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ELABORATION OF INNOVATIVE SAFETY EQUIPMENT CONCEPTS FOR INFANTS

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ABSTRACT
Designing safety systems for infants poses several methodological problems. One consequence of these is that existing systems fail to effectively prevent accidents in this specific population. In this paper, we present an approach to the design of such systems. Its main originality is that it made use of a task model to help guide team creativity in the elaboration of innovative product concepts. Secondly, in order to help select concepts that were most relevant to design, participatory simulations were carried out with caregivers, relying on the use of external representations of task situations and product concepts to help these future users anticipate how they might use or reject systems based upon these concepts. Having described the issues underlying the design of innovative, acceptable safety systems for infants as well as the method used to design such systems, we then present some results obtained in the design of personal protection equipment to prevent drowning in infants.

Keywords: product concept design, accident prevention, infants

1 INTRODUCTION

In the US, a survey carried out in 2005 by the Center for Disease Control and Prevention [1] listed drowning as the one of the leading causes of accidental injury in infants aged 1-4, with a majority of accidents involving the use of a swimming pool. Similar surveys have been carried out since 2001 in France [2], which have led to tightened regulations in the field of drowning prevention. Although French law now requires pool builders to construct pools using certified, integrated safety equipment (e.g. safety covers, fences, alarms, etc.), these inquiries show no significant reduction in infant mortality since the inception of this law. In addition, many studies carried out by government and consumer groups tend to cast doubt over the reliability of integrated equipment, even in the case of certified systems. There is therefore a growing need for innovation in the field of drowning prevention, in particular regarding infants. One alternative to integrated equipment involves the design of Personal Protective Equipment (PPEs), such as lifejackets or rubber rings. In 2008, our lab carried out a design project whose goal was to design an innovative PPE for the prevention of drowning in infants. In this paper, we describe the method used for the elaboration of product concepts in the scope of this project and investigate some underlying theoretical and methodological issues.

2 RESEARCH CONTEXT

Three elements of our project involved specific methodological difficulties. Firstly, the project involved designing a safety system. Secondly, that system was meant to be used by infants. Thirdly, the system had to be acceptable in order to be worn by users. Following the “Design for X” terminology, we present these specific aspects of the project below.

2.1 Design for safety

“Design for safety” [3] refers to a number of attempts made in industrial settings to ensure hazard and damage control within complex systems, typically resting on early identification and mitigation of possible hazards based on a small set of design principles. In our project, the design of a PPE-type system presented us with a number of methodological issues which we describe here, following a brief overview of the major research trends in this field.

2.1.1 Trends in research

The design of safety systems has been the focus of much research, which can be categorized into two distinct bodies of work. The first of these focuses specifically on the design of PPEs and dates back to early work in biomechanics [4]. Studies incorporated early on the idea of designing protective equipment based on a balance between protection efficiency on the one hand, and effects on task performance on the other. Comfort was used as a variable to explain this relationship. However, this variable proved to be the source of several difficulties, related to three factors in particular [5]: (1) it combines physiological, psychological and physical factors; (2) it relates not just to the constraints associated with a static posture, but also to effects of system use on biomechanical performance; and (3) it is a relative, not an absolute, term. More recent work tends to confine the word "comfort" to biomechanical factors, and introduce new concepts, such as wearability, as an overarching framework [6]. However, from a design point of view, they pose the same problems.

A second tradition tends to view risk prevention from a more systemic perspective. The occurrence of several major industrial accidents in the 1970s and 1980s, e.g. Chernobyl, Bhopal, Three Mile Island, etc. led several scientists to focus their efforts on the accident rather than the man-machine system involved. Successive models of accident causation led to three distinct tendencies in the design of safety systems [7]. Early models focused on the accident as a linear process, as illustrated by Reason's "Swiss cheese model" [8], and led to the assumption that redundancy was the best approach to system reliability. However, accidents continued to occur in such systems, in ways which were increasingly difficult to predict. Later models were based on an epidemiological analogy, according to which accidents resulted from "dormant pathogens" being awoken by a combination of environmental factors, causing complex failures which spanned several levels of the system. Furthermore, this extended the focus of analysis to organizational factors of safety. In this view, complex interactions between various, closely-coupled safety systems may cause unforeseeable and catastrophic failures. Reliability then rests on providing aids for system control and anticipation of possible accidents [9]. Systemic models such as CREAM (Cognitive Reliability and Error Analysis Method; [10]) then viewed accidents as an emergent property of complex systems whose prediction rested on modeling the cognitive processes involved in system operation. Resilience engineering [11] is the latest in a long line of design paradigms and involves designing the system so that it might retain or rapidly recover a stable and safe state of operation following an incident. Training, collaborative safety practices between users and improvement of safety culture are all geared toward improving system resilience through human action.

Our own view is closely based on this second strand of research. Although the question of user comfort is of great relevance in the design of wearable safety systems, work in this field tends to focus on the user-PPE system with little regard for context of use. A more systemic view, such as that characteristic of the second body of work mentioned above, seems more appropriate to the problem at hand. Indeed, infant safety today is ensured both by technical systems and by human supervision, two types of defense whose interactions are complex. Human centered design of safety systems should therefore allow integration of knowledge regarding future use of these systems. This raises at least two important issues: the first concerns the complexity of PPE use, as well as what methods may be used, and which persons should be approached in order to collect reliable data on situations of use; the second is related to biases involved in the construction of mental models of accident situations.

2.1.2 The first issue: collecting data on accidental situations

We start by pointing out that, although the system is designed to avoid the occurrence of specific scenarios (those leading to injury or death), a large number of scenarios involve the infant wearing the PPE without it being instrumental to the task at hand (e.g. playing, resting, exploring one's surroundings, etc.). These "nominal" situations of use refer to an extremely large number of potential tasks whose sole common denominator is physical proximity of the infant to a swimming pool.

However, system use also potentially involves accident situations. For ethical reasons, one cannot simply observe nominal situations and wait for the accident to happen. Methods therefore generally focus on prospective or retrospective investigations with users. Some of the methods used include:

- The critical incident technique [12], an interview method based on retrospective recall and analysis of critical events, incidents or accidents;

- Incident report systems rely on testimonies from witnesses of incidents and accidents in large socio-technical systems;
- HAZOP (HAZard and OPerability study) relies on structured examination of a formal process model by a team of experts following a limited set of guide words, etc.

To sum things up, most methods used to identify accident situations rely on top-down approaches and expert examination of a task model of nominal processes to identify "what might go wrong" or "what went wrong". Shortcomings of these approaches include the need for detailed knowledge of nominal processes. Although such information can be readily available in the case of industrial processes, where such methods are most often used, things are far from easy when dealing with the potential uses of a consumer product such as a swimming pool, which can be very diverse (e.g. family use *vs.* public use, sporting use *vs.* leisure use, etc.). Bottom-up approaches seem more relevant because there is seldom any cause for users to model leisurely, pool-related activities where system performance is not an issue. On the other hand, conducting an inquiry on real-life accidents entails a difficult dilemma:

- Collecting data based on users who have been exposed to a real-life accident, for example in an interview, can be traumatic to participants and should be rejected on ethical grounds;
- Collecting data based on users who have never been exposed to such situations may cause irrelevant or unreliable data to be gathered.

In both cases, biases surrounding the construction of mental models may also lead to the collection of unreliable data, as we now hope to show.

2.1.3 The second issue: biases in the construction of mental models of accident situations

Accidents are rare. Information regarding these situations can be gathered through interviews with witnesses and other reporting-based methods, but most users have never been confronted to such situations firsthand. In these cases, reasoning about accidental situations is counterfactual, i.e. concerns events which *might* have happened or *may* happen in future, as opposed to reasoning about real situations that have already come to pass. Several authors have studied biases associated to such forms of reasoning, in particular:

- The hindsight bias [13] refers to an exaggerated belief in the likelihood of a given event following its occurrence, as evidenced by the phrase "I knew this would happen". Counterfactual inferences are common in reaction to accidents. They heighten the hindsight bias and can lead to errors in causal attribution. This makes interviewing caregivers involved in accidents unreliable, since the explanation of an accident typically focuses on a single, self-centered element, e.g. "I must have left the fence open" ;
- Comparative optimism refers to the belief that one is less likely than other people to experience negative events. This process has been described as one geared toward self-protection [14]. This results not only in an inability of users unexposed to accidents to formulate relevant mental models, but can also result in diminished perception of risk and disruption of protective behavior. Furthermore, several studies have addressed situations in which safety is ensured by the use of external systems, leading to effects of complacency on the part of the user [15]

The research described above tends to cast doubt over the reliability of both past (e.g. relatives of accident victims) and end users as sources of information for user needs analysis. To circumvent this, we proposed a specific approach to participatory design relying on what some authors term "user advocacy" [16]. These authors define user advocates as members of a design process with extensive experience of interactions with users and an understanding of underlying technical issues. Following this approach, an ergonomist can be viewed as a user advocate [17], but so can representatives of user groups. Our hypothesis is as follows:

H1: User advocates, being individuals who have made a commitment to expressing user needs for product design, are capable of expressing these needs based on personal experience and on communication with peers;

2.2 Design for infants

Unlike design for safety, the design of products for infants has not, to the best of our knowledge, been the subject of any attempts to formulate design rules applicable to all products. Individual efforts have focused on specific products such as toys [18] or high-tech products [19], but with little interest in a generic approach to better satisfy infant needs. One reason for this may be the fact that infants are incapable of satisfying their own needs and generally rely on a socially designated caregiver (often a parent) whose role is to see that these needs are met. User needs analysis in the design of such products poses two problems. The first concerns the expression by the infant of his/her own needs; and the second is that caregivers themselves can also be viewed as users of the product whose needs should be formalized and met.

Most methods for user needs analysis rely on some form of verbal communication. Infants cannot reliably understand or produce complex forms of speech before several years into life. However, this should not be interpreted as a claim that infants are incapable of expressing their needs. Some authors [20] have provided conclusive evidence for the existence of alternate forms of infant-caregiver communication, based either on primitive forms of verbal communication (e.g. crying), or on alternate modes of communication (e.g. grimaces). This allows the infant to express needs, in such a form that the caregiver might understand and cater to them.

Beyond the fact that infants can encounter difficulties in expressing their needs, one could argue that their expression is not entirely relevant to safety. In the case of infants, cognitive development is ongoing and the perception of danger is not yet a fully-acquired skill [21]. Indeed the infant must learn to distinguish self from environment, then master causality before understanding the concept of danger. Morrongiello *et al* [22] pointed out that since infants are incapable of ensuring their own safety, it is necessary to take into account the safety practices of caregivers to construct a relevant model of product use.

Interviewing caregivers should therefore be viewed as relevant to system design on two levels. On the one hand, caregivers have their own needs and may express themselves on the matter. On the other hand, they are also prime sources of information regarding infant needs, which are often expressed in a cryptic fashion. We contend that it is essential to design a system which is acceptable to both infants and caregivers for two reasons:

- Infants may express disapproval through actions rather than words, resulting in the system being rejected, damaged, etc.;
- Parents may also find the system unsuited to their needs, resulting in a refusal to purchase or use it.

Our hypotheses regarding the design of products for infants are as follows:

- *H2 : Designing a product suited to user needs involves studying product use both from the caregiver's and the infant's points of view;*
- *H3: Caregivers formulate mental models of infant needs and are capable of expressing a point of view which is relevant to system design.*

2.3 Design for acceptability

2.3.1 System acceptability and its relevance to innovation in the design of safety systems

The concept of system acceptability was initially described by as "whether the system is good enough to satisfy all the needs and requirements of the users and other potential stakeholders, such as users' clients and managers". Nielsen's initial model [23] described acceptability as having two components, one practical which includes concerns of utility, usability, etc., and one social, referring to how well the system complies with societal needs. The complexity of these factors has so far prevented any proposals for structured principles of "design for acceptability". In the scope of our work, PPEs can be thought of as being used by both infants, who wear the system in pool-related activities, and caregivers, who are involved in most aspects of its use (e.g. putting the equipment on, taking it off, carrying out maintenance operations, etc.).

Several authors have advocated taking into account information related to product use early on in the design process, in the concept generation stages, as a gateway to innovation. Social innovation theories stressed the fact that innovation could stem from satisfying a social need [24]. Concepts such as “Life years lost” and the existence of user advocacy groups, make it clear that prevention of accident and injury has a strongly social component. Innovation in this field is mostly geared towards improving system reliability, i.e. averting the occurrence or limiting the consequences of accidents. In the case of designing PPEs, one major cause for system unreliability is that the system must be worn in order to be effective. System acceptability therefore emerges as a strong perspective for the design of more reliable safety equipment.

Assessing the reliability of a future safety system is far from easy. This is a major cause for lack of radical innovation. In the area of safety science, Amalberti [25] goes so far as to say that lack of innovation may prove to be the downfall of what he calls “ultra-safe systems”, i.e. those claiming near-absolute reliability, which society relies upon to satisfy essential needs (e.g. nuclear power plants, industrial processing plants, etc). In the case of such installations, continuously increasing demands lead to pressure towards better performance. However, this continuous pressure does not allow for current operational logics and working practices to evolve jointly with this changing context of operation. In order to circumvent this problem, creative product concepts must be generated and tested in the early stages of design.

2.3.2 Counterfactual reasoning as a means to generate and evaluate acceptable concepts

Creativity is viewed as a fundamental characteristic of innovative products. A product is said to be creative if it shows some degree of novelty but also of appropriateness [26]. In the case of PPEs, the system is said to be appropriate if it satisfies user needs better than existing products do, i.e. is more effective in preventing accidents. Designers must therefore be able to (1) identify and distinguish existing concepts, to construct mental models of future use of products based on these concepts; and (2) propose novel appropriate concepts and evaluate the reliability of products based on these concepts in comparison to existing solutions. The goal here is to select concepts that will be deemed acceptable by the end user. King and Sivalognathan [27] described concept selection as “the Rubicon of the design process” and advocate flexibility in system design, i.e. elaborating a core design which may give rise to several different products. In the case of safety equipment design, the core might refer for example to the system’s technical components, while its variable elements could refer to aesthetic features or use-related concepts. These variable elements might aim to improve system acceptability.

Several views coexist in the literature as to how acceptability is evaluated in light of the evidence. Following Roese [13], we view this as a process involving what he calls *prospective counterfactual reasoning*, i.e. construction and examination of mental models of future or potential situations of use. Such reasoning might occur at two main levels:

- In designers, during the concept generation stage, in order to suggest concepts which are likely to be well received by end users;
- In users, mainly during the purchase and use stages of the product lifecycle, in order to decide whether the product is effective enough to be worth using.

Such forms of reasoning can provide valuable resources to the design process. Extensive evaluations based on mock-ups may not be compulsory, although they can be very informative. Counterfactual reasoning, particularly in users, may thus provide a choice resource for the selection of product concepts, based for example on *a priori* judgments of trusthworthiness. Since this relies on building mental models that are literally “far from the facts”, external aids may be necessary to contextualize the process.

2.3.3 Selecting acceptable concepts based on user feedback

In this view, evaluation of product concepts relies on the user examining and commenting on these counterfactual mental models. Depending on problems encountered in design and on the questions relevant to the project at hand, various methods might be used. Some questions of interest to the design of PPEs might be:

- How do caregivers envision the system’s situations of use, whether those situations are nominal or dangerous?

- Have all dangerous situations been anticipated by the project team?
- Which are the factors that impact caregiver relationship to the system, and how might these factors impact product use?
- Which are the criteria for product design and use that define a system that is acceptable to caregivers?

Semi-directed interviews are a method of choice to provide specific answers to these questions since they address some sensitive issues. Verbal reports have long been viewed as a potential source of data for design [28]. However, as Vermersch [29] points out, some elements of user experience require a considerable amount of "unfolding" (his term) to be accessed and made explicit. He proposes to rely on a second-person approach, the interview being carried out by a person with expertise in gaining access to subjective experience. The goal of the interview is for the interviewee to carry out some form of introspection in order to identify, and then verbally express, specific elements of his own activity, e.g. motivations, assumptions, likely courses of action, etc.

System concepts can then be evaluated based on user feedback. However, interview-based methods do not allow easy comparison of feedback between users. To solve this problem, the interview may be followed by a quantitative method such as a questionnaire. In keeping with our goal to preserve the complexity of user experience, user reaction to product concepts should be analyzed according to several dimensions. Is the concept interesting? Is it attractive? What would the system look like if it were based on this concept? How would one use it? Etc. Concept selection can then be carried out by identifying concepts highly scored by respondents.

This method for selection of product concepts is derived from risk compensation theory [30]. This theory suggests that users of safety systems have a propensity to take risks, influenced both by the perceived rewards of risk-taking and by the perceived level of safety. This theory has two major consequences as regards the use of safety systems:

- In infants, the use of safety systems translates to increased risk taking [31];
- In caregivers, the perception of system reliability improves system acceptability [32].

However, one possible side-effect of using interview-type methods, which allow the user to carry out a reflective activity, is that it might introduce complex variables in system acceptability through perception of self-efficacy in the prevention of infant injury [33]. Thus, perception of reduced self-efficacy in the use of the system may influence its use in one of two ways: firstly, through removal of the factor diminishing self-efficacy, i.e. rejection of the system; secondly, through development of compensatory practices, the system can be accepted provided some behavioral adjustments allow the caregiver to retain a constant level of self-efficacy. This complexity precludes designing the product based solely on user feedback regarding concepts. A second stage of evaluation should rely on observation of user behavior ("users" refers here to both infants and caregivers) during the use of mock-ups. Designing such models involves "concept fusion", i.e. combining those concepts viewed as relevant by caregivers within a small number of mock-ups.
Future evaluation can then rest on observation of the use of mock-ups in real-world situations. Observation must involve all users, i.e. both infants and caregivers in real world situations.

Regarding the elaboration of acceptable system concepts, our hypotheses are as follows:

- *H4: Task models may be used as a resource for the elaboration of product concepts;*
- *H5: Users are capable of generating mental models of a system's future use through counterfactual reasoning, to formulate judgments of acceptability;*
- *H6: This process can be facilitated through involvement in participatory simulations and the use of intermediate representations (IRs)*

3 AN OVERALL VIEW OF OUR APPROACH

The elements mentioned in part 2 led us to a number of methodological choices described in figure 1.

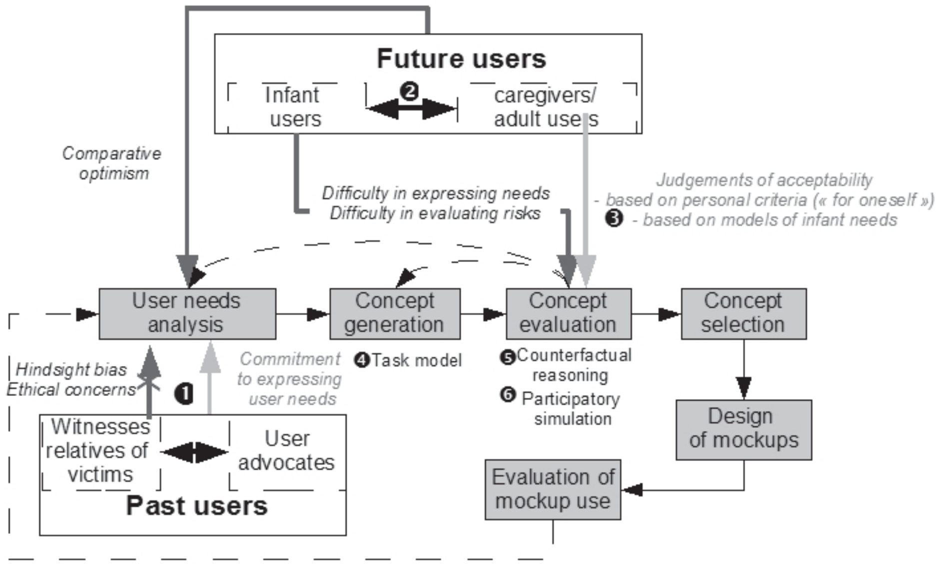

Figure 1.Overall view of our approach. Dark arrows indicate methodological obstacles to user centred design. Light arrows indicate the solutions put forth to circumvent them. Thick arrows indicate pathways of communication between various types of users. Dashed arrows highlight the long (mockup-based) and short (concept-based) feedback loops. Numbers point out our main hypotheses.

4 RESULTS

The team involved in the aforementioned design project comprised four engineers, one designer and one ergonomist (one of the authors). For obvious reasons relating to industrial secrecy, we will only present those of the project results which are directly relevant to illustrate our methodological approach.

4.1 Concept generation

4.1.1 Method

In the first part of the study a semi-directed interview was carried out with a user advocate, who was chairperson of a support group for the relatives of victims of infant drowning. The interview was carried out using the critical incident technique. The interview covered three major topics: (1) factors contributing to the occurrence of drowning accidents; (2) drawbacks of existing safety systems, especially those made compulsory by law; (3), following a short description of a potential design concept, the perceived advantages and drawbacks of a system based on this concept.

4.1.2 Results

4.1.2.1 TASK MODEL

Interviewing the user advocate allowed us to identify three major contributing factors to the occurrence of drowning accidents in infants:

- Misuse of existing safety systems;
- Infant attraction to water;
- Imperfections in caregiver supervision.

Misuse of safety systems refers to all forms of system use which are contrary to conditions of use defined as acceptable by designers (e.g. not replacing a pool alarm's exhausted battery). The notion of activity as arising from differences between prescribed tasks and tasks as they really are carried out is prevalent in the so-called "French-speaking" tradition of ergonomics [17] and seems particularly relevant to our work. In this view, unanticipated uses of the system arise from a process of adaptation to task constraints: for example, one might leave a safety fence open because the pool is currently in use; unwanted and haphazard activation of a pool alarm quickly leads to it being left turned off; an infant wandering too close to the pool is intercepted and removed from immediate danger. Similar mechanisms may be at work when infants indulge in risk-taking behavior, e.g. attempt to escape a caregiver's notice or intentionally remove a pair of armbands. In this view, even interpersonal strategies can be viewed as an adaptation of the infant to the constraints of caregiver supervision.

To sum things up, we propose a model of PPE acceptance or rejection based on the concept of "room for maneuver" described by Coutarel et al [34]. This concept is defined as an abstract space, subjectively constructed by the user to accommodate the variability of task demands. As Morrongiello et al [31] point out, one of the shortcomings of current safety systems is that infant and caregiver mutually reduce their respective room for maneuver: the caregiver, by moving the infant away from water which seems to be a focal point of his activity; the infant, by not complying to parental prescriptions and indulging in risk-taking behavior. Fig. 2 describes this model.

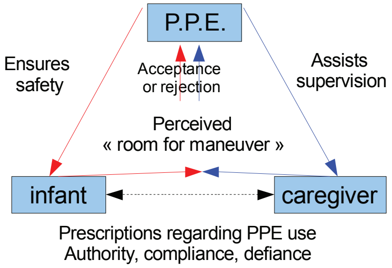

Figure 2 : a three-sided model of system acceptability dynamics

4.1.2.2 PRODUCT CONCEPTS

The three-sided task model described in fig. 2 clearly identifies three avenues for the design of safety systems. The first two are focused on improving system acceptability for infants on the one hand and for caregivers on the other hand. As a third prospect for improvement of product acceptability, the PPE may be designed to support a collaborative activity involving both infants and caregivers.

Based on these three avenues for design, we conducted a meeting involving all team members using various project-related documents (e.g. interview transcripts, survey results, pictures of existing systems, etc.). The meeting allowed further specification of these avenues, leading to the generation of eight distinct concepts:

- Acceptability for infants yielded two concepts, one centered on product personalization, and the other on optimization of comfort of PPE wear. Each of these yielded 2 subordinate concepts, adding up to four concepts in total;
- Acceptability for adults yielded one concept;
- Collaborative activities between the infant and the caregiver yielded three concepts.

4.2 Concept evaluation

4.2.1 Method

Following the generation of product concepts, we conducted evaluation sessions with ten couples, all of them parents of young children (age <3 yrs.). Evaluation relied on two separate methods. Questionnaires allowed investigation of the respondents' family composition; habits regarding the use

of swimming pools; experience of past pool-related accidents; personal attitudes towards the risk of drowning; and personal attitudes towards existing safety systems.
Following this preliminary stage, interviews were carried out with respondents, using three separate types of intermediate representations:

- Storyboards, all hand-drawn, depicting 18 prospective situations of use, both nominal and accidental;
- Concept boards, describing 8 product concepts using series of words and illustrations of the product, both "free-standing" and in use by a child. Illustrations were either hand-drawn or made using photomontage techniques;
- Trend boards, describing 4 current design trends in the area of products for infants.

All IRs were produced by the team designer in collaboration with the ergonomist. Situations of use were listed according to user testimonies based on results of the initial interview with the user advocate, and on analysis of incident reports stored on the advocacy group's website. This analysis led to production of work documents which were submitted to the team and discussed in the course of design meetings to increment this "database" of use scenarios. Concept boards were freely elaborated following the meeting. Trend boards are a staple method of design and were carried out by the designer through personal research.

Interviews with parents were audio-taped and transcribed *verbatim*. They were semi-guided and centered on specific aspects of product use. Table 1 lists these aspects. In order to help select relevant concepts, these factors were also, when possible, graded numerically using a questionnaire based on five-point Lykert scales. Concepts were selected according to overall scores attributed to the various concepts, and also according to project-specific factors, specifically the wish to explore specific product concepts in these early iterations of the design process.

Part 1 : Situations of use	Part 2 : product concepts	Part 3 : design trends
Likelihood of described situations; Acceptability of PPE wear to the caregiver; Acceptability of PPE wear to the infant; Perceived PPE efficacy in the situation described	Interest for product concept; Attractiveness of product concept; Trustworthiness of concept, i.e. Likelihood of product concept to yield an effective safety system	Attractiveness of design trend Degree to which the design trend is viewed as reassuring; Estimated attractiveness of design trend to the infant; Likelihood of products based on trend to be better accepted by infants.

Table 1 - List of criteria explored in the interviews

4.2.2 Results

Questionnaire results allowed us to select the most relevant concepts for product design based on criteria of interest, attractiveness, and trustworthiness to users (fig. 3).

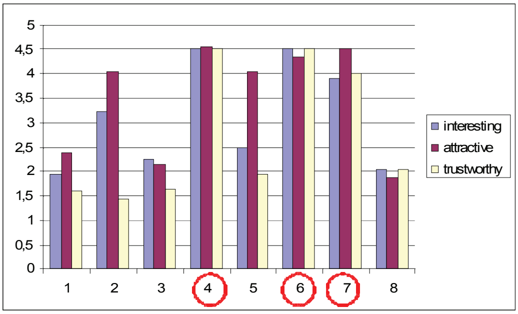

Figure 3- Average scores for each of the 8 concepts developed by the design team. Circles highlight concepts initially selected for product design.

This approach to concept evaluation allowed us to select three product concepts (4, 6 and 7). All of them were related to designing the product for collaborative infant-caregiver activities. The design team also chose to retain another concept, with slightly lower scores, for future development. This concept (2) was geared toward improving acceptability of the system for infants.

Secondly, analysis of the interview data (collected alongside questionnaire data) allowed us to determine the reason why some situations, concepts and designs were rejected by the respondents, as being respectively unlikely, untrustworthy or unlikely to improve system reliability. Respondents also suggested we add new situations of use and new product concepts to the existing database. Thus this methodology allowed not us only to evaluate productions and mental models of the design team, but also to add new concepts for future examination. Concepts were merged in order to design a series of mock-ups. Evaluation of these models is ongoing. In the final part of this paper, we describe the issues underlying this second stage of the evaluation as well as the other stages of the process.

5 DISCUSSION

In this specific design project, we proposed and applied a new methodology for collective and participatory elaboration of product concepts. This methodology allowed us to formulate a range of concepts and evaluate them with little expense and delay due to production of large numbers of mockups. A number of results of the evaluation are thought-provoking, and we hope that the second stage of evaluation will provide some answers to our questions.

5.1 If users find it interesting, does that make it safer?

The first of these questions concerns the significance of the results regarding product concepts. Indeed, all concepts which involved supporting collaborative activities between infant and caregiver in system use sparked considerable interest in respondents. Secondly, all concepts viewed as interesting were also viewed as more likely to give rise to a more trustworthy system. This result is interesting because it ties the perceived novelty of the product concept to its perceived reliability. One explanation for this is the current social climate: users are constantly bombarded with messages such as “A pool is never safe enough”. Publicly available statistics, as well as gruesome media reports, are also constant reminders that accidents can happen even in the safest of pools, i.e. one in which safety systems are state-of-the-art. In such a context, absolute safety is still a shared ideal, and all products which are innovative and perceived as trustworthy are also likely to be viewed as reliable. Since no safety system today can claim a perfect track record, innovation is perceived as a factor of reliability.

5.2 Is there such a thing as an intrinsically safe concept?

One other result of interest is that respondents encountered no difficulty in formulating judgments of trustworthiness based on abstract product concepts. Explanations regarding these grades were invariably met with verbal descriptions of scenarios of use constructed by the respondent. These statements were often introduced by the words “What if” or “Imagine if”, which are strong indicators of counterfactual reasoning. Analysis of verbal data supported the claim that counterfactuals are constructed from a variety of sources: hearsay (“One of my brother’s friends knows a couple who lost their child in a swimming pool”), media reports and public service announcements, knowledge of existing incidents, or in some cases, personal experience (witnessing an accident firsthand).

5.3 If users think it is safe, will it be so it the future?

A number of intriguing results led us to wonder to what degree users’ mental models regarding future situations of use accurately reflect future behavior and product use. Firstly, most respondents declined to answer questions regarding the trustworthiness of design trends, claiming for example, that “just as long as it works on the inside, the design doesn’t matter”. Secondly, some dangerous situations were described as irrelevant by some users, accompanied by claims such as “That would never happen, I never leave my child alone” As Roese [13] points out, this certainty of being able to ensure infant safety is no guarantee for it to be absolutely effective. *A posteriori* revision of mental models of the situation is a common component of guilt and regret. Furthermore, judgments of absolute reliability have been greeted with responses that no system can claim to such safety performances, or ever will. Perrow [35] for example explains this by invoking the complexity of situations of use: there will always be a turn of events through which an accident can happen.

6 CONCLUSION

User centered design of safety equipment for infants poses several methodological problems. Infants, who are primarily concerned with product use, insofar as they wear it in order to be protected, are inaccessible to traditional investigation methods based on verbal communication. Since the goal is to design systems aiming to help manage rare and traumatic accident situations, neither past nor future users can provide accurate information regarding user needs. Caregivers and user advocates may provide useful information regarding these. But any data collected will only refer to a personal point of view and behavior in a real-life accident is likely to be quite different.

Nevertheless, the caregivers' point of view is not just a useful resource for designers. In this paper, we contended that it was a crucial aspect of product use since it oversees the act of purchasing the system, but also its everyday use. The originality of our methodology is that it introduced a specific form of participatory design: concepts generated from task models were essentially selected by caregivers. Our method, based on fostering counterfactual reasoning in future users, allowed not only explicit verbalization of criteria for the relevance of safety equipment to caregivers; it also allowed design assumptions to be confronted to user feedback. However, numerous biases still surround this approach. Further work will have to be carried out regarding the determinants of PPE perception in both caregivers and infants to reduce these biases.

Lastly, in proposing this methodology for the selection of product concepts, a number of hypotheses were made which can only be validated based an examination of the end product's efficiency in preventing accidents in the real world. User needs analysis by user advocates, the use of task models to generate product concepts, and all the hypotheses cited in this paper can only be truly validated if they allow the design of a PPE which is demonstrably more reliable than its existing counterparts. In particular, examination of the real world use of the system should focus on PPE use and rejection by caregivers and infants. Only then will it be possible to move on from measuring the *a priori* acceptability of product concepts through involvement of caregivers in participatory simulations, to measuring the acceptance of a safety system in the real world. This stage, we feel, is a compulsory step towards validating this methodology for the design of safety systems for infants.

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