A framework for unisensory and multisensory design for hospital alarming systems.

Author 122
Track 10: The machine that goes 'ping'

ABSTRACT

This paper will state a framework for unisensory and multisensory design for alarming hospital systems. The paper will start with a brief introduction on the common situations in hospitals and the possible value of using tactile, visual or multisensory cues. Further on the real value of these sensors will be reviewed. First I will talk about the effect that vibrotactile sensors have on the response time of a person. To add an extra dimension I will also review multisensory researches including audiovisual sensors that can attract spatial attention in dual-task performance and audio-tactile sensors that can provide an even faster response time if both sensors come from the same direction. These findings will be abstracted and put in the hospital context as an inspiration for future designers. As a conclusion I will provide a framework for designers to have a quick look at the biggest findings in the previously mentioned research that is done in the field of unisensory and multisensory design for alarming systems.

Keywords

senses, hospital alarms, car-warnings, design.

INTRODUCTION

There are more machines in the hospital then ever and the designers all try to make their machine the most important one and therefore the loudest (Hilton, A., 1987). All these loud similar sounding alarms causes alarm fatigue by nurses (Højlund M. K. & Have I., 2016) and stress for the patient. (Donchin, Y., & Seagull, F. J., 2002) (Meredith, C., & Edworthy, J., 1995)

Most of these monitors make sounds as the alarming factor and there is quite some research done about this subject. (Burt et all., 1995) Most of them conclude that the designers should stick to one coherent system of pitches and frequencies that are connected to the urgency and the nature of the machine. (Finley, G. A., & Cohen, A. J., 1991)

However the human body has more sensors that can detect warnings, like our tactile and visual sensors. (Baldwin et all., 2012). To make the design of alarming hospital machines as efficient as possible it is necessary to take these senses into account. Using tactile or visual sensors could have some serious benefits. These could for example be;

- The nurses being able to make a better distinction between different urgencies of the alarms.
- The nurses being able to act more naturally to the different alarms causing less stress.
- The patient being able to sleep better, because the alarms could be more personal to the nurses and doctors.

Researches about different sensory alarms in hospitals are quite rare, but the car industry has some interesting researches that can be used as useful inspiration. (Baldwin, C. L., & Lewis, B. A., 2014) The findings from the car-industry can give designers some useful inspiration for possibly more efficient designs and they can be an inspiration for further research in this field.

To use this researches of the car industry in a correct way for designers there are a few important questions to be answered. It is important to know how these examples of the car industry can be abstracted and how these abstractions would fit in the desired frameworks of the hospital alarm researches.

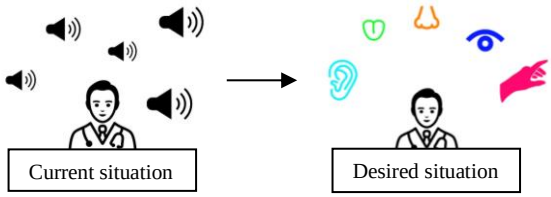

Figure 1. visualization of the possible future perspective of hospital alarms when different kinds of sensory alarms are included.

METHOD

To be able to give a good advice for designing sensory alarm systems in hospitals this research needs a certain approach. First there will be an explanation about the research that is already done in this field. Second the relationship between these studies will be explained and after that these abstractions will be connected to the field of design. All these connections together will form a framework to help designers use the design of alarms that use different senses in the right situation.

UNISENSORY

Looking into all the different senses that can be used to alarm people, auditory, visual and tactile are the most promising to use in design and also the most tested ones. (Baldwin, C.L. et al, 2012)

Vibrotactile

Different studies have proven that vibrotactile signals have a lot of potential for alarming use. (Baldwin, C.L., Eisert, J.L., Garcia, A., Lewis, B., Pratt, S.M., Gonzalez, C. (2012) found a graph that contains the urgency of auditory, visual and tactile parameters at different frequency levels. (figure 2) From this research they concluded that a tactile stimulus with an inter pulse interval of 9 ms had the highest urgency rating compared to auditory and visual stimulus with an interpulse rate of 9ms or more. As addition to this, a study of Scott, J. J., & Gray, R. (2008) also concluded that drivers with a tactile warning had a significantly shorter response time than drivers without a warning and had a significant advantage over drivers with visual warnings.

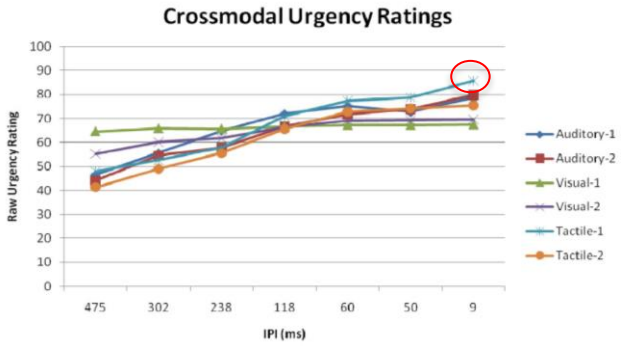

Figure 2, Psychophysical ratings of perceived urgency. 0 being no urgency and 100 being very urgent. A red circle is drawn around the highest urgency rating. Adapted from Eisert, J.L., Garcia, A., Lewis, B., Pratt, S.M., Gonzalez, C. 2012

These researches are about a fast response time of seconds (Scott, J. J., & Gray, R., 2008) and therefore should only be used in life-threatening situations like preventing front-to-rear-end collision in a car. In the context of the hospital this could the Capnometer or Oxygen analyser, because this is extremely urgent according to experts. (Finley, G. A., & Cohen, A. J., 1991)

If this kind of signal is used in other situations it will possibly cause more stress for the nurses. Though this approach of using vibrotactile signals could release the stress of the patient, because they wouldn't notice the alarms. On the other hand it could also give the patient more stress, because they do not know if the their physical state is still monitored, which could give them a feeling of ignorance.

MULTISENSORY

As a single sensor the tactile sense works to provoke a high urgency as is mentioned in the previous part of this review. Moreover, using multiple sensors for the affect gives a new dimension to the subject.

Audiovisual and spatial attention

There is a big confusion in the effectiveness of audiovisual multisensory cues and its effect on spatial attention. There are a lot of studies that conclude that multisensory cues do not capture spatial attention more effectively than unisensory. (Santangelo, V., Spence, C., 2008b)

Although as Charles Spence and Valerio Santangelo explain in their article it does capture spatial attention more effectively than unisensory cues, at least under conditions of concurrent perceptual load/dual-task performance.

All together these researches state that it would be more effective to use audiovisual signals to improve the spatial attention of people when they are in a dual-task performance. In the hospital context this could be very useful, because there are many of these situations. It could for example be very useful to identify the right machine in the room when there are a lot of different monitors.

Audiotactile and response time

In a research of Ho, C., Reed, N., Spence, C. (2007) they prove that multisensory alarms have an even faster response time than only vibrotactile or auditory sensors. This is concluded from figure 3, that shows that the mean braking response times is the lowest at audio tactile, which means that this had the quickest response time.

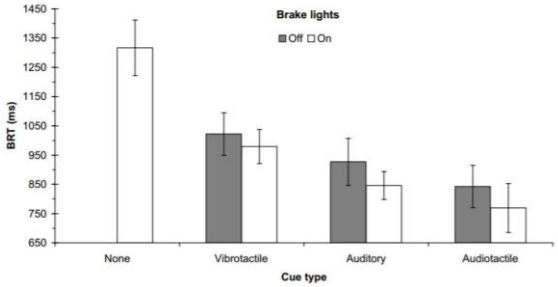

Figure 3, Mean braking response times (BRTs) in milliseconds as a function of cue type and brake lights condition. The error bars indicate the standard error of the means. From Ho, C., Reed, N., Spence, C., 2007.

Although in a later research of Ho, C., Santangelo, V., Spence, C. (2009) they conclude that this only has a significant effect if the stimuli are presented from more or less the same direction. This is true for not only audio tactile, but also in the first case of audiovisual cues.

This means that if designers want to design audio tactile alarms they could fail when they do not know that the stimuli have to be presented from the same direction. In the hospital context this could be used to design for the ventilator disconnect, which is an extremely urgent alarm according to experts (Finley, G. A., & Cohen, A. J., 1991). Since it is perceived as extremely urgent it is invaluable to take the rareness of the alarm into account to prevent extreme stress for the nurses and/or patients.

FRAMEWORK FOR DESIGN

All together there are a few main researched possibilities to design alarms that trigger different senses. Although at the same time it is important for designers to know the requirements they have to fulfill in order to let the alarm

	Cue type	Effect	Requirements	Example
Unisensory	Vibrotactile	Response time seconds	Most effective during single-task performance.	Capnometer or Oxygen analyser
Multisensory	Audio-tactile	Response time seconds (most urgent)	Most effective during dual-task performance	Ventilator disconnect
	Audio-visual	Spatial attention	Only works when both signals are presented from more or less the same direction.	Detecting the right machine in the room.

Figure 4, Framework for designers of unisensory and multisensory alarm design in hospitals. Note that a darker red color means a higher perceived argents level.

work the way they intended to. In figure 4 I proposed a framework where the most important options and requirements are visualized to give designers a quick overview.

The figure lists the most important aspects for the designer. First the kind of useful sensors will be listed, after that the effect of this particular sensor. This effect will only be achieved if the requirements are taken into account. These three parts together form a researched foundation for effective sensory alarm design. To inspire the designer and to give a better image in the hospital context I also added an example for every kind of sensor that presumably would need the named effect.

Further information and resources are listed in the start of this review. The framework is meant as a guideline for design to easily get back to during the design process.

DISCUSSION

In this review article I summarized the different possibilities of unisensory and multisensory alarms. It is hard to make a fair comparison, because it is sometimes unclear if certain aspects of the test situations are the same for every research. It is therefore important to see this review mostly as an inspiration for further research.

The comparisons of the researches need to be checked. This could optimally be done if there was one bigger research that would have different experiments of every category, but they would use exactly the same test accept for the sensors in the right conditions. These conditions would be like they are mentioned in the framework.

This review and its findings are mostly based on research in the field of the car-industry. Therefor more research should be done in the hospital context, about unisensory and multisensory alarm systems. The following reasons could have an entirely different turn to the car-industry research and should be taken into account;

- The profession of the nurses and doctors can bring certain ways of acting with them. These could change the perception of these nurses and/or doctors.
- The surroundings of the hospital differ a lot from cars.
- The feelings of the patient that is monitored should also be taken into account while this is not a big issue in a car.

As told before most research is focused on visual. Auditory and tactile senses, while we actually have more senses than only these. It could be interesting to look into these other senses as alarming systems.

Most of the previously mentioned research is about the response time. This effect is easier to put into a different context while in the article I also talked about the spatial attention. The assumption that this could be used to detect the right machine in the room needs to be further researched. This would start with a research in context where is tested if nurses can distinguish machines better when using different multisensory sensors.

For designers it is important to look into the way they can use the information in this article. They could for example make a body that nurses could wear under their scrubs. This would possibly have the same effect as the vibrotactile sensor that was attached to the seatbelt and therefor cause a very quick response time of the nurse. This should of course be tested in further research to see if it has the sought effect.

Effecti-veness	Effect 1	Effect 2	Stress level (nurses)
7	sensor A *requirements	sensor B *requirements	5
5	sensor C *requirements	sensor D *requirements	1
1	sensor E *requirements	sensor F *requirements	5

Figure 5, A abstract possible lay-out of the desired future framework for designers of unisensory and multisensory alarm design in hospitals.

All together this framework is the beginning of a much bigger framework that would also include existing auditory warnings. (figure 5) This ideal framework would have all the different effects with levels of effectiveness. In the table the level of stress and the requirements will also be taken into account. If this framework would be final it could be the foundation of alarm design in hospitals.

CONCLUSION

This paper gives a good foundation for a lot of possible future research. It concludes that designing hospital alarms that trigger tactile, audio-tactile and audio-visual senses are a useful addition if the nurses/doctors need to perceive different kinds of urgencies or get better spatial attention. This is only if the requirements listed in figure 4 are fulfilled.

The framework in figure 4 could be used as inspiration for future design and as inspiration for a much bigger framework including future research. This framework should be the foundation of sensory alarm design in the context of hospitals.

REFERENCES

1. Baldwin, C.L., Eisert, J.L., Garcia, A., Lewis, B., Pratt, S.M., Gonzalez, C., 2012. Multimodal urgency coding: auditory, visual, and tactile parameters and their impact on perceived urgency.
2. Baldwin, C. L., & Lewis, B. A. (2014). Perceived urgency mapping across modalities within a driving context. Applied ergonomics, 45(5), 1270-1277.
3. Boll, S., Asif, A., & Heuten, W. (2011). Feel your route: A tactile display for car navigation. IEEE Pervasive Computing, 10(3), 35-42.
4. Burt, J. L., Bartolome, D. S., Burdette, D. W., & Comstock Jr, J. R. (1995). A psychophysiological evaluation of the perceived urgency of auditory warning signals. Ergonomics, 38(11), 2327-2340.
5. Donchin, Y., & Seagull, F. J. (2002). The hostile environment of the intensive care unit. Current opinion in critical care, 8(4), 316-320.
6. Ferris, T.K., Sarter, N.B., 2008. Cross-modal links among vision, audition, and touch in complex environments. Human Factors: The Journal of the Human Factors and Ergonomics Society 50 (1),17e26. http://dx.doi.org/10.1518/001872008X250566.
7. Finley, G. A., & Cohen, A. J. (1991). Perceived urgency and the anaesthetist: responses to common operating room monitor alarms. *Canadian Journal of Anaesthesia*, *38*(8), 958-964.
8. Hilton, A. (1987). THE HOSPITAL RACKET: HOW NOISY IS YOUR UNIT?. AJN The American Journal of Nursing, 87(1), 59-61.
9. Ho, C., Reed, N., Spence, C., 2007. Multisensory in-car warning signals for collision avoidance. Human Factors: The Journal of the Human Factors and Ergonomics Society 49 (6), 1107e1114. http://dx.doi.org/10.1518/001872007x249965.
10. Ho, C., Santangelo, V., & Spence, C. Multisensory warning signals: When spatial location matters. *Journal of Experimental Psychology: Applied*
11. Ho, C., Tan, H. Z., & Spence, C. (2006). The differential effect of vibrotactile and auditory cues on visual spatial attention. Ergonomics, 49(7), 724-738.
12. Højlund M. K. & Have I. (2016) sound effects an interdisciplinary journal of sounds and sound experience.
13. Kestin IG, Miller BR, Lockhart CH. Auditory alarms during anesthesia monitoring. Anesthesiology 1988; 69:106-9.
14. Kim, S., & Dey, A. K. (2015). Augmenting human senses to improve the user experience in cars: applying augmented reality and haptics approaches to reduce cognitive distances. Multimedia Tools and Applications, 1-21.
15. Lewis, B.A., Baldwin, C.L., 2012. Equating perceived urgency across auditory, visual, and tactile signals. Proceedings of the Human Factors and Ergonomics Society Annual Meeting 56 (1), 1307e1311
16. Meredith, C., & Edworthy, J. (1995). Are there too many alarms in the intensive care unit? An overview of the problems. Journal of advanced nursing, 21(1), 15-20.
17. Santangelo, V., & Spence, C. (2007a). Assessing the automaticity of the exogenous orienting of tactile attention. Perception, 36(10), 1497-1505.
18. Santangelo, V., & Spence, C. (2007b). Multisensory cues capture spatial attention regardless of perceptual load. *Journal of Experimental Psychology: Human Perception and Performance*, *33*(6), 1311.
19. Santangelo, V., Van der Lubbe, R.H.J., Olivetti Belardinelli, M., Postma, A., (2008c) Multisensory integration affects ERP components elicited by exogenous cues. Experimental Brain Research 185, 269–277.
20. Scott, J. J., & Gray, R. (2008). A comparison of tactile, visual, and auditory warnings for rear-end collision prevention in simulated driving. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *50*(2), 264-275.
21. Spence, C., & Santangelo, V. (2009). Capturing spatial attention with multisensory cues: A review. Hearing research, 258(1), 134-14