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PROBLEM FRAMING AND DESIGN OPPORTUNITIES

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ABSTRACT
A comprehensive study of early childhood injuries undertaken by Nationwide Children's Hospital in 2010 revealed that the common household spray bottle was the most likely source of injury for young children under the age of five. Due to the size of their hands, small children typically point the spray nozzle directly at the eyes and mouth when attempting to actuate the trigger with both thumbs.
Nationwide Children's Hospital contacted The Ohio State University seeking help with a new trigger design that would effectively eliminate the spray bottle as a source of injury. A design and engineering team conducted additional human-centred research and found a range of alternative design opportunities that could reduce the number of injuries caused by household cleaners. The hospital team was interested in developing a solution to the design problem as they defined it. The design team, following the directive of the Hospital team, proceeded to design and prototype a successful two–stage-triggering mechanism that is currently going through the patent process in the USA. This design was tested and found to meet all the requirements set by the hospital's design brief.
Although the design of the mechanism was successful from a functional standpoint, it has not as yet been adopted by industry. This paper presents a critical case study of the process by which the re–designed trigger mechanism was created, paying special attention to the "framing" of the design problem and the limited understanding of market constraints faced by the hospital and design teams. We believe this case study represents a useful example of how addressing a compelling need through a good design solution translates to a commercially viable alternative in the market.

Keywords: Problem framing, design constraints, market constraints.

1 BACKGROUND

A study conducted by researchers from the Centre for Injury Research and Policy at Nationwide Children's Hospital, concluded that household cleaning products are responsible for many accidental poisonings in children. Household cleaning products are consistently in the top five categories for paediatric poisoning exposure. An estimated 268,000 children were treated in US emergency departments for household cleaning product-related injuries during a sixteen-year period. The number of injuries attributable to household cleaning product exposure decreased 46.0% from 22,141 in 1990 to 11,964 in 2006. Children 1 to 3 years of age accounted for 72.0% of cases. The primary mechanism of injury was ingestion (62.7%), and the most common source or container was spray-bottles (40.1%). Although rates of household cleaner-related injuries from regular bottles or original containers and kitchenware decreased during the study period, spray bottle injury rates showed no decrease [1]. Recommendations from the American Academy of Paediatrics include storing poisonous substances in locked cabinets, buying products with child-resistant packaging, keeping products in their original containers, and properly disposing of leftover or unused products [2]. After publishing this study, the researchers received considerable attention from the media due to the significance of the numbers associated to a device commonly perceived as harmless. The researchers, compelled by what the data from the study revealed, decided to pursue a redesign of the current spray bottle. An additional motivation was the earlier success of the cigarette lighter safety mechanism. As a result of the change in design and the development of the child-resistant lighter, there was a 58% reduction in fires caused by children under the age of five in 1988 [3]. This policy began as a voluntary standard but eventually became law in 1994 (16 CFR Part 1210). The immediate goal of the research team from Nationwide Children's Hospital was to develop a spray bottle trigger mechanism that greatly resembled the locking mechanism of the child–resistant cigarette lighter. The long–term result of this product would

be i) to significantly reduce the number of injuries and ii) to encourage the implementation of a similar policy standard as that of the cigarette lighter. With this initial data, the hospital team defined the design problem and sought design expertise from the Design Department at Ohio State University.

2 THE DESIGN PROCESS

The University team was comprised of two Industrial Design Faculty, one Mechanical Engineering faculty and one design graduate student. The hospital and the university have a well-established research collaboration agreement; initial funding for the project came from the research fund from a member of the hospital team. During the initial project meeting the design team led a discussion with regard to the problem definition. In short, the design team wanted to explore the problem space beyond the trigger mechanism. They felt strongly that a need existed to understand what other elements were influencing children's behaviour, given the fact that all spray bottles were already equipped with a safety mechanism on the nozzle. The design team felt that understanding use, misuse, and storage, product, and user interactions was a crucial factor in the success of the project. A need existed to expand the framing of the problem from a narrow focus on the trigger mechanism to the larger context of use if the ultimate goal was to reduce injury from chemical exposure due to use of spray bottles in children five and under.

2.1 Research

The design team's initial task was to persuade the hospital team to further explore the problem space. This is often a challenge when working with scientists whose research focus often lies in exploring solutions to relatively well–defined and understood problems. In contrast to science, design treats both the problem *and* the solution as something to be explored [4]. To address the need to explore the problem space, the design team requested additional research and developed two protocols for in-home observation and parent-child focus group/interview sessions at the hospital's research lab. The hospital team followed the protocol and conducted home observations with twenty-five families of young children, and conducted interview sessions with nine randomly selected families. In the home observations a total of 36 percent of all cleaning product containers were identified as spray-bottles (n=238 spray-bottles in twenty–five homes). Of those spray-bottles, a total of 75 percent had nozzles that were not in the closed or off position. The storage areas were cabinets in kitchens and bathrooms, closets, pantries and laundry rooms. Cleaning products were found alongside sport drinks, foods, soaps and beauty products and the locking systems were mostly disengaged. Parents were asked to clean a surface while the process was videotaped and later analyzed by the design team. During the lab observations, children ages four to five were asked to clean a table and were given five different types of spray bottles filled with water in the "on" and "off" position.

Figure 1. Lab Observations

Most of the children were able to turn the locking nozzle from the "off" position to the "on" position, but had difficulty actuating the trigger due to a lack of strength, reach, and dexterity due to their small hand size. Most of the children were quite inventive, and developed strategies to overcome their inability to trigger the mechanism by engaging their body in the effort, turning the bottle and facing the nozzle in order to engage the trigger with both thumbs, as shown in Figure 1.

From these research activities, the design team identified a range of design opportunities beyond the trigger. Limiting access to chemicals by children can be achieved through a number of different strategies, including a safer package, a different dispensing system, a different set of cabinet locks, a different colour chemical (that clearly differs from sport drinks) or a combination of those. We summarized our findings through the use of visual diagrams and mindmaps (Figure 2).

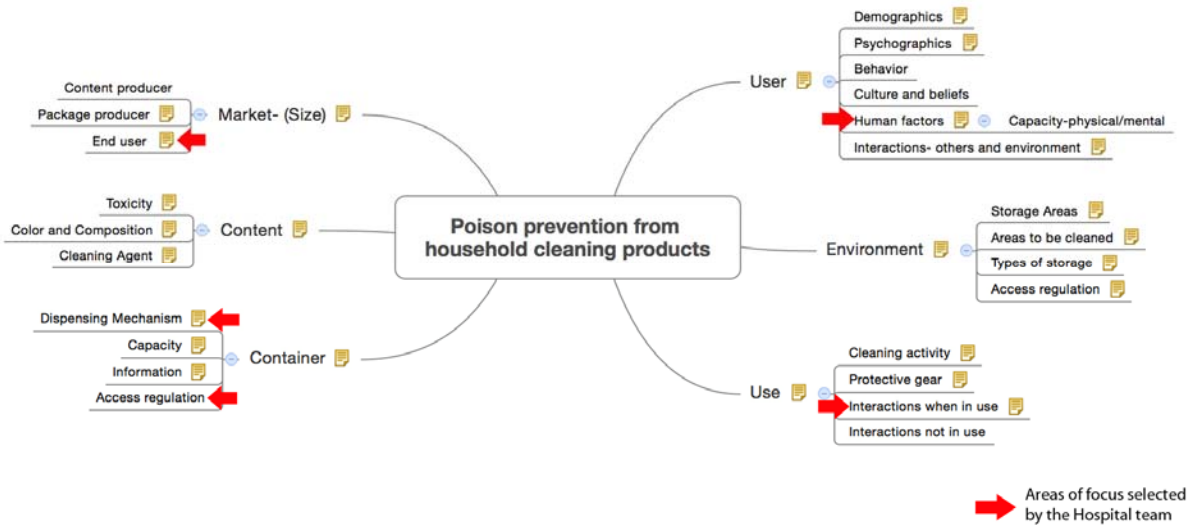

Figure 2. Problem Opportunities Mindmap

These ideas were presented to the hospital team as complimentary to the trigger direction but the hospital team further constrained the problem definition by insisting that the design: i) must meet the US Consumer Product Safety Commission (CPSC) standards for child-resistance (non of the existing dispensers and spray bottles meet this standard), ii) must use a safety mechanism similar to the cigarette lighter's, and iii) must also require minimal expenditure on the part of any company that adopted the technology. The red arrows on Figure 2 highlight the areas of focus selected by the hospital team.

2.2 Design and Development

The design team proceeded to develop a solution to the problem as further defined by the hospital team. The expertise of the hospital team is in the area of behavioural research. The goals for the Centre for Injury Research and Policy are to improve scientific understanding of the epidemiology, biomechanics, prevention, treatment and rehabilitation of injuries [5]. Areas of focus include home safety and poison prevention. The Hospital team is dedicated to reducing injury-related paediatric death and disability worldwide. After identifying compelling numbers of injuries through the initial research effort, the spray bottle was identified as the most obvious and effective way to addressing the problem. However, there is a gap between identifying a compelling need and defining an effective product development brief. One of the challenges of our collaboration was to educate the hospital team on the design and development process but more importantly, to educate them on the constraints that the problem as defined presented. In an earlier paper [6], we outlined a system for organizing design constraints that we have successfully taught for many years at our University. This system places all constraints into one of five distinct categories: market, physical, technological, cultural, and usage. In developing our concepts for the new spray mechanism, our research led us to concentrate primarily on physical, technical and usage constraints. Several constraints of *use* came into focus when the design team observed parents of toddlers using spray bottles in the home, some of which had been overlooked by the hospital team. First, parents with small children often were forced to deal with more than one child at a time: the persona/scenario we developed involved a young mother holding an infant while working in the kitchen in the presence of a very observant toddler. This led us to conclude that one–handed operation of a device that would automatically lock upon being replaced on the kitchen counter was essential.

Further, we realized that strict *physical* constraints existed that we could not ignore. The redesigned spray mechanism clearly needed to be compatible with existing bottle dimensions, would almost certainly be injection molded from polystyrene or a similar thermoplastic, and ideally would require as little re–engineering of the spray mechanism as possible. In the United States alone, over two billion spray bottles are sold every year; a new design that required a major redesign of the basic pumping mechanism thus had little chance of success. This basic design, which has been in use for several decades, employs a simple spring–loaded piston/cylinder arrangement with two one–way valves to

force liquid from the reservoir through the nozzle. With this in mind, we constrained our design concepts to those that could be readily integrated into this market–dominant design.
One major hurdle we had to overcome was the hospital team's fixation with the cigarette lighter locking mechanism. The design team understood that cigarette lighter lock was a two-step locking system that couldn't be directly implemented on the spray bottle in its initial form. On the cigarette lighter, in order to actuate the igniter, the locking mechanism has to be disabled. This is a difficult task but it is appropriate for the cigarette lighter because its use is only for the instance in which the lighter "lights" something. With the spray bottle, the context of use was very different. The spray needs to be activated multiple times while holding a bottle full of liquid with one hand.

Figure 3. Prototypes

We developed multiple concept sketches for a self–locking device that could be easily activated with one hand and that didn't require much strength to activate. An additional objective was to be inclusive of aging adults. We presented the sketches to the hospital team but we couldn't move them past the cigarette lighter design. We then proceeded to demonstrate the problem with quick prototypes that depicted the physical constraints on the hand and use of the cigarette lighter (Figure 3).
Only after experiencing the physical difficulty of holding the bottle and activating the trigger, were we able to convince the hospital team that the analogy to the cigarette lighter was valuable in its function but not its form. After building different prototypes and quickly testing them with a five year old boy, we settled on the design shown in Figure 4, in which the user unlocks the trigger by depressing a lever at the rear of the spray head, thereby forcing the 'shroud' to retract laterally, thus releasing the trigger and permitting use. The shroud is spring loaded, returning to its original position and locking the trigger upon release. The rear lever is intended to blend into the shroud as much as possible, thus concealing its function from alert four–year–olds.

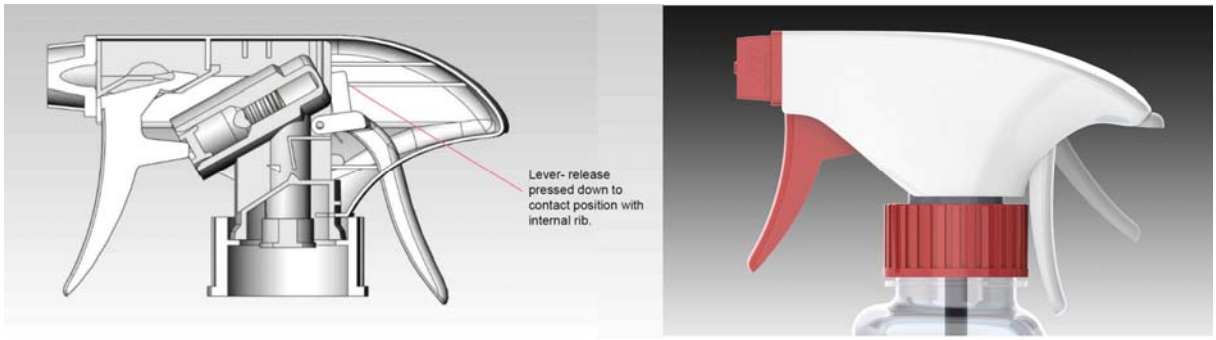

Figure 4. Final Design

3 THE COMMERCIALIZATION PROCESS

Once the final design was approved and the patent process begun, the question of commercializing the invention immediately arose. After negotiation, Ohio State University agreed, and the commercialization staff at the Hospital began the search for interested customers. This process began with very high hopes, because both the Hospital and University teams felt that we had confronted a compelling problem and solved it efficiently. The legal team further assured us that there did not seem to be any prior patents that would stand in the way. Our design appeared to be destined for success when considering the very large market of spray bottles.

The commercialization team began immediately to market the design to major manufacturers of common household products in North America, specifically targeting the very largest manufacturers or brands. After an initial flurry of interest (which included quite a few mentions on the Internet, CNN, and national and local newscasts), these firms backed away from the concept. The commercialization team then approached the small number of firms who manufacture the actual spray mechanisms, and met a similar response. The initial utility patent was issued in November 2011, but interest in the device from industry was minimal at the time.

4 THE FRAMING OF THE PROBLEM

With the benefit of hindsight, how could we have solved this problem in a manner that resulted in an immediate response from industry Thinking strictly in terms of a *solution to the problem as we understood it*, it is clear that we were successful: our design prevented young children from injuring themselves, while still allowing a young mother to use the bottle with one hand, while being assured that the trigger would re–lock the instant she put the bottle down. The problem actually is not with the design, but rather with how the original problem was framed. Rather than ask how to prevent young children from poisoning themselves, the hospital team immediately (and understandably) focused instead on the device that the child was holding when they were injured. Rather than ask, "How do we avoid this situation?" they asked, "How do we make this device safer for small children?" Initially, the design team attempted to widen the frame of the problem in order to explore alternative areas of focus but the hospital team was convinced that the scope they identified was the appropriate problem to solve.

In effect, at the inception of the process, Nationwide Children's Hospital looked at one of the indicators of the problem before writing the design brief. They reported high numbers of patients presenting injuries sustained from spraying themselves in the eyes. The research data was collected from emergency room reports but there was no data available from parents to find out if the access to the spray bottle in the home was rectified. Also, there was no record of any of the patients being re-admitted with the same issue a second time. This check would have indicated if the parent took responsibility for the accident and modified the home environment. The assumption was made that by changing the spray bottle without considering the perception of the problem and the complexity of the market, the situation could be corrected in the same way it was with the implementation of the lock on the cigarette lighter. The primary difference is that with the cigarette lighter, the effects of misuse are significantly worse and parent's acknowledged the deadly consequences. The perception of danger from spray bottles is low and thus there is less sense of urgency from parents.

In terms of the market, the constraints were not as clear for either team. The primary consideration given was the number of spray bottles currently sold worldwide but the business model that supports the packaging industry works differently from that of a standard product. Both teams overlooked the fact that the bottle manufacturer is an intermediary. The consumer goods company that manufactures the chemical formulation purchases a spray bottle from a supplier of bottles. The spray bottle supplier is only beholden to their customer: the consumer goods firm. This firm believes (along with their attorneys) that the warnings on the label indemnify them from liability if the end user puts the bottle within reach of a child. Additionally, they claim the twist lock is an *anti-leak feature* that was *never intended as a childproof system.* When there is a claim, there is a higher risk for liability. The bottle/sprayer supplier does not carry any liability because they are a sub-contractor and only react to their customer, not the end user. They are also not responsible for what is placed in the bottle. If either company offers a child-resistant product they immediately assume liability, so rather than offering a feature to improve the life of their customers, by adopting our improved design they would also be acknowledging responsibility for its use. The current system is better for both companies because the responsibility of keeping the chemical away from children is placed on the parent.

To the best of our knowledge, consumer product companies have not been sued, thus there is little or no motivation to pursue a mechanical solution, nor even acknowledge that there is a potential problem with the existing bottle by entertaining the notion of changing the design and thereby opening a new area of risk exposure. Further, the bottle suppliers are also not motivated to re-tool a new bottle when their customers will not purchase it and do not demand it.

We believe our design is effective in keeping children safer and does not represent a major investment for any consumer product company. We also believe that companies shouldn't offer toxic products in packages that can be accessed by kids. However, the fact that no lawsuits have been filed against

companies does tell us that the perception of the problem by parents is a major hurdle in addressing it. Understanding perceptions and the parents' sense of accountability should have been at the center of our inquiry. This information would have allowed the design team to shift the focus from the bottle to the environment. If the problem had been framed as finding a solution that can limit access to chemicals by children under 5 years old, there is a good chance we would have considered alternative solutions for storage, safety mechanisms and locks in the home environment.

Even though the prospect of manufacturing our safer spray bottle has not been completely ruled out at this time, we believe that the case study shows an excellent design that faces additional hurdles in the commercialization process due to the lack of understanding of the market, the business model and the perceptions of the problem by the end users. This case study serves as a good example of how framing a problem by expressing product requirements in terms of mechanical functions rather than in contextual terms can limit product viability.

We have used this case study in our design and engineering classes for the past two years, and find that the students relate to it well, since the common spray bottle is an artefact that almost everyone has used at some point. This case fits very naturally into a discussion of constraints and problem framing, and allows us to explore options that could have resulted on either an alternative solution to the wider problem or a more effective commercialization process for our design.

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