A model of product-induced pain

Andy Dong, Bernard Yannou

NordDesign 2016
August 10 – 12, 2016
Trondheim, Norway

A model of product-induced pain

Andy Dong[1], Bernard Yannou[2]

[1]*The University of Sydney*
andy.dong@sydney.edu.au
[2]*Laboratoire Genie Industriel, CentraleSupélec, Université Paris-Saclay*
bernard.yannou@centralesupelec.fr

Abstract

In industry circles, customer "pain points" has replaced customer needs as the source of ideas for products and services. The premise is that the more pressing the 'pain', the more likely the customer will seek to find a solution. In this article, we develop a model to describe customer pain induced by a product. The model includes semantics to describe the pain elements and relations between the semantics. We evaluate the model to ascertain the extent to which individuals can use it consistently to identify pain points in a dataset of consumer product injuries. The paper concludes with a discussion on the use of the model in a pain-minimization design process, in which the aim is to bring essential health, social, and economic value.

Keywords: Creativity tools, innovation, user needs

1 Introduction

Solving customer "pain points" has almost become a mantra in industry. The Value Map by (Osterwalder, Pigneur, Bernarda, & Smith, 2014, p. 9) recommends business models that produce "pain relievers", that is, products and services that reduce "bad outcomes, risks, and obstacles related to customer jobs". When industry refers to pain points, what is meant are the pressing and urgent problems that need to be solved.

This article takes as a general premise that pain reduction is a productive position from which to think about possible product and service innovations. Scholars have collaborated with disabled persons as lead users to identify needs that may not be evidence in a broad user base (Conradie, de Couvreur, Saldien, & de Marez, 2014). Preventing pain and injury is both ethically and economically responsible. One study from the UK in the mid-1990s identified that products such as a bicycle, ladder, stepladder, and DIY knife caused the highest total medical cost (Hayward, 1996); in 1996, bicycle injuries cost £81270 per million persons per year, for example. In the US, power tools cause about 30% of all eye injuries each year (McGwin Jr., Hall, Seale, Xie, & Owsley, 2006). Where ethical and economic imperatives fail, legal requirements compel product designers and manufacturers to eliminate the risk of injury and pain to those who use their products (Vernick, Mair, Teret, & Sapsin, 2003). Knowing that solving a customer pain is economically and ethically important is, of course, not sufficient to identify the pain. While there is deep literature about specific products and how to design them to minimize the potential of injury, we have been unable to locate a general framework to identify potential situations of pain induced by a product. Therefore, in this paper, we propose a generic model and ontology to describe situations of pain induced by a product for the purpose of designing them out.

Anticipating all possible sources and situations that may result in pain is challenging, though. In recent research on improving medical products safety, it was identified that the lack of systems thinking about medical errors that could result in patient pain and injury led to the increased likelihood of errors (Clarkson et al., 2004). The U.S Centers for Disease Control initiative of Prevention through Design (PtD) (National Institute for Occupational Safety and Health Education and Information Division, 2014) aims to “design out” possible injury. While the initiative regards the design of safety as a transdisciplinary problem, it does not offer a useful causal model through which to identify potential pains caused by products (Ertas, 2000).

A systematic method is needed to describe the mechanisms that can lead to accidental misuse, error and accidents, and possibly injuries. The challenge to designers is systematically finding predictable mechanisms that could induce pain as the basis for a design intervention that averts individuals from pain. While it is possible that some visionary individuals have some intrinsic and non-imitable skills to recognize highly valuable pain points to solve, this is an approach to innovation that depends upon chance rather than organizational capabilities.

Our perspective on pain reduction differs from the conceptual basis of design orientated around user needs, sometimes called user-centered design. While there is no single definition of user-centered design, user-centered design generally places a focus on the activities and goals of the end-user of a product (Gulliksen et al., 2003) and generally defines the system boundary by the end-user(s), the product, and the tasks engaged between the end-user(s) and the product. Predominantly, the literature in user-centered design has placed attention toward improving usability and positive experiences. We were not able to identify any papers in which the minimization (or elimination) of predictable mechanisms that would create pain as the objective of the design process.

This paper develops a model to describe the sources and situations of pain associated with a product. The model contains semantic elements and relations between the elements to model the relations between elements of situations in which pain occurs. The aim of the model is to establish the basis for systems thinking about usage scenarios or segments for new or revised products and services that are likely to bring essential health, social, and economic values (Bekhradi, Yannou, Farel, Zimmer, & Chandra, 2015). The philosophy underlying our design process is to try to design products and services that achieve their nominal performance requirements without creating unintended consequences and negative externalities. By removing potentially painful situations, we hope to promote more inclusive design (Clarkson & Coleman, 2010).

The first part of the paper reviews definitions of pain points and differentiates this concept from user needs. The paper then presents a model for pain induced by products and services. We present an evaluation of the model on a real-world database of consumer product injuries. The paper concludes with a discussion on the use of the model in a pain-minimizing design process that we call PxD.

2 Theoretical development

2.1 Defining pain

2.1.1 Physical and mental pain

This article takes a perspective on innovation as being about finding solutions that maximize the well-being of individuals by minimizing their pain. The philosophical basis of our position is based upon the legal philosophy of Jeremy Bentham (1823). While most of Bentham's treatise is on the morality of meting pain as a form of punishment, he provides a characterization of pain (Bentham, 1823, p. 65):

A man's happiness, then, may be said to depend more or less upon the relation he bears to any sensible object, when such subject is in a way that stands a chance, greater or less, or producing to him, or averting from him, pain or pleasure.

Interpreting Bentham's position on pain from the perspective of product design, pain is induced when a situation causes actual ("pain of actual *sufferance*" (Bentham, 1823, p. 125) or perceived ("the pleasure or pain may result immediately from the perception which it accompanies" (Bentham, 1823, p. 65) mental or physical harm. Bentham (1823, pp. 125-126) develops a list of nine kinds of personal injuries. He points out that pain can be both physically (the first eight) and mentally injurious (the last type of pain).

Simple corporal injuries
Irreparable corporal injuries
Simple injurious restraint
Simple injurious compulsion
Wrongful confinement
Wrongful banishment
Wrongful homicide
Wrongful menacement
Simple mental injuries

The distinction between and acknowledgement of both physical and mental pain is reflected in current medical definitions of pain. According to the International Association for the Study of Pain, pain is (emphasis added), "An unpleasant sensory and *emotional* experience associated with *actual or potential* tissue damage, or described in terms of such damage." (Coderre, Mogil, & Bushnell, 2003; International Association for the Study of Pain, 2011). Individuals experience pain as a reaction to noxious stimulation (Coderre et al., 2003).

Similar ideas are embodied in definitions of hazards. In systems engineering, a hazard is, "A system state or set of conditions that, together with a particular set of worst-case environment conditions, will lead to an accident (loss)." (Leveson, 2011, p. 184) In other words, a hazard is a set of conditions that could cause pain when the accident is inflicted upon the user.

While physical pains are generally readily observed, except in circumstances requiring specialized detection equipment, mental injuries are phenomenologically difficult to observe and describe. They are no less real than physical pains. One way to characterize negative mental pain is through the concept of emotions. Models of emotion (Thamm, 2006) generally follow either the *classical* approach of a set of mutually exclusive dimensions or the *prototype* (Russell, 1991) approach, which aims to identify emotions based upon exemplars of similar ways in which people label emotions. As our aim is to identify how products and situations may cause pain, or negative emotion, we follow the classical approach, and specifically, structural models of emotion that are based upon objects and situations (Ortony, Clore, & Collins, 1988) and individuals' appraisals of the objects and situations of significance to their well-being (Ellsworth & Scherer, 2003). The structural approach is appropriate in this context since the purpose of our model is to describe the mechanisms (Edwards & Bagozzi, 2000) linking antecedents of products, situations, and personal matters to pain.

Emotional pain may be observed externally even if the person being observed does not 'feel' any pain; observing someone as being self-destructive, neglected, oppressed or persecuted reflects an evaluation by the observer that, according to Ortony et al. (1988), does not directly refer to the psychological state of the person observed, but may indicate sympathy or empathy by the observer. Pain can be an Internal - Nonmental - Physical & Bodily State such as being nauseous and weary. Given the preceding discussions, for the purposes of this paper and our model of pain, we will adopt the notion that pain can be nonmental, in which case it is affect-mental, or physical.

2.1.2 Economic pain

Lastly, we consider pain that is neither physical nor mental. In most product liability laws, consumers are eligible for compensation due to 'loss' and 'damage' as a result of using a defective product. It is noteworthy that product liability laws permit compensation for economic loss including, e.g. in Australia, damage to or destruction of other property (Product Safety Australia, 2015), such as another product. Thus, while the previous concepts of pain dealt with physical or emotional injury, product liability laws also include economic pain. Recent scholarship has proposed that injury should be extended to social harms; companies should have a legal obligation to reduce the negative social costs of their products under performance-based regulation (Sugarman, 2009). As such, we include economic pain as a possible type of pain.

Having discussed the manifestation of pain, through physical & bodily, mental injury (negative emotion), or economic loss, we now turn to developing a model to describe the links between product and service characteristics that can induce pain. In particular, we briefly review the scholarship on negative experiences with products on the assumption that those negative experiences may either be precursors to or indicators of pain induced by a product.

2.2 How Products Cause Pleasure or Pain

The expression of negative opinions toward products and services is a growing area of concern in product marketing, especially arising from the significant volume of social media content about products and services. A number of scholars have therefore attempted to understand how products and services can stimulate emotional responses in individuals. In design research, Desmet (2012) identified six main sources of positive emotions elicited through human-product interactions: a) the object; b) the meaning of the object; c) interaction with the object; d) activity facilitated by the object; e) the individual; and f) other individuals involved in interacting with the object. In interaction design, researchers investigate how an interactive product can create a positive 'user experience' (Law & van Schaik, 2010). One of the most highly cited models identifies two types of product attributes perceived by users as causing a positive experience: *pragmatic quality* or the perceived utility and usability of the interactive product in supporting the individual to achieve personal behavioural goals; and, *hedonic quality* or the perceived ability of the interactive product to communicate values of importance to the individual or to facilitate personal development through stimulation, novelty, and challenge (Hassenzahl, 2004). Figure 1 describes the causal relation between product attributes and positive user experience.

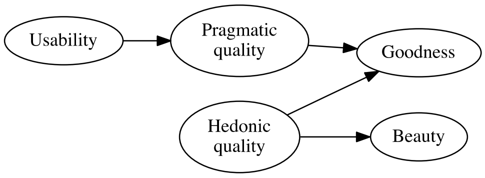

Figure 1 Causal model of positive user experience

While the absence of beauty and goodness will prevent a positive experience from occurring, it is unclear whether the model would predict pain. Nonetheless, the basic concept is that hedonic characteristics and pragmatic qualities cause a positive user experience. There are some problems extending this model into our model to describe situations that can induce pain. First, it is not directly obvious that the absence of hedonic characteristics could produce pain. Second, depending upon the subjective preferences of the individual, products that are too novel or too challenging to use, or require a significant investment of effort to learn to use properly and effectively, could constitute an annoyance -- an affect-mental pain. Answering whether or not such an annoyance constitutes pain may depend upon the population of individuals who report the annoyance and whether this population is worth addressing. Finally, some pragmatic product characteristics may annoy a user or be a “pet peeve” (a minor annoyance that recurs across a number of products or situations) -- such as individuals who do not like the touch screen interface on a cell phone. Whether this dislike constitutes pain is an empirical problem rather than an existential one. Our model aims to describe whether or not the characteristics of a situation could nonetheless be characterized as causing pain no matter how objectively minute.

3 Ontology development

3.1 Assumptions

In producing the ontology, we make the following assumptions:

- The ontology is limited to describing a construct for pain induced by objects and their use within situations. It is not a general ontology of pain.
- The ontology is not intended to measure pain or the quality and intensity of pain perceived.
- The ontology excludes individual differences in the subjective experience of pain, i.e., pain-sensitive and pain-resistant individuals.

We must also necessarily delineate a system boundary as shown in Figure 2. The pain model does not extend beyond the system boundary defined by the operator, the recipient, and a bystander (defined below). While the pain caused can extend to the supply chain and to society, such as the social loss due to large-scale injuries, the current model does not include these conditions.

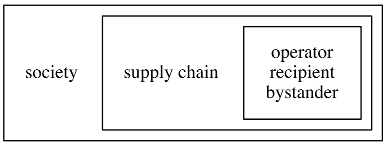

Figure 2 System boundary of pain model

3.2 Causal model

The concept is that the **source** of a pain produces a **type** of pain within a particular **situation** as shown in Figure 3. From Desmet (2012), we describe a) the object; b) the meaning of the object; c) interaction with the object; and, d) the activity facilitated by the object as sources of pain. We believe that these categories subsume the pragmatic and hedonic qualities of a product as suggested by Law and van Schaik (2010). In turn, pain can be experienced by a) the individual and b) other individuals. We distinguish these other individuals with reference to whether the individuals were the ones who were actively engaged in using the source of the pain or whether they circumstantially happened to be present when the source of the pain caused injury. In considering mental pain, we consider all types of negative affect as described previously.

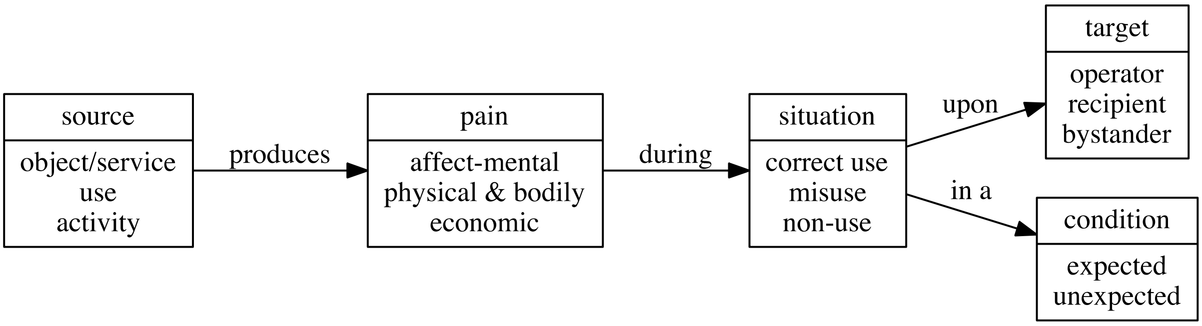

Figure 3 Ontology of pain model

Definitions of the semantic elements in the pain model follow, with examples taken from actual accidents recorded in the National Electronic Injury Surveillance Systesm (NEISS) (Division of Hazard and Injury Data Systems, 2004) are shown in Table 1.

4 Validation

4.1 Experiment

Ontology evaluation entails a number of criteria including consistency, completeness, conciseness, expandability, and sensitiveness (Gómez-Pérez, 2001; Vrandečić, 2009). In this study, we performed evaluations for consistency. To test for consistency, we performed a study of inter-coder reliability to determine whether the definitions for the semantic elements could be consistently applied to the same data.

To test the ontology, we investigated the consistency of its application over the NEISS (Division of Hazard and Injury Data Systems, 2004). The NEISS records all hospital visits associated with an injury due to a consumer product. The database records in the "Comments narrative" a description of what the individual was doing when the injury occurred, the product involved, and the location of the incident. A sample narrative is, "70YOM FELL 6 FEET OFF A LADDER ONTO HEAD FRACTURED NECK" [70 year old male fell 6 feet off a ladder onto head and fractured neck]”. Under the PxD ontology, the pain source is the *Use* (“fell off”) of the “ladder”, which produced *Physical & Bodily Injury* to his “neck” during *Correct use* to the *Operator*, a “70 year old man”, under *Expected* conditions.

Table 1 Pain ontology with salient words *emphasized*

Semantic Element	Definition	Example
Source	The source of the pain	
Object	The *object* itself (object focus) caused the pain, including if defective or lacking in quality, or when a problem with the object causes the pain. A person or person’s body part may be an object.	“exposed to *carbon monoxide* at home *from generator*” “hit in the face by *another child’s tennis racket* during a game” “falling against *a chair* when he slipped in water as he was leaving a restaurant” holding ladder for dad, he accidentally *stepped on his hand* while stepping down
Use	*Interactions with the object during its use* (interaction focus) caused pain. The pain is directly caused in the interaction with the object.	“got her left first finger *caught in bathroom door*” “*dropped 10 lb weight* on toe” “finger crushed between roll bar and pipe *when closing gate*” “slipped *getting out of swimming pool*”
Activity	The *activity enabled or facilitated* by the object (activity focus) is the cause of the pain; an object itself may not necessarily be involved in causing the pain.	“*attempted overhead hit while playing tennis* when shoulder popped out” “injured thumb *while playing baseball*”
Pain	The type of pain	
Affect – Mental	Pain is affective or emotional (psychological)	
Physical & bodily	Pain affects a part of the body	
Situation	The usage scenario during which the pain occurred	
Correct use	Pain caused during appropriate and intended use of the product including accident or mismatch between user capabilities and product use expectations	“*fell down the steps* of his mobile home” “*fell off bed*” “*slipped and fell on wet floor* today”
Misuse	Pain caused during inappropriate use of the product	“*used his fleece jacket to get a hot waffle out of the toaster* & burned thumb & pointer fingers” “*started fire using gasoline*, flashed back in face” “ankle pain after falling off *a toolbox that she was standing on* in garage”
Non-use	Pain caused even when object is not in its intended use	“*walked into glass wall*” “contusion to eye when *part of the ceiling fell and hit her*
Condition	External, independent factors that originate outside of the product boundary	
Expected	The use condition was within a case that was expected	“fell from a bike *to concrete* at daycare” *tripped over rope* and fell . . . hurting hip area
Unexpected	The use condition was outside of a case that was expected	“*had a cell phone thrown to him* & it hit him in the head – passed out” “2 year-old male tried to climb in a chair at grandma’s & chair fell hitting patient’s face”
Target	The person upon whom the pain is inflicted	
Operator	The person who is actually using the product	Nurse *operates* a syringe
Recipient	The person who received the pain. The recipient is the operator when it is the same person.	A patient is the *recipient* of pain from a syringe as the patient is not normally the operator of a syringe.
Bystander	An individual or individuals outside of the system boundary of the operator, the beneficiary, and the product	A delivery person who transports used syringes is a *bystander* if injured by a syringe

4.2 Intercoder reliability evaluation

One author coded a set of 50 randomly selected narratives and then recoded the set with a 24-hour break period in between. Definitions and their interpretations were clarified and then the data set re-coded (with 24 hour breaks in between) until the coder reliability exceeded 0.8. Krippendorff’s alpha (Krippendorff, 2004) is used for all calculations of coder reliability.

Narratives for which the codes were inconsistent across two coding were discussed with the other author to obtain agreement on their definition.

Another person uninvolved with the project was trained for one hour on the coding using a random set of 20 narratives. One author and the coder discussed the coding for each of the narratives until the coder felt confident on its use. The trained coder then coded independently the same set of 50 narratives coded by the author. One author and the coder reviewed their codes and discussed discrepancies. Discrepancies were discussed so that the author and the trained coder could agree upon consistent definitions for each of the categories and exemplars for each definition. Finally, one author and the trained coder coded another 50 randomly selected narratives. Krippendorff's alpha was calculated using SPSS (Hayes & Krippendorff, 2007) for each category, as shown in Table 2. The overall inter-coder reliability was 0.8937. For the category of Condition, there were only two discrepancies out of 50 cases. However, given 50 cases and only two possible values per case, even one discrepancy would lead to a value of α=.6598. Thus, the low value for this category can be attributed to the single category and small number of scale points. Nonetheless, the overall inter-coder reliability is sufficiently high to accept the coding as reliable (Lombard, Snyder-Duch, & Bracken, 2002). It can therefore be concluded that the definitions for the pain situations is likely to be clear enough such that with appropriate training, any individual would be able to use it to code situations in which pain occurs.

Table 2 Intercoder reliability

Category	alpha (α)
Source	.9403
Type	1
Situation	.8462
Condition	.4844
Target	.8657

5 Conclusion

This paper introduced a model and ontology to describe customer pain induced by a product. The model was shown to be consistent through an inter-coder reliability study based on actual data of pains as recorded by a US-based database of injuries reported to emergency rooms. While the model focuses on products, it should be readily extensible to processes, which are more likely to produce mental pain rather than physical or bodily pain. In addition, the model is silent about the magnitude of the pain. The judgement on the value of pain minimization could be handled using the concept of value buckets (Yannou, Jankovic, Leroy, & Okudan Kremer, 2013).

The purpose of the model is not to code pain for the sake of coding. Rather, its aim is to assist designers in uncovering the factors that may cause pains so that those situations could be designed-out, where appropriate. From a design management perspective, the follow-on matter is what designers and companies should do with insights into causes and situations of pain. One way forward is to utilize the pathways through the pain-driven design ontology as usage scenarios (Yannou, Yvars, Hoyle, & Chen, 2013). The design strategy in this case would be to identify a product that best covers the usage scenario space that produces, e.g., the most number of bodily & physical pain.

Acknowledgements

References

Bekhradi, A., Yannou, B., Farel, R., Zimmer, B., & Chandra, J. (2015). Usefulness Simulation of Design Concepts. *Journal of Mechanical Design, 137*(7), 071414-071414. doi: 10.1115/1.4030180

Bentham, J. (1823). *Introduction to the principles of morals and legislation*. Oxford: Clarendon Press.

Clarkson, P. J., Buckle, P., Coleman, R., Stubbs, D., Ward, J., Jarrett, J., . . . Bound, J. (2004). Design for patient safety: A review of the effectiveness of design in the UK health service. *Journal of Engineering Design, 15*(2), 123-140.

Clarkson, P. J., & Coleman, R. (2010). Inclusive design. *Journal of Engineering Design, 21*(2-3), 127-129.

Coderre, T. J., Mogil, J. S., & Bushnell, M. C. (2003). The Biological Psychology of Pain. *Handbook of Psychology*.

Conradie, P., de Couvreur, L., Saldien, J., & de Marez, L. (2014). *Disabled persons as lead users in product innovation: a literature overview*. 10th Biannual NordDesign Conference, Espoo, Finland.

Desmet, P. M. A. (2012). Faces of Product Pleasure: *25 Positive Emotions in Human-Product Interactions*. *International Journal of Design, 6*(2), 1-29.

Division of Hazard and Injury Data Systems. (2004). *National Electronic Injury Surveillance System (NEISS)*. Bethesda, MD: U.S. Consumer Product Safety Commission.

Edwards, J. R., & Bagozzi, R. P. (2000). On the nature and direction of relationships between constructs and measures. *Psychological Methods, 5*(2), 155-174.

Ellsworth, P. C., & Scherer, K. R. (2003). Appraisal Processes in Emotion. In R. J. Davidson, K. R. Scherer & H. H. Goldsmith (Eds.), *Handbook of affective sciences [electronic resource]*. New York: Oxford University Press.

Ertas, A. (2000). *Prevention through design: transdisciplinary process*. Lubbock: The Academy of Transdisciplinary Learning & Advanced Studies.

Gómez-Pérez, A. (2001). Evaluation of ontologies. *International Journal of Intelligent Systems, 16*(3), 391-409.

Gulliksen, J., Göransson, B., Boivie, I., Blomkvist, S., Persson, J., & Cajander, Å. (2003). Key principles for user-centred systems design. *Behaviour & Information Technology, 22*(6), 397-409. doi: 10.1080/01449290310001624329

Hassenzahl, M. (2004). The Interplay of Beauty, Goodness, and Usability in Interactive Products. *Human–Computer Interaction, 19*(4), 319-349. doi: 10.1207/s15327051hci1904_2

Hayes, A. F., & Krippendorff, K. (2007). Answering the Call for a Standard Reliability Measure for Coding Data. *Communication Methods and Measures, 1*(1), 77 - 89. doi: 10.1080/19312450709336664

Hayward, G. (1996). Risk of injury per hour of exposure to consumer products *Accident Analysis & Prevention, 28*(1), 115-121.

International Association for the Study of Pain. (2011). *Classification of Chronic Pain, Second Edition (Revised), Part III: Pain Terms: A Current List with Definitions and Notes on Usage*. Washington, D.C.: International Association for the Study of Pain.

Krippendorff, K. (2004). Reliability in Content Analysis. *Human Communication Research, 30*(3), 411-433. doi: 10.1111/j.1468-2958.2004.tb00738.x

Law, E. L.-C., & van Schaik, P. (2010). Modelling user experience - An agenda for research and practice. *Interacting with Computers, 22*(5), 313-322. doi: 10.1016/j.intcom.2010.04.006

Leveson, N. G. (2011). *Engineering a safer world: systems thinking applied to safety*. Cambridge: MIT Press.

Lombard, M., Snyder-Duch, J., & Bracken, C. C. (2002). Content Analysis in Mass Communication: Assessment and Reporting of Intercoder Reliability. *Human Communication Research*, *28*(4), 587-604. doi: 10.1111/j.1468-2958.2002.tb00826.x

McGwin Jr., G., Hall, T. A., Seale, J., Xie, A., & Owsley, C. (2006). Consumer product-related eye injury in the United States, 1998-2002 *Journal of Safety Research, 37*(5), 501-506.

National Institute for Occupational Safety and Health Education and Information Division. (2014). *Prevention through design*. Atlanta: Centers for Disease Control and Prevention.

Ortony, A., Clore, G. L., & Collins, A. (1988). *The Cognitive Structure of Emotions*. Cambridge: Cambridge University Press.

Osterwalder, A., Pigneur, Y., Bernarda, G., & Smith, A. (2014). *Value Proposition Design: how to create products and services customers want*. Hoboken: John Wiley & Sons.

Product Safety Australia. (2015). *Product liability*: Australian Competition & Consumer Commission.

Russell, J. A. (1991). In defense of a prototype approach to emotion concepts. *Journal of Personality and Social Psychology, 60*(1), 37-47. doi: 10.1037/0022-3514.60.1.37

Sugarman, S. D. (2009). Performance-Based Regulation: Enterprise Responsibility for Reducing Death, Injury, and Disease Caused by Consumer Products. *Journal of Health Politics, Policy and Law*, *34*(6), 1035-1077.

Thamm, R. A. (2006). The Classification of Emotions. In J. E. Stets & J. H. Thurner (Eds.), *Handbook of the Sociology of Emotions* (pp. 11-37). New York: Springer Science+Business Media LLC.

Vernick, J. S., Mair, J. S., Teret, S. P., & Sapsin, J. W. (2003). Role of Litigation in Preventing Product-related Injuries. *Epidemiologic Reviews, 25*(1), 90-98.

Vrandečić, D. (2009). Ontology evaluation. *Handbook of Ontologies*, pp. 293-313.

Yannou, B., Jankovic, M., Leroy, Y., & Okudan Kremer, G. u. E. (2013). Observations From Radical Innovation Projects Considering the Company Context. *Journal of Mechanical Design, 135*(2), 021005-021005.

Yannou, B., Yvars, P.-A., Hoyle, C., & Chen, W. (2013). Set-based design by simulation of usage scenario coverage. *Journal of Engineering Design*, *24*(8), 575-603.