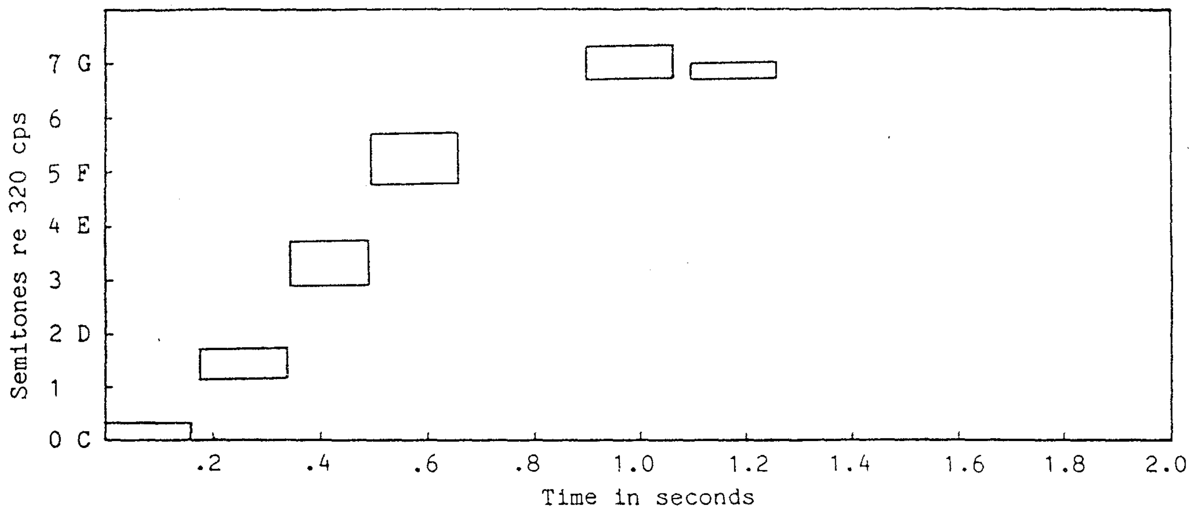






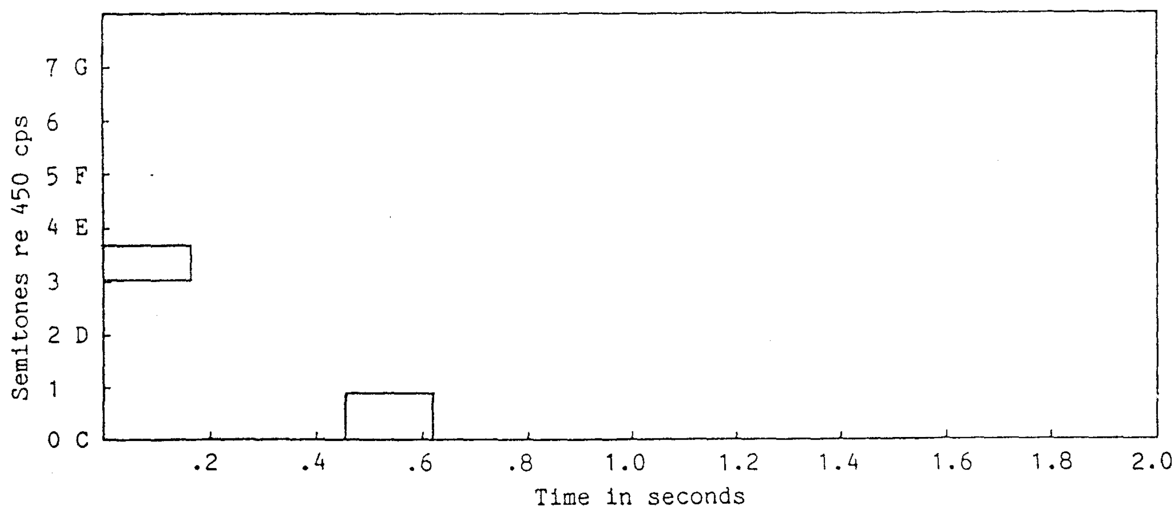


HOSPITAL AUDITORY WARNING EMERGENCY BURST: GENERAL



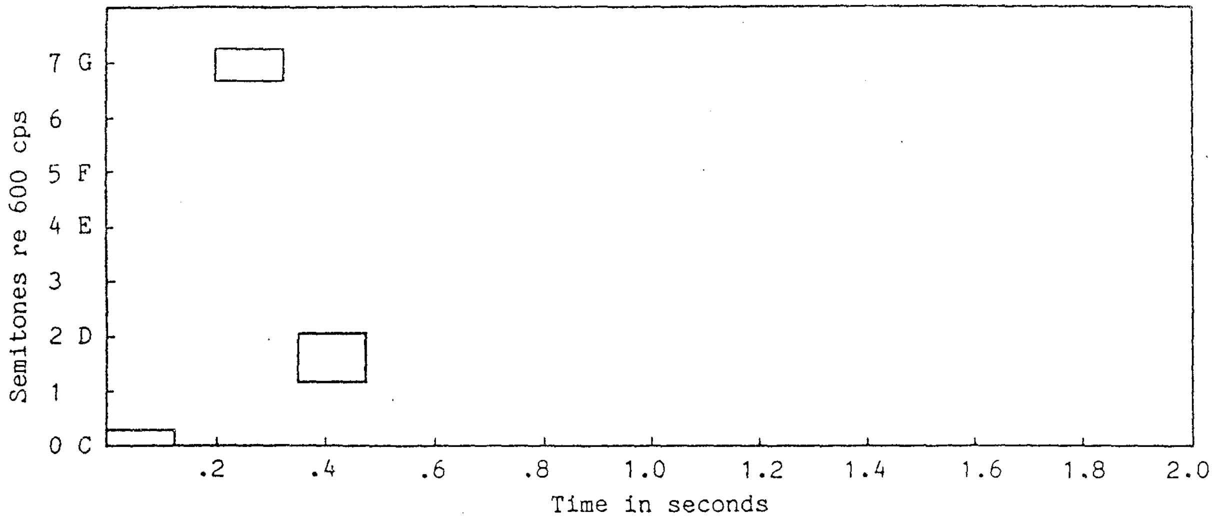
Pulse Number		1		2		3		4		5		6	
Emergency Burst	P (Hz)	322		346		381		425		475		475	
	A (dB)	8		4		0		0		4		8	
	PS (ms)		180		170		150		400		200		
Cautionary Burst	P (Hz)	322		346		381		425					
	A (dB)	14		10		6		6					
	PS (ms)		230		190		150						

HOSPITAL AUDITORY INFORMATION AVAILABLE BURST: GENERAL



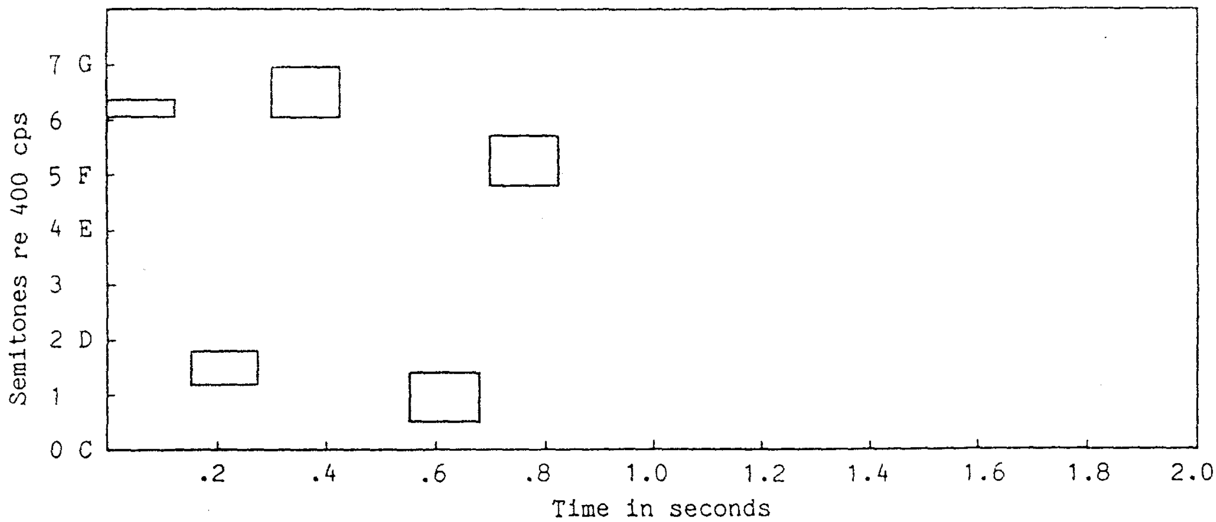
Pulse Number		1		2
Advisory Burst	P (Hz)	537		450
	A (dB)	10		6
	PS (ms)		450	

HOSPITAL AUDITORY WARNING EMERGENCY BURST: OXYGENATION



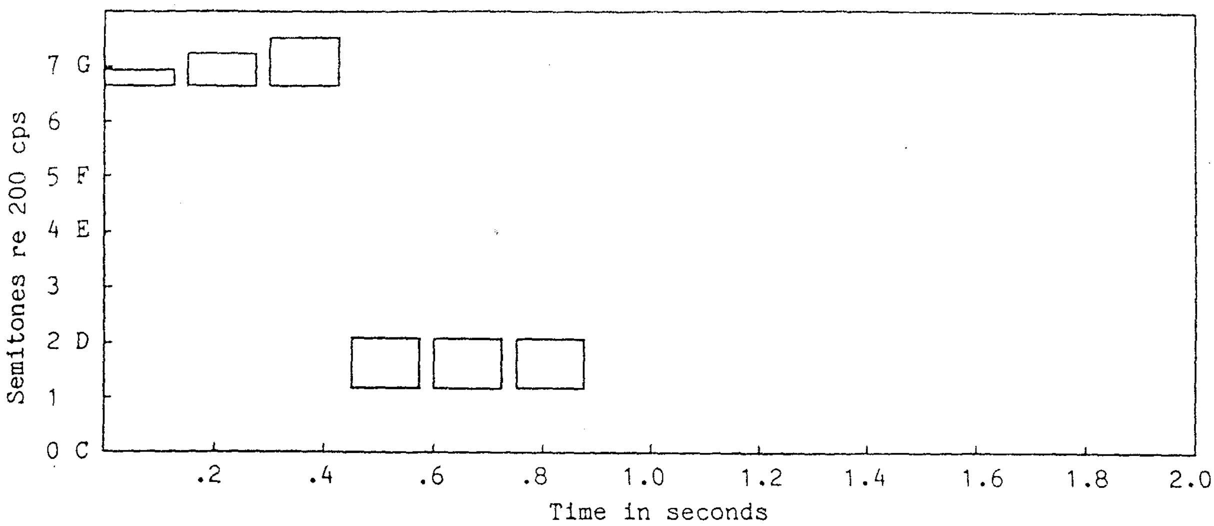
Pulse Number			1		2		3
Emergency Burst	P	(Hz)	600		879		644
	A	(dB)	8		4		0
	PS	(ms)		200		150	
Cautionary Burst	P	(Hz)	600		787		630
	A	(dB)	14		10		6
	PS	(ms)		300		300	

HOSPITAL AUDITORY WARNING EMERGENCY BURST: VENTILATION



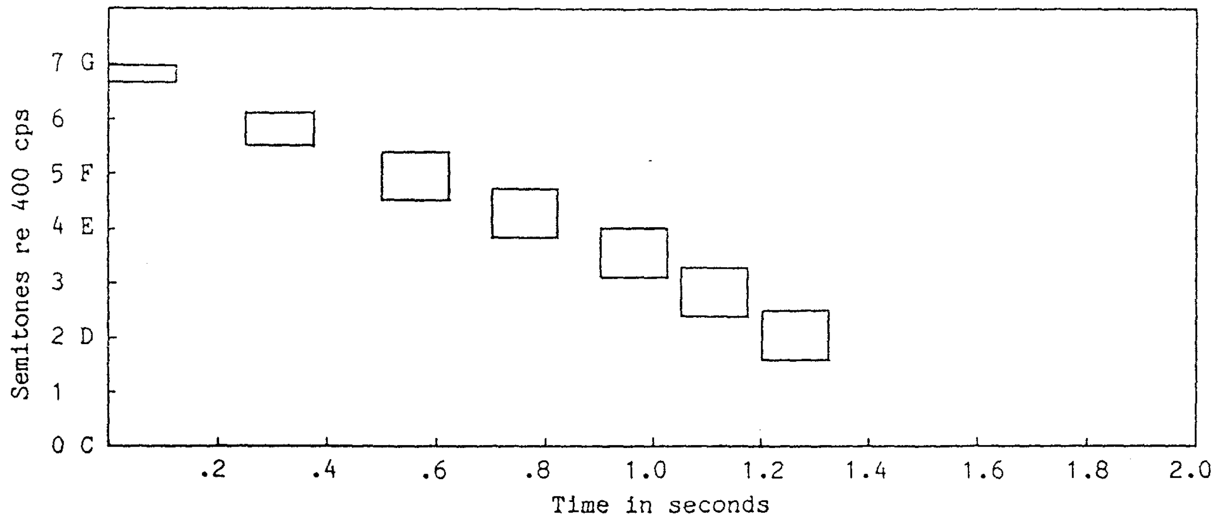
Pulse Number			1		2		3		4		5
Emergency Burst	P	(Hz)	566		430		566		410		527
	A	(dB)	8		4		0		0		0
	PS	(ms)		150		150		250		150	
Cautionary Burst	P	(Hz)	515		423		515		410		489
	A	(dB)	14		10		6		6		10
	PS	(ms)		225		225		500		400	

HOSPITAL AUDITORY WARNING EMERGENCY BURST: CARDIOSVASCULAR



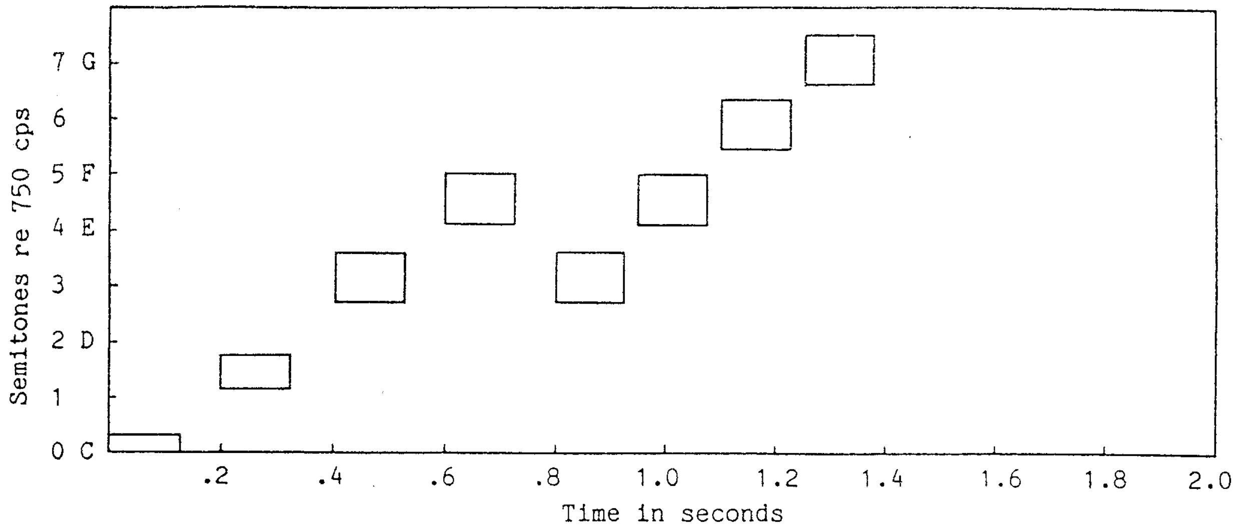
Pulse Number			1		2		3		4		5		6
Emergency Burst	P	(Hz)	293		293		293		215		215		215
	A	(dB)	8		4		0		0		0		0
	PS	(ms)		150		150		150		150		150	
Cautionary Burst	P	(Hz)	267		267		267		215		215		215
	A	(dB)	14		10		6		6		10		14
	PS	(ms)		200		200		200		300		350	

HOSPITAL AUDITORY WARNING EMERGENCY BURST: ARTIFICIAL PERFUSION



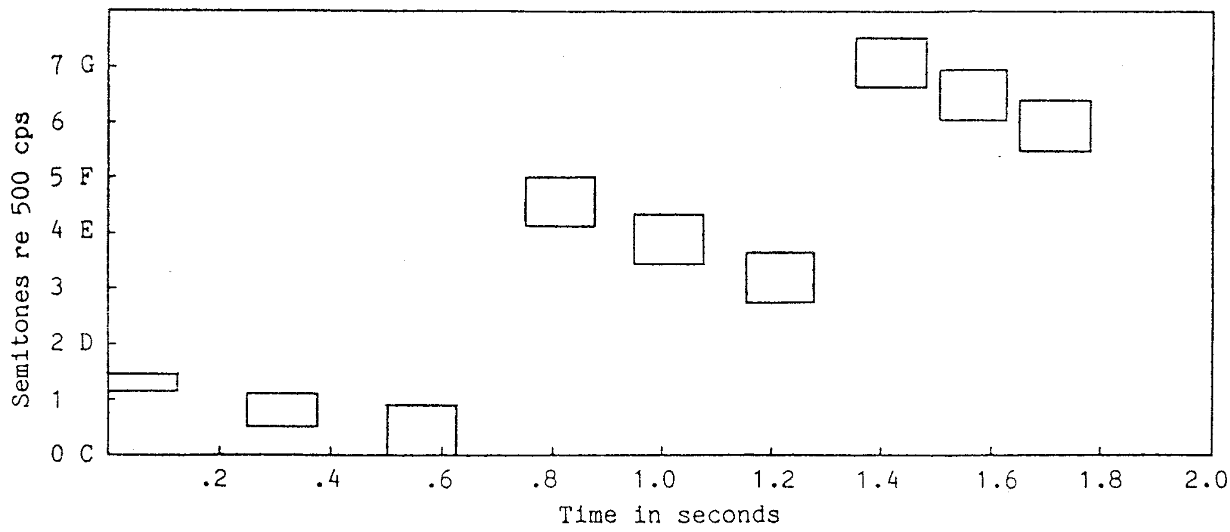
Pulse Number			1		2		3		4		5		6		7
Emergency Burst	P	(Hz)	589		547		518		498		479		459		439
	A	(dB)	8		4		0		0		0		0		0
	PS	(ms)		250		250		200		200		150		150	
Cautionary Burst	P	(Hz)	517		511		492		479		466		459		439
	A	(dB)	14		10		6		6		6		10		14
	PS	(ms)		300		300		250		250		300		300	

HOSPITAL AUDITORY WARNING EMERGENCY BURST: DRUG ADMINISTRATION



Pulse Number			1	2	3	4	5	6	7	8
Emergency Burst	P	(Hz)	750	806	879	952	879	952	1025	1099
	A	(dB)	8	4	0	0	0	0	0	0
	PS	(ms)	200	200	200	200	150	150	150	
Cautionary Burst	P	(Hz)	750	781	831	880	820	880	929	978
	A	(dB)	14	10	6	6	6	6	10	14
	PS	(ms)	250	250	250	250	300	300	400	

HOSPITAL AUDITORY WARNING EMERGENCY BURST: TEMPERATURE



Pulse Number			1	2	3	4	5	6	7	8	9
Emergency Burst	P	(Hz)	537	513	488	635	610	586	732	708	683
	A	(dB)	8	4	0	0	0	0	0	0	0
	PS	(ms)	250	250	250	200	200	200	150	150	
Cautionary Burst	P	(Hz)	537	513	488	586	562	537	635	610	586
	A	(dB)	14	10	6	6	6	6	6	10	14
	PS	(ms)	275	275	350	275	275	300	350	400	