General Anesthesia

The perceived urgency of auditory warning alarms used in the hospital operating room is inappropriate

[Caractère inapproprié de l'urgence perçue des alarmes sonores utilisées dans les salles d'opération d'hôpitaux]

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Purpose: To examine the perceived urgency of 13 auditory warning alarms commonly occurring in the hospital operating room.

Methods: Undergraduate students, who were naïve with respect to the clinical situation associated with the alarms, judged perceived urgency of each alarm on a ten-point scale.

Results: The perceived urgency of the alarms was not consistent with the actual urgency of the clinical situation that triggers it. In addition, those alarms indicating patient condition were generally perceived as less urgent than those alarms indicating the operation of equipment. Of particular interest were three sets of alarms designed by equipment manufacturers to indicate specific priorities for action. Listeners did not perceive any differences in the urgency of the 'information only', 'medium' and 'high' priority alarms of two of the monitors with all judged as low to moderate in urgency. In contrast, the high priority alarm of the third monitor was judged as significantly more urgent than its low and medium urgency counterparts.

Conclusion: The alarms currently in use do not convey the intended sense of urgency to naïve listeners, and this holds even for two sets of alarms designed specifically by manufacturers to convey different levels of urgency.

Objectif : *Vérifier l'urgence perçue de 13 alarmes sonores utilisées couramment dans les salles d'opération.*

Méthode : *Des étudiants, novices quant à la situation clinique associée aux alarmes, ont estimé l'urgence perçue de chaque alarme d'après une échelle en dix points.*

Résultats : *L'urgence des alarmes perçue n'était pas conforme à l'urgence réelle de la situation clinique qui la déclenche. De plus, les alarmes qui indiquent l'état du patient étaient généralement perçues comme moins urgentes que celles qui indiquent le fonctionnement du matériel. On note, en particulier, trois ensembles d'alarmes conçues par des fabricants de matériel pour indiquer des priorités d'action spécifiques. Les auditeurs n'ont perçu aucune différence d'urgence concernant l'alarme pour "l'information seule", celle d'une priorité "modérée" ou "élevée" de deux des moniteurs, car tous les ont jugé comme une urgence faible ou modérée. Par ailleurs, l'alarme de priorité élevée du troisième moniteur a été jugée comme significativement plus urgente que ses homologues de priorité faible et modérée.*

Conclusion : *Les alarmes couramment utilisées ne transmettent pas le sens de l'urgence souhaité à des auditeurs novices; la situation a été notée pour deux ensembles d'alarmes fabriquées spécifiquement pour indiquer différents niveaux d'urgence.*

THE modern operating room is replete with computerized equipment dedicated to monitoring patient condition. Although a wealth of information is available from these monitors, the attention of the attending physician cannot be allocated exclusively to these displays. Indeed, attention must be shared between multiple sources including the monitoring equipment, the patient, other physicians, and other pieces of equipment. This demanding situation necessarily means

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that information presented visually on a patient monitor will occasionally be missed entirely or reacted to slowly.[1] For this reason, many patient monitors include auditory alarms designed to alert physicians to a change in a patient's condition. Unfortunately, as a group, the alarms used in the past were found by many physicians to be quite irritating and distracting both in the frequency with which they sounded to indicate a patient problem which in fact did not exist (i.e., 'false alarms') and in their physical properties (a high-pitched 'beep' was often the warning sound of choice). For these reasons alarms have often been disabled prior to surgery.[2] For example, Finley and Cohen[2] found that practicing anesthesiologists were unable to identify the clinical situation indicated by alarms that were commonly available in the operating room. The low level of performance existed, presumably, because anesthesiologists were in the habit of deliberately disabling the alarms[1,3–6] and so were relatively unfamiliar with them, or because different alarms had similar acoustic qualities. This is hardly an ideal state of affairs given that auditory alarms may substantially increase the speed and appropriateness of a physician's response.[7,8] However, in the last few years manufacturers have moved both to reduce false alarm rates and to improve the acoustic pleasantness of the warnings as a means of increasing the use of the available alarms.

TABLE I ISO standards for alarm design: characteristics of bursts

Characteristic	*High priority*	*Medium priority*
Number of pulses in burst	5	3
Pulse spacing		
Between 1st and 2nd pulses	150 msec-250 msec	250 msec- 500 msec
Between 2nd and 3rd pulses	150 msec-250 msec	250 msec- 500 msec
Between 3rd and 4th pulses	300 msec-500 msec	NA
Between 4th and 5th pulses	150 msec-250 msec	NA
Burst spacing	2 sec ± 0.2 sec	NA
Repeat time	10 sec ± 0.2 sec	25 sec ± 5 sec
Difference in amplitude between any two pulses	10 dB (A) maximum	10 dB (A) maximum

TABLE II ISO standards for alarm design: characteristics of pulses

Characteristic	*Value*
Pulse frequency	150 Hz–1000 Hz
Number of harmonic components in the range 300 Hz–4000 Hz	Minimum of 4
Effective pulse duration	2 sec ± 0.2 sec
Rise time	10 sec ± 0.2 sec
Fall time	10 dB (A) maximum
Amplitude	45 dB (A) – 85 dB (A)

Some of these changes in alarm design have occurred in response to recently adopted international standards for auditory warning alarm design.[9] Although permitting some latitude in alarm design, the ISO recommendations (Tables I and II) set out clear limits for the design of medium and high priority alarms, including such factors as the dominant frequency of an alarm, the number of individual pulses that may comprise a 'burst', and the repetition rate of both the pulses within a burst and of the bursts themselves.

The ISO recommendations also include suggestions that the auditory characteristics of low priority alarms and signals intended to provide information should generally be quite different from the medium and high priority alarms. In addition, these two types of alarms should be nonintrusive and nonstartling, with amplitudes no more than that of the corresponding medium priority alarm, and onset and offset times of at least 40 msec.

One of the principal motivations in establishing these recommendations for the design of auditory warning signals appears to have been "to have a pattern which is instantly recognizable to the trained respondent, but which will not usually evince anxiety in others".[9] Thus, the guidelines established by ISO are intended to facilitate the generation of alarms that are clear and easy to interpret but that are not so strident as to upset patients and their families. The recommendations also speak to another important element of alarm design; namely, the importance of tailoring the acoustic properties of each alarm to the urgency of the triggering situation. In particular, the ISO standards include a suggestion that the time between pulses within a burst and the most prominent frequency component of a pulse be modulated to exert some control over the sense of urgency induced in a listener by the alarm. This recommendation is consistent with research indicating that basic auditory features such as pitch, loudness, and repetition rate may have a dramatic influence on the perception of the urgency of an alarm.[3,10,11] Thus, a sound with a high pitch or a rapid repetition rate will be perceived as more urgent than a sound with a lower pitch or repetition rate. An auditory warning alarm designed with these principles in mind could reduce the need for interpretation of urgency and, thereby, reduce the possibility of a misclassification leading to an inappropriate response.

The present study was designed primarily to evaluate the perceived urgency of a set of patient and equipment auditory warning alarms that are common in the hospital operating room. In addition, however, we were interested in examining the perceived urgency of three sets of alarms specifically designed by equipment manufacturers to represent different levels of clinical priority. To this end, specific comparisons of perceived urgency were conducted of the alarms used in the Datex AS/3 monitor (information only, medium and high priority alarms), the Hewlett-Packard model 66S monitor (low, medium and high priority), and the North American Dräger Vitalert 3200 (medium and high priority).

Methods

1. Participants

Eleven undergraduate psychology students attending Mount Allison University volunteered to participate in exchange for course credit. None of the subjects reported any corrected or uncorrected hearing problems.

2. Materials

COMPUTER AND SOUND SYSTEM

A 486/150 personal computer running the Micro-Experimental Laboratory[12] was used to present sounds and to record responses. Sounds were presented over Sennheiser HD 250 linear headphones.

ALARMS

Thirteen alarms were recorded at the IWK-Grace Health Centre and the Queen Elizabeth II Health Sciences Centre in Halifax, Nova Scotia, Canada, on a Dell P133ST laptop computer at a sampling rate of 32,000 Hz. Background noise was removed from the recordings using the filtering functions of CoolEdit 96.[13] All alarms were equated in subjective intensity and presented to listeners in the experiment at a comfortable volume of approximately 70 decibels sound pressure level. The acoustic characteristics of each of the 13 alarms used in the study are described in Table III. This summary is based on a frequency analysis performed using CoolEdit 96.

3. Design and procedure

Testing took place in a quiet room. At the beginning of the experimental session, each of the participants was presented with the 13 alarms once each to familiarize them with the sounds that they would be rating. Participants next completed 13 practice trials (one for each alarm) and 104 experimental trials. The experimental trials were arranged in eight trial blocks within which each of the 13 alarms was presented once. Presentation order within each block was randomly determined by the computer software. For each of the practice and experimental trials, listeners were required to rate the urgency of each alarm on a scale from 1 (lowest) to 10 (highest). Responses were made on a computer keyboard. The experiment was self-paced such that listeners initiated the presentation of each alarm by pressing any key on the keyboard with the alarm beginning 750 msec later.

Results

The mean urgency rating for each of the 13 alarms is presented in Table IV. A one-way within-subjects ANOVA with alarm as the sole independent variable and urgency rating as the dependent variable revealed a highly statistically significant main effect, $F(12, 120) = 25.006$, $P < 0.001$. More specific investigation of this main effect was performed using Tukey's HSD test which permits calculation of the minimum difference between means required to reach significance, while limiting the probability of a Type 1 error for all comparisons taken together to a maximum of 0.05 (when a P-level of 0.05 is used) or 0.01 (when a P-level of 0.01 is used). In this case, the required difference was determined to be 2.03 for a P-level of 0.05, and 2.35 for a P-level of 0.01. The differences between pairs of means are shown in Table V along with an indication of whether or not each of the differences is statistically significant.

Although there are many differences between individual alarms, there appears to be a clear group of low urgency alarms (the three Datex, and the two Vitalert alarms), and a clear group of high urgency alarms (the Bair, Ritchie, Hotline and HP 3 alarms). In addition, a direct comparison of the perceived urgency of those alarms associated with monitors of patient condition (the three Datex, three Hewlett-Packard, and two Vitalert alarms) with those alarms associated with equipment performance (Valleylab, Bair, Hotline, Abbott and Ritchie alarms) indicated that the equipment alarms were perceived as of significantly higher urgency, $F(1, 10) = 62.57$, $P < 0.001$. For example, the Bair Hugger alarm received the highest urgency rating even though its immediate clinical relevance is quite low and it occurs infrequently.

Planned comparisons of alarm sets designed by equipment manufacturers

Datex AS/3 monitor ("ISO2" setting; ISO 9703-2 compatible, with increasing frequency)

The Datex AS/3 monitor incorporates a set of three alarms, one to indicate a just-completed blood pressure measurement (within an acceptable range; i.e., for information only), one to indicate a moderately urgent

TABLE III Description of the auditory warning alarms used in the study

Equipment/Alarm	*Label*	*Primary frequency components (Hz)*	*Repetition*
Datex AS/3 monitor (information only) [Datex-Ohmeda (Canada) Inc 1093 Meyerside Drive, Unit 2 Mississauga, ON L5T 1J6]	Datex 1	Pulse 1: 250, 750, 1250, 1750, 2250, 2750, 3250 Pulse 2: 525, 1050, 1575, 2100, 2625, 3150, 3675, 4200, 4725, 5250, 6300, 7350	Pulse 1 is 200 msec in duration and pulse 2 is 150 msec in duration. There is 950 msec between pulses
Datex AS/3 monitor (medium priority)	Datex 2	Pulse 1: 524, 1571, 2618 Pulse 2: 783, 2350 Pulse 3: 990, 2970	Each of the three pulses is 125 msec in duration. There is 75 msec of silence between the pulses.
Datex AS/3 monitor (high priority)	Datex 3	Pulse 1: 524, 1572, 2620 Pulse 2: 698, 2094, 3490 Pulse 3: 783, 1566, 2350 Pulse 4: 880, 2640 Pulse 5: 990, 2970	The five pulses, each 100 msec in duration, are presented in order within each of the two consecutive sets. The time between pulses within a set is 50 msec except between pulse 3 and 4 where the gap is 130 msec. The time between the end of one set and the beginning of the next set is 1000 msec.
Hewlett-Packard model 66S monitor (low priority) [Hewlett-Packard (Canada) Ltd 6877 Goreway Drive Mississauga, Ontario L4V 1M8]	HP 1	500, 1500, 2500, 3500	Single pulse of 650 msec with 1500 msec between each of four successive pulses.
Hewlett-Packard model 66S monitor (medium priority)	HP 2	500, 2500, 3500	Single pulse of 750 msec with 1500 msec between each of four successive pulses.
Hewlett-Packard model 66S monitor (high priority)	HP 3	2900	Single pulse of 850 msec with 150 msec between each of four successive pulses
NA Dräger Vitalert 3200 (medium priority) [North American Dräger 148 B Quarry Road Telford, Pennsylvania 18969]	Vita 1	Pulse 1: 850, 2550 Pulse 2: 850, 2550 Pulse 3: 1009, 3027	The first two pulses are 150 msec in duration with the third 185 msec in duration. There are no silent gaps between pulses as each pulse flows smoothly into the next.
NA Dräger Vitalert 3200 (high priority)	Vita 2	Pulse 1: 1275 Pulse 2: 1275 Pulse 3: 1008, 3024	The three pulses are 185 msec, 140 msec and 160 msec in duration respectively. There are no silent gaps between pulses as each pulse flows smoothly into the next.
Valleylab Force 2 electrosurgical unit: no ground connection [Valleylab Canada 50 Mural Street, Unit 11 Richmond Hill, ON L4B 1E4	Valley	1046, 3138	Single pulse of 700 msec with 300 msec between each of two successive pulses.
Bair Hugger model 500/OR: overheating [Augustine Medical Inc. 10393 West 70th Street, Eden Prairie, MN 55344]	Bair	2600	Single pulse of 170 msec duration repeated 15 times with an ISI of 65 msec between successive pulses
Level 1 Hotline fluid warmer: overheating [Level 1 Technologies Inc. 160 Weymouth Street, Rockland, MA 02370]	Hotline	3360	Single pulse of 1025 msec duration repeated four times with an ISI of 775 msec between successive pulses
Abbott XL Plum infusion pump: general [Abbott Laboratories Inc. 8401 Trans Canada Highway St. Laurent, Quebec H4S 1Z1]	Abbott	2800	Single pulse that repeats once. The first instance is 250 msec in duration and the second is 625 msec. The ISI is 150 msec.
NA Dräger Narkomed 2A: Ritchie whistle	Ritchie	Continuous glide; frequency falls from 3600 to 3300	Continuous glide 17 sec in duration. The amplitude declines steadily from onset to offset of the sound.

TABLE IV Mean urgency ratings, and standard errors for each of the 13 alarms

Equipment/Alarm	*Mean*	*Standard error*
Datex AS/3 monitor: information/ "BP ready"	2.666	0.336
Datex AS/3 monitor: (2)	3.127	0.525
Datex AS/3 monitor (3)	3.627	0.583
Hewlett-Packard model 66S monitor (1)	4.896	0.505
Hewlett-Packard model 66S monitor (2)	4.522	0.488
Hewlett-Packard model 66S monitor (3)	7.127	0.434
NA Dräger Vitalert 3200 (also NA Dräger Narkomed 2B: low oxygen)	3.138	0.524
NA Dräger Vitalert 3200 (also NA Dräger Narkomed 2B: ventilation pressure)	3.127	0.541
Valleylab Force 2 electrosurgical unit: no ground connection	6.639	0.393
Bair Hugger model 500/OR: overheating	8.809	0.400
Level 1 Hotline fluid warmer: overheating	7.708	0.470
Abbott XL Plum infusion pump: general	5.764	0.494
NA Dräger Narkomed 2A: Ritchie whistle	7.808	0.751

TABLE V Differences in mean urgency rating between pairs of alarms (absolute values)

	Datex 1	*Datex 2*	*Vita 1*	*Vita 2*	*Datex 3*	*HP 2*	*HP 1*	*Abbott*	*Valley*	*HP 3*	*Hotline*	*Ritchie*	*Bair*
Datex 1	—												
Datex 2	0.461	—											
Vita 1	0.461	0.000	—										
Vita 2	0.472	0.011	0.011	—									
Datex 3	0.961	0.500	0.500	0.489	—								
HP 2	1.856	1.395	1.395	1.384	0.895	—							
HP 1	2.230^{A}	1.769	1.769	1.758	1.269	0.374	—						
Abbott	3.098^{B}	2.637^{B}	2.637^{B}	2.626^{B}	2.137^{A}	1.242	0.868	—					
Valley	3.973^{B}	3.512^{B}	3.512^{B}	3.501^{B}	3.012^{B}	2.117^{B}	1.743	0.875	—				
HP 3	4.461^{B}	4.000^{B}	4.000^{B}	3.989^{B}	3.500^{B}	2.605^{B}	2.231^{A}	1.363	0.488	—			
Hotline	5.042^{B}	4.581^{B}	4.581^{B}	4.570^{B}	4.081^{B}	3.186^{B}	2.812^{B}	1.944	1.069	0.581	—		
Ritchie	5.142^{B}	4.681^{B}	4.681^{B}	4.670^{B}	4.181^{B}	3.286^{B}	2.912^{B}	2.044^{A}	1.169	0.681	0.100	—	
Bair	6.143^{B}	5.682^{B}	5.682^{B}	5.671^{B}	5.182^{B}	4.287^{B}	3.913^{B}	3.045^{B}	2.170^{A}	1.682	1.101	1.001	—

A = $P < 0.05$; B = $P < 0.01$.

situation and a third to indicate a highly urgent situation. Although our naïve subjects did rank these three alarms in the expected order (mean urgency ratings of 2.666, 3.127, and 3.627, respectively), none of the differences approached statistical significance. Moreover, all three of these alarms, including the one designed to convey an urgent clinical situation, were perceived as low in urgency.

North American Dräger Vitalert 3200

The North American Dräger Vitalert 3200 includes two alarms, one intended to indicate a medium priority situation and the other intended to indicate a high priority situation. Participants judged these alarms as essentially equivalent in urgency (3.138, and 3.127, respectively). In addition, and as was the case for the Datex alarms, neither alarm was perceived as indicating anything more than quite a low level of urgency.

Hewlett-Packard model 66S monitor

Whereas the alarms designed by Datex and by North American Dräger did not convey the intended sense of urgency to our subjects, the set of three alarms designed by Hewlett-Packard for the model 66S monitor did induce, to at least some degree, differences in perceived urgency. Specifically, although listeners did not differentiate between the low priority and medium priority alarms (mean ratings of 4.896 and 4.522 respectively), they did perceive the high priority alarm as possessing a significantly higher urgency (7.127).

Discussion

Clear differences in the perceived urgency of alarms commonly used in the hospital operating room were apparent in this study. Surprisingly, as a group those alarms associated with alerting physicians to patient condition were perceived as less urgent than those associated with indicating problems in equipment functioning. Because the participants in our study were naïve with respect to the relation between individual alarms and the clinical situation which trigger them, their judgements of urgency were likely influenced primarily by the physical composition of the sounds.

Previous research has shown that sound properties such as frequency composition, repetition rate, amplitude, and harmonic relation of the frequency components can significantly influence the interpretation of the urgency of an auditory alarm (e.g., 3, 11). An examination of the fundamental frequencies of the four alarms judged as most urgent indicates that they were based on the four highest fundamental frequencies in the set of 13 alarms [Bair (2600 Hz), Ritchie (3300–3600 Hz), Hotline (3360 Hz), and HP-high priority (2900 Hz)]. In addition, although the Ritchie whistle is continuous, the other three alarms all have quite a rapid repetition rate (Table III). The Bair alarm, in particular, which was judged as most urgent has both a high frequency combined with the most rapid repetition rate of all 13 alarms. In contrast the alarm judged as least urgent (Datex AS/3 monitor: information/BP ready") consists of a range of harmonically-related frequency components (F0 = 250 Hz with even harmonics F2 to F12) with a slow repetition rate (one second between pulses). It is interesting to note that for those alarms that include multiple frequency components these are always harmonically-related. Edworthy *et al.* have shown that complex sounds with inharmonic relations are often judged as higher in perceived urgency than sounds that include only harmonic relations.[3] A harmonic structure has undoubtedly been chosen by manufacturers in an attempt to generate alarms that are pleasing to the ear, perhaps in hopes of encouraging physicians to use them. Table III includes a description of the frequency composition and repetition characteristics of each of the 13 alarms.

The importance of basic acoustic characteristics in determining the perceived urgency of an alarm was apparent for the alarm sets designed by manufacturers. For example, the urgency of the three alarms of the Datex monitor AS/3 was judged as essentially equivalent in perceived urgency even though they are intended to convey distinct levels of urgency. Although the frequency composition and the number of pulses do differ somewhat across the three alarms for all of the alarms, the fundamental frequency on which a pulse is based is never higher than 990 Hz. This is important because fundamental frequency carries a significant weight in determining the overall pitch of a sound[14] with higher frequencies associated with higher levels of urgency.[3] Interestingly, although the repetition rate (operationally defined as the time between successive pulses) for the medium and high priority alarms is quite fast, this did not influence urgency ratings. Thus, pitch appeared to dominate in determining the perception of urgency for these three alarms. Finally, these alarms appear to have been designed to convey urgency information primarily through the number of pulses incorporated within each alarm (one burst of two pulses, one burst of three pulses, and two bursts of five pulses for the information, medium priority, and high priority alarms respectively). This would appear to be a poor choice as the attending physician must wait until the end of the alarm to interpret its urgency.

The Vitalert 3200 includes medium and high priority alarms, both of which consist of three pulses that flow smoothly from one to the next. Thus, the individual pulses are not perceived as discrete but as part of a continuous sound. Although the fundamental frequency of the first two pulses of the high priority alarm (1275 Hz) is higher than that for the medium priority alarm (850 Hz) this is quite a modest difference, and both fall in a low range. Moreover, the slow onset and offset times of the pulses within each alarm (approximately 60 msec ramps for the medium priority alarm and approximately 100 msec ramps for the high priority alarm) would appear also to create the impression of low urgency.[3]

In contrast with the other two sets of alarms, the three alarms used in the HP monitor did engender some difference in the perception of urgency with the high priority alarm judged as significantly more urgent than the other two. The low and medium priority alarms, which were not perceived as different in urgency, both consist of fairly long duration pulses (650 msec and 750 msec respectively) with long silent periods between pulses (1500 msec for both alarms). In addition to this slow repetition rate, both alarms are based on a very low fundamental frequency of 500 Hz. In contrast, the high priority alarm is composed of a single frequency of 2900 Hz and although the pulses are 850 msec in duration the time between successive pulses is quite brief at 150 msec. Thus, the high priority alarm is both higher in pitch and has a faster repetition rate than the other two alarms. The design of this high priority alarm is, of course, consistent with the known influence of pitch and repetition rate on perceived urgency.

Participants in the study were naïve with respect to the relation between individual alarms and the clinical situations that trigger them. It is unlikely, then, that the urgency ratings were influenced by any prior familiarity with alarms because those used in the study are quite different from the everyday alarms people are familiar with (sirens, fire alarms, buzzers of various kinds). Thus, it seems reasonable to assume that the urgency ratings we obtained are founded primarily on an interpretation of the physical characteristics of the alarms themselves. However, quite aside from basic acoustic composition, interpretation of the situational urgency indicated by an alarm may be determined by the accumulated knowledge and experience of the physician. For example, in pulse oximetry increasing urgency is represented by a reduction in pitch. One might argue that elementary physical features such as pitch and repetition rate are of little consequence when the perceiver is familiar with the relation between individual alarms and the urgency of the triggering situation. As seductive as this argument may be, it ignores the fact that alarms are likely to sound when the attention of the physician is engaged elsewhere. Literally hundreds of studies have shown that the accuracy of perception and identification of an auditory (or visual) stimulus may be significantly influenced, either positively or negatively, by the direction of attention.[15–17] More importantly, those elements of an event that depend on complex cognitive processing or interpretation are most severely compromised when insufficient attention is available.[15] For example, when attention is directed to one verbal message, a change in the voice speaking a second message will likely be noticed but the semantic content of the unattended message will likely be missed.[18,19] Given the conditions in which alarms are likely to sound, such research indicates that the physical properties of the alarm are much more likely to be accurately perceived than are those attributes that require deliberate analysis and interpretation. For this reason, auditory alarms that must be interpreted to support an accurate determination of urgency, such as most of those used in the current study, would appear to be ill-suited to the clinical situation (see also Block,[20] who proposed a set of melodic alarms that depend entirely on interpretation). It is critical that in designing alarms as much information as possible be included within the elementary physical features of the sound itself. Such thoughtful design would facilitate rapid differentiation of urgency and, thereby, permit physicians to establish priorities for rapid action.

In summary, it is important to note that auditory alarms can serve an important role in alerting physicians to the presence of a potential emergency situation. Indeed, because visual alarms must be fixated to be perceived and interpreted, auditory alarms are potentially much more useful in capturing attention in many settings including the operating room.[21] Ideally, the physical composition of each alarm should be specifically designed to convey a perception of urgency that matches, as closely as possible, the actual urgency of the triggering situation. In this way, the cognitive processing required for interpretation of the urgency of a situation signalled by an alarm may be reduced, thereby increasing the speed and appropriateness of the operator's response.[7,8] In contrast with this ideal design, our examination indicates that the alarms currently in use do not convey the intended sense of urgency to naïve listeners. More critically, this failure applies also to two of the three sets of alarms designed specifically by manufacturers, with the Datex AS/3 monitor 'information only', medium priority and high priority alarms and the North American Dräger Vitalert 3200 medium and high priority alarms all judged as low to moderate in urgency with no significant differences between them. Although the Hewlett-Packard model 66S monitor high priority alarm was judged as significantly higher in urgency than its low and medium priority alarms there was no difference in urgency of the latter two. Clearly, manufacturers would do well to engage in more thoughtful alarm design.

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