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Perception and Imagination in Engineering Ethics*

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Engineers are counted on to employ their expertise in exercising responsible judgement. Ethical rules and principles have an important role to play in this. However, so do perception and imagination. How engineers come to perceive engineering problems and their possible solutions in the ways they do is a function of their expertise, experience and the dispositions they bring to bear on their work. This paper discusses relationships between ethical commitment and expertise. It argues that what is required is the integration of ethical commitment and engineering expertise, such that, in the midst of engineering practice, perception and imagination contribute to responsible engineering judgement.

INTRODUCTION

ENGINEERING ETHICS literature quite appropriately emphasizes the importance of ethical principles, rules of action, justification, and decision-making in particular circumstances that call for good judgment. Should a vendor's offer of a free round of golf at an exclusive country club be accepted? Should short cuts be taken in order to meet deadlines? Given expected low temperatures and evidence of O-ring erosion in cold temperatures, should a delay in launching the Challenger space-shuttle be recommended? Engineers are counted on to employ their professionalism and expertise in exercising responsible judgment in such circumstances. However, typically overlooked is the role of perception and imagination in positioning engineers to make these judgments. This paper is an exploration of that role.

Several years ago, philosopher Lawrence Blum took moral philosophy to task for focusing its attention on moral principles, justification, and decision-making to the exclusion of what he calls *moral perception* [1] His view is that, although perception plays an essential role in decision-making, it also plays an important role prior to our making judgments about what we should do; in brief, it contributes to our understanding of the circumstances in which these judgments are made, as well as to our ability to imagine different possible courses of action [1, p. 30]. Blum asks: 'How do agents come to perceive situations in the way that they do? How does a situation come to have a particular character *for* a particular moral agent?' To explain what he has in mind, it will be helpful first to look at a fictional everyday example he provides. Then examples from engineering will be considered.

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EVERYDAY PERCEPTIONS

John and Joan are seated on a crowded commuter train. There are no vacant seats and some people are standing, including a woman who is holding two relatively full shopping bags. Blum comments on John and Joan's perspectives: 'John is not particularly paying attention to the woman, but he is cognizant of her. Joan, by contrast, is distinctly aware that the woman is uncomfortable' [1, p. 32] The main contrast, Blum goes on to say, is what is *salient* for John and Joan in this situation. What is salient for Joan is the woman's discomfort. Even if John is vaguely aware of her discomfort, this is not salient for him.

There are many possible explanations of the perceptual differences between John and Joan in this particular case. John may be preoccupied with worries about the workday ahead of him, the illness of his daughter, and so on. Joan may have noticed the woman struggling with the packages as she boarded the subway, whereas John noticed her only after she settled into her current position. However, Blum continues, if this is how he typically perceives others in such situations, this suggests that he often fails to see vital aspects of the moral world in which he resides. This does not necessarily mean that John is callous or uncaring. When someone's discomfort is brought to his attention, he may respond as sympathetically as we might imagine Joan does. The connection between perception and decision-making here is this. For Joan, and perhaps for John if the woman's discomfort is brought to his attention, the perception of the woman's circumstance provides a reason for action, a reason that is grounded in the perception of her discomfort. Joan may be more readily disposed than John to fully notice and respond sympathetically to the visible discomfort of others.

Blum contrasts Ted with both Joan and John. Ted may be fully aware of the woman's discomfort but remain indifferent to her circumstance. If this is characteristic of Ted, his shortcoming is that he does not *care* enough about others to act in their behalf even when their discomfort is quite transparent to him. John's shortcoming is that he does not *see* with sufficient salience the discomfort of others; and it is this that accounts for his inaction.

Sometimes our failure to take much note of the circumstances of others is because, bearing no special responsibility for creating or controlling those circumstances, we may be preoccupied with other matters. Perhaps the woman's discomfort was not salient for John because it was not of his making, even though he was in a position to offer some relief. However, it is clear that we often are responsible for putting others at risk of discomfort, or even harm. Recently, for example, we were visited by an elderly friend. When she arrived, I stepped out the front door to greet her, only to see her struggling to get past the tangled garden hose draped across our narrow walkway. Prior to her arrival, had I simply asked myself whether our walkway was clear, I would have known the hose was there even without looking. So, in one sense, I knew everything I needed to know in order to prevent a possible accident. Nevertheless, I failed to prepare properly for her arrival. Fortunately, no accident occurred. (I can only hope that this illustrates an occasional lapse rather than a character trait!)

At least with occasional prodding, it is relatively easy to avoid putting others at such risk in the first place. Better yet is developing habits that minimize risk and inconvenience to others. Putting tools, garden hoses, and the like out of harm's way rather than letting them lie about when not in use is one example. Slowing down in play areas for children and stopping at stop signs even when it looks like no one is around is another.

However, even good character and good habits cannot guarantee good consequences. Normally sensitive and compassionate, Joan's frustration at being late for work might interfere with fully appreciating the discomfort of fellow passengers. Preoccupied with finishing an exciting novel, I might neglect to clear the sidewalk for a visitor. Aside from occasional lapses, sometimes there are problems that could not reasonably have been anticipated. Driving down a two lane road after dark, your headlights suddenly reveal a young skateboarder moving in the opposite direction; she is swerving back and forth, coming dangerously close to crossing the center line. Whether we become aware of such problems in time to handle them well may be, to some extent, a matter of luck. Nevertheless, given all the ways in which things can go badly, it is desirable that we prepare ourselves to notice and respond appropriately both to the expected and unexpected.

PERCEPTION AND IMAGINATION IN ENGINEERING

Keeping one's sidewalk clear and maintaining good driving habits are ways of caring about others even when they are not in view—something engineers need to bear in mind, for they typically do not directly encounter those most affected by the bridges, elevators and microwaves they design, build, and maintain. Furthermore, engineers are employed in specialized work that creates risks that only they may be in a good position to perceive in advance—and only if they are adequately prepared and properly disposed to do so. Thus, what is salient in the perceptions of engineers is crucial for what they are likely to imagine as possibilities; and what turns out to be salient is, in large part, a function of the basic dispositions and skills engineers bring to their work. But the perceptual dynamics for engineers are likely to be quite different than in the examples discussed so far. In Blum's example, the woman is in the presence of John, Joan, and Ted—quite literally, 'before their eyes'. No special expertise is required in order to respond sympathetically to her discomfort. In engineering, expertise plays a special role both in detecting and resolving the problems at hand.

Blum's questions about agents in general could be reformulated for engineers:

- How do engineers come to perceive situations in the way that they do?
- How does a situation come to have a particular character for a particular engineer?

The answer to both questions is the same. How engineers come to perceive situations in the way that they do and how those situations come to have the particular character for them that they do is a function of their engineering experience and the dispositions they bring with them into those situations. William May notes that character and virtue are especially important in professional life, since they shape how professionals approach their work [2]. This certainly applies to engineers. Like most professionals, engineers typically work in complex institutional settings, sometimes making it difficult to assess individual responsibility. Also, professional expertise, particularly in large organizations, is not widely shared, even by professionals in the same general areas (e.g., electrical engineering). Here *trust* in professionals is essential, says May: 'Few may be in a position to discredit [them]. The knowledge explosion is also an ignorance explosion; if knowledge is power, then ignorance is powerlessness.' He adds, 'One test of character and virtue is what a person does when no one else is watching. A society that rests on expertise needs more people who can pass that test' [2].

May's way of putting this might conjure up fears of professionals taking advantage of the trust we must place in them. Of course, those who get caught are the ones we hear about, while we worry about the possibility that there are many others who go unseen and are never caught. However, equally unseen, and uncelebrated, are professionals who quietly live up to the trust we invest in them. *How* these professionals pass May's test receives surprising little attention. Instead, we simply take for granted the responsible, sometimes exemplary, work that they do. So, in the case of engineers, largely we assume their work is reliable, even though we have little understanding of what routinely goes into it—let alone the special efforts that may have prevented failures or improved reliability.

However, in engineering, as in everything else, even the most well-intentioned plans can go awry. For a time, shoulder and lap safety belts in automobiles operated independently of each other. Lap belts had to be manually engaged, whereas shoulder belts were automatically engaged by shutting the car door. Most consumers were unaware that failure to engage their lap belts placed them at higher risk of serious injury or death than having no seat belt at all. Feeling the shoulder belt across their bodies frequently lulled drivers into thinking they had also engaged their lap belts. In fact, I frequently found this happening to me; and I was among those unaware of the increased risk. When I learned about the higher risk from an engineer, I asked how consumers normally were informed about it. I was told that warnings are supposed to be placed on visors on the driver's side. Never having noticed this warning in the several years I had driven my car, I was surprised to find it on the backside of my seldom used visor! No doubt, on those few occasions that I might have previously moved the visor, I was concentrating more on the glaring sun and the road in front of me than the warning patch on the back of my visor. Of course, it could be argued that I bore responsibility for my own ignorance, as the warning was there; and it is likely that there was also a similar warning somewhere in my owner's manual. However, even had I known about the higher risk, I might still occasionally have been lulled into thinking my lap belt was engaged. The rather simple engineering solution was to attach the shoulder and lap belts in such a way that they engage *together*, manually. Sacrificing the automatic feature of the shoulder belt was rather insignificant compared to the resulting benefit.

The introduction of a separate shoulder belt was a safety innovation that, contrary to expectations, actually had the opposite effect for many. Here is another —a current traffic light problem in the United States. Instead of having the light turn green as soon as the crossing light is red, traffic lights at many intersections now delay the onset of the green light until the crossing traffic has had a red light for a few moments. Some drivers have adjusted in the following way. When approaching an intersection, they estimate that they will still be able to pass through it even if the yellow light has been on for some time—or even a few moments after their light has turned red. This means that crossing traffic cannot be confident that it is safe to proceed when their light turns green. In fact, now it is much more likely that cars will go through red lights. (I've counted clusters of as many as six cars passing through a red light at an intersection I travel through each day.) This also causes problems for those waiting to turn left once the oncoming traffic has stopped. One needs to proceed cautiously even if there is a green left turn arrow. It is even worse at intersections that do not have left turn arrows. Typically the first car in line edges up so that at least it will be able to complete a left turn before crossing traffic can proceed. Uncertainty about whether oncoming traffic will stop when their light turns yellow, or at least once it is red, makes this a hazardous practice. Furthermore, if the car turning left has moved far enough into the turning area so that it must complete the turn, crossing traffic may have to delay their start even longer.

Had traffic light programmers anticipated how drivers would respond to the changes, perhaps they would have left things as they were until other alternatives occurred to them. Unfortunately, better alternatives often come to mind only after one sees the shortcomings of decisions already made. However, examples like this are a reminder that engineers need to prepare themselves for unexpected and unfortunate consequences by readying themselves to make needed adjustments when necessary. A highly publicized instance is the response of Johnson & Johnson in 1982, when three people died from cyanide planted in their Extra-Strength Tylenol capsules [3]. Not only did Johnson & Johnson immediately recall its product, it promptly repackaged it in tamper-proof containers; in short, its packaging experts were well prepared to respond to the crisis quickly in a way that restored consumer confidence and enabled Johnson & Johnson to regain its standing in a highly competitive market.

Recently, cell phones have come under unexpected criticism. As their popularity has increased, so have safety concerns. Ironically, one of the many advantages promised by the wide scale introduction of cell phones is increased safety and assistance for travelers, who can use them to make for emergency calls when they encounter problems. However, cell phones are also a convenience and form of entertainment when traveling. In the face of evidence that the hand-held use of cell phones poses serious driving risks, local ordinances prohibiting their use while driving are on the rise. At the same time, technical solutions have quickly become available that make it possible to use cell phones in automobiles without holding them in one's hand.

Although some engineering problems can be solved quickly and inexpensively, many call for more expensive, longer term solutions. Engineers familiar with the widespread use of roundabouts in Europe might suggest this as a long term solution to the traffic light problems like the one discussed above [4, 5]. Well designed roundabouts move traffic along more efficiently and more safely. In the long run, they are also more cost effective, as the installation and maintenance of elaborate traffic lights is no longer necessary. Of course, where pedestrians are involved, additional provisions are necessary. Crosswalks and pedestrian tunnels and bridges can be constructed, but only at considerable additional expense.

In response to the concern that US drivers are not accustomed to roundabouts and will find them both confusing and dangerous, it can be countered that the USA already has some roundabouts and, like European drivers, US drivers will, in time, successfully adapt. However, if a system of roundabouts is to work well, it is clear that engineering imagination is required. There are basic problems regarding the movement of motorized vehicles that need to be addressed. In addition, especially in residential areas, there are concerns about pedestrians and bicyclists. However, commonly overlooked, or at least under-appreciated, are problems experienced by blind and visually impaired pedestrians. Apparently there has been very little systematic study of special problems they might encounter in crossing streets at roundabouts where the traffic flow seldom requires cars to stop. Researchers at my university are currently undertaking a large scale study of problems that roundabouts may present to the blind and visually impaired, particularly those associated with relying on hearing to determine the presence of traffic.

What is involved in recognizing that special consideration needs to be given to the blind and visually impaired in addressing the roundabout question? First, one must imaginatively consider how the introduction of roundabouts might affect the navigational abilities and safety of *all* who have a stake in what is done, not simply motorists, bicyclists, and *most* pedestrians. There must be a realization that part of the population that will be affected consists of people who cannot rely on the visual cues that most can. Second, it must be acknowledged that this population, too, is entitled to reasonably safe and efficient ways of navigating on foot. Of course, the blind and visually impaired do not exhaust the special populations that need to be considered. The deaf and hearing impaired, those with impaired mobility, and young children may also need special consideration.

That special legislation addressing problems of equal access (the Americans with Disabilities Act) was introduced as recently as 1990 suggests that neither of these points should be taken for granted. In fact, the expenses incurred in making older buildings accessible to all is further indication of a longstanding failure to take adequately into account the needs (and abilities) of the visually impaired, those whose ability to walk is impaired, and others with physical disabilities. As a case in point, the Graduate College at my university has recently established a writing center for graduate students. Directly across the street is an older building that has ample space for such a center on its second floor. Unfortunately, the building has no elevators!

BEING PREPARED

Although the importance of combining the ethical principles and guidelines with engineering expertise is implicit in engineering codes of ethics, little attention is given to details. Instead, the fundamental principles and rules of practice consist largely of lists of do not's (e.g., not divulging confidential information, not allowing one's judgment to be affected by conflicts of interest, not misrepresenting findings, and so on). However, in a more positive vein, it should be noted that, guided by ethical principles, the exercise of technical expertise is not simply technical; it is infused with positive values in ways that can significantly affect what is noticed (or perceived), how what is noticed is taken into account, and what alternatives are given serious consideration. At the same time, developing and maintaining expertise is essential for fulfilling responsibilities to one's employer, as well as to the public.

To illustrate this last point, consider a case study developed by Cutler,.which recounts the failed effort of two young engineers to develop a more efficient heat transfer surface [6]. (This case is one of a set of fictional cases intended to reflect real world problems in engineering ethics that Cutler has contributed.) Their manager is angered at learning that neither engineer had consulted the company's filed report of a nearly identical failed effort by another team just five years earlier. In fact, neither had consulted any current technical literature for related publications. This seems to the manager to fall well below an acceptable threshold for responsible engineering research. Apparently the manager holds the view that engineers have a responsibility to try avoid repeating mistakes, particularly when contraindications are so readily available.

Did the two engineers fail to meet their responsibilities as professionals and employees? This question addresses issues of competence and professional development. The Institute for Electrical and Electronics Engineers (IEEE) code of ethics addresses these concerns more explicitly than most engineering society codes. Two provisions are particularly relevant here. Committing themselves to 'the highest ethical and professional conduct', IEEE members also agree [7]:

- to improve the understanding of technology, its appropriate application, and potential consequences;
- to maintain and improve our technical competence and to undertake technological tasks for

others only if qualified by training or experience, or after full disclosure of pertinent limitations.

Arguably, failing to consult current technical literature, or even the company's recent history in this area, falls below an acceptable threshold of responsibility. This could be regarded as a failure of professional duty, or obligation.

However, in many cases it is not so clear whether one is simply fulfilling a *duty* in acquiring information that will prevent bad things from happening. Responsible practice can be exemplary ('above and beyond the call of duty') as well. I explore the idea of *exemplary* engineering practice in [8] which was supported by National Science Foundation Grant #SBR-930257. Although not an example from engineering, the Fran Kelsey example is also discussed in this article. In the early 1960s, despite being subjected to considerable external pressure to change her mind, FDA official Dr. Kelsey refused to approve the marketing of Thalidomide as a sleeping pill in the United States [9]. In 1962 it was discovered that Thalidomide was responsible for thousands of physically deformed children in Europe. She read an article indicating that the pill failed to put many of the test animals to sleep, and she had read a letter in a British medical journal that reported patients taking Thalidomide for a long time experienced tingling nerve inflammation in the fingers.

Unlike the two engineers in Cutler's fictional example, Fran Kelsey did consult literature relevant to the area of research under her purview. Should she have been faulted if she not noticed the article about test animals not falling asleep or the letter in the British journal about tingling inflammation in the fingers? Or, if reading the article and letter had not raised her concerns, should she have been faulted? Given the extreme pressure she was under to approve the drug, this is unlikely. Nevertheless, her active search for reports on the drug's performance, even in other countries, and the salience of certain things she read resulted in preventing a major tragedy in the United States.

The importance of noticing and following up on cues is equally evident in engineering. The 1978 collapse of the Hartford Civic Center roof is the story of a costly engineering disaster that, fortunately, did not result in injury or loss of life. Eugene Ferguson explains what happened, and what might have prevented the collapse [10]. 'The roof failed under a moderate snow load because some of the long compression members buckled and brought the rest of the truss down in domino fashion. The programmer apparently had not expected those long members to be subjected to anything but pure compression. The possibility that a partial roof collapse might cause one or more members to buckle and thus nullify most of the assumptions made by the programmer either was not considered or was judged to be too remote to warrant inserting the several hundred stiffening braces necessary to arrest the domino action of an unbraced truss. Now this is a small decision in the scheme of things, although it will no doubt be a big consideration in the design of future space trusses. If somebody involved in the Hartford design had seen or had been able to visualize some of the buckling accidents that have occurred since the 1907 collapse of a railroad bridge under construction at Quebec City, stiffening stays or braces might have been added. In any case, assumptions and matters of judgment will always be present in engineering design, whatever the format of the design'.

It is noteworthy that Ferguson avoids the language of blame in this account. His fundamental point is that it is crucial for engineers to be prepared to examine assumptions, look for trouble, imagine alternatives, and to exercise good judgment—all the while realizing that crucial items may go unnoticed or under-appreciated.

The Hartford design problem was not unique. In fact, in principle, a 70-year history could have been written. Access to only a small part of that history might have been sufficient. However, it may not have been as readily available as the company's history of failure in Cutler's fictional example. So, a much more interesting story of how someone involved in the Hartford design might have come to see the problem would have to be told.

Such a story might well have involved an engineer, or group of engineers, with professional qualities as commendable as Fran Kelsey's. However, it is unlikely that this story would have been widely circulated, for it would lack the drama of the Thalidomide story. In the case of Thalidomide, disaster was prevented in the United States, but not in Europe; and the disaster in Europe is what initially attracted the media's attention.

We have little idea of the number of accidents that have not occurred because of the timely dedication, perception, and imagination of engineers. Stories of accidents that never happen because of the efforts of engineers are seldom told. However, there is one that has been told—but only recently, despite the fact that the key events were contemporaneous with the Hartford Civic Center story. Through a series of unexpected events, chief structural design engineer William LeMessurier discovered a problem that, because of the Citicorp building's unusual features, rendered the 59-story building vulnerable to 16-year rather than 100-year storms [11]. Unfortunately, this occurred after the building was completed and fully occupied. LeMessurier figured out how to correct the problem, but only at the cost of millions of dollars. Revealing the problem to others, he feared, would also put his reputation and career at risk. Nevertheless, he did not hesitate in notifying Citicorp executives, the chief architect of the building, lawyers, and insurers. Unlike the more typical newsworthy engineering ethics stories, this one has a happy ending. Corrections were made, all parties were cooperative, and

LeMessurier's reputation and career were, if anything, enhanced rather than damaged.

One might ask to what extent LeMessurier's discovery of Citicorp's structural problems was a matter of luck. (I first explored the question of the role of luck in the LeMessurier story in [12] and here extend that analysis.) After all, the discovery was triggered by two fortuitous events: a phone call from a student who, at his professor's prodding, questioned the structural integrity of the building; and LeMessurier's discovery that, contrary to his specifications, Citicorp's structural joints were bolted together rather than welded. Can *luck* have a significant role to play in engineering ethics? One might think not. Ethics has to do with right and wrong, good and evil, praise and blame, virtues and vices, and the like. Certainly these notions have a place in engineering ethics. Luck, however, seems to be more a matter of chance than anything for which one can appropriately be credited or praised, discredited or blamed; it is, we might say, matter of good or bad fortune. Nevertheless, it is important to explore ways in which luck can be intimately related to character and imagination, both of which are fundamental in ethics. In short, being lucky in engineering practice in the way LeMessurier was seems to depend on his being *prepared to be lucky*. In such cases, unlike winning a lottery, luck can be understood only against the background of the settled dispositions and imagination of engineers.

Many, perhaps most, other engineers would not have capitalized on the two fortuitous events in the way LeMessurier did; and it is not clear that they could fairly be faulted for this. LeMessurier could have politely dismissed the student's query, perhaps commenting that, unusual looking as the structure is, it more than amply satisfied all safety standards and regulations. This would not be unexpected from a highly successful engineer who is busy with many new projects. Instead, LeMessurier explained to him that his design could handle quartering winds more effectively than more standard structures, and he referred him to a technical article on the matter written by one of his engineering partners. In fact, although New York City regulations only required wind resistance testing at 90° angles, LeMessurier had made calculations at 45° as well. Next he shared technical aspects of his design with students in one of his own classes, explaining to them that the building would be vulnerable only to 100-year storms, well beyond the minimally acceptable requirements.

Even after learning that the joints were bolted rather than welded, apparently LeMessurier remained confident that the building would still more than satisfy the New York building code, which required wind resistance tests only at a 90° angle. However, his curiosity not satisfied, he decided to find out how the joints would handle winds at 45°. To his dismay, his calculations led him to the conclusion that his building was much less safe than his original calculations indicated.

The particular twists and turns of LeMessurier's investigations indicate that his engineering imagination, or as he puts it, his 'intellectual play', has special connections with his sense of professional responsibility. They reveal his abiding concern for public safety, his curiosity, his persistence, and his willingness to take the chance of discovering that his work was flawed. Had the student's call not prompted him to re-examine his structural design, perhaps LeMessurier would not have engaged in this 'intellectual play'. If so, then, indeed, the student's call was a piece of luck. And, had the question of the cost of welds not come up in Pittsburgh, there would not have been an occasion for re-calculating. This, too, was a piece of luck. But had LeMessurier not responded in the ways he did, neither the phone call nor the question would have been matters of *luck*; they would simply have been unremarkable, and ignored, events.

So, the key point seems to be this: In order for such events to have counted as *lucky*, as distinct from simply uneventful, something had to be made of them. But this, it seems, was very much a function of special qualities of character and imagination possessed by William LeMessurier. As a result, he *sees* things differently than most engineers. Like scientist Fran Kelsey, engineers like LeMessurier seem to be somehow prepared to be lucky. That is, because of their special competence and commitment, they are prepared to notice what others fail to notice, and to respond imaginatively and responsibly. So, from the public's standpoint, it was a matter of good fortune, or luck, that someone like LeMessurier was involved, rather than any number of other quite capable structural engineers who do good work, but who may be less likely to notice and take advantage of the sorts of things he does.

Engineers like William LeMessurier occupy the high end of responsible practice. They are exemplars for others, and it is important that their stories be told and understood. Of course, insofar as these are stories of bad things that did not happen, there may be some difficulty in gaining access to them. LeMessurier's story itself could easily have gone untold. In fact, it was told only after 17 years had passed since the drama was played out.

Even less likely to be told are stories of preventive actions taken by conscientious and imaginative engineers *before* a problem developed. LeMessurier discovered a problem after the structure was completed, and he faced a series of dramatic challenges. Had he been fortunate enough to learn during the construction phase that switching from welds to bolts was under consideration, he might have made his calculations earlier and spared everyone the excitement and expense that eventuated. But this story would not have attracted writer Joe Morgenstern's attention. In fact, it might have seemed rather routine for

LeMessurier himself. 'Luckily,' he might have thought, 'I found out about this before it was too late.'

WORKING WITH OTHERS

The preceding examples may be misleading, as they emphasize the role of individuals as individuals. William LeMessurier, for example, is treated as an exceptional individual, which no doubt he is. However, he did not work alone in wrestling with the Citicorp problem—either in the diagnosis of the problem or its solution. Like most professionals, engineers work and consult with others; and they have available to them a vast array of technical literature prepared by others to assist them. Thinking that one should operate alone in addressing engineering problems with ethical dimensions is unrealistic. Aside from needing the support of others to be effective in making changes or altering courses of action, we often need the assistance of others in *seeing* what the problems are and what constructive alternatives might be available.

A striking example of the importance of group approaches to ethical problems is that of human subject institutional review boards (HSIRBs) at medical and university research centers. Particularly in the arena of medical research, for example, there are complicated problems in determining risks and benefits of the proposed research, in determining how best to seek the informed consent of participants, and in ensuring that there are no serious conflicts of interest. It is not unusual for an HSIRB to discover complications unnoticed by even the most well intentioned researchers.

Because HSIRBs are designed to represent many diverse perspectives, the dynamic of group interaction often results in perceptions that individual members do not bring with them into board meetings. By complementing one another, members are able collectively to come up with important considerations that it is unlikely that any one or two individuals would. But even conscientious HSIRBs can miss important ethical dimensions of a research project. A good illustration is the recent, highly publicized case of the first patient to receive the AbioCor artificial heart [13]. Although the informed consent statement lists a variety of risks posed by this remarkable product of bioengineering, Boston University medical ethicist George Annas objects that it contains no discussion of the most likely causes of death (failure of organs other than the heart), and there are no provisions regarding decisions to be made should the patient suffer a stroke. Finally, Annas comments that one of the physicians may have seriously misled the patient by promising to go bass fishing with him someday, a most unlikely prospect given Abiomed's own projection that it will regard the experiment a success if the patient lives as long as 60 days.

Need for the advice of others is as evident in engineering as in the medical world. General Motors recently came up with a good solution to the vexing problem of young children locking themselves inside car trunks [14]. Of course, it could be argued that adults have the responsibility to keep their children from climbing into trunks. This is true. But this does not mean that automobile companies have no responsibility to design trunks in ways that minimize risks. How did GM approach the problem? Engineers worked with child psychologists and, eventually, children themselves.

The ethical issues surrounding the problem tackled by GM are quite interesting. First, its search for ways to child-proof trunks was prompted by public concern about several reported incidents in 1998 of children dying in locked trunks. Cynics might suggest that the real motivation was to avoid possible legal liability for contributing to the deaths of children, or at least a desire for good public relations resulting from an effective and affordable solution. However, it is at least plausible to suppose that a good part of the motivation was genuine concern for the wellbeing of children. In any case, whatever GM's motivation, there is little reason to suppose that engineers working on the project were not motivated, at least in part, by their dedication to public safety in general, and the safety of children in particular.

Second, beyond this general ethical concern to solve a safety problem, there was a need to employ technical expertise in imagining and testing out different possible ways of improving safety. However, this could be meaningfully done only insofar as the impact of possible technical changes on child behavior could be determined. As it turned out, the initial ideas of both engineers and psychologists vastly underestimated the difficulty of the problem. It was not until children themselves were asked to participate in situations simulating being trapped in a trunk that they were able to make significant headway. But this meant subjecting children to conditions that they might find very frightening. (In fact, if the conditions were not frightening at all, it is not clear to what extent the researchers could determine how children might respond when actually trapped.) In short, engineers were involved in an important research project involving the use of human participants. Had this study been, in part, sponsored by a university research institution, it would have required approval by its HSIRB. Working under the guidelines of its policy for protecting human subjects in research, an HSIRB is required to look very carefully at research involving children, as they are classified as a 'vulnerable population,' especially in regard to issues regarding informed consent.

Regardless of whether the GM study had to undergo any HSIRB review, the underlying ethical issues remain; and, to its credit, apparently GM exercised considerable care in making sure that the children would not be either panicked, on the one hand, or encouraged to think that climbing into car trunks is simply a fun activity. Engineers tested nine types of trunk releases. They installed cameras in the trunks so that the children's behavior could be observed, as well as microphones so that the children could talk with their parents and those who were monitoring the tests. Researchers were surprised to learn that some children:

- would not touch release cords and handles that glowed in the dark because they feared they were hot;.
- pulled at handles but gave up if the trunk did not open immediately;
- refused to flip the light switch unless told to, because they associated it with turning lights on and off rather than opening the trunk door;
- patted all the surfaces of the trunk in search of a trap door;
- rested passively in the trunk without trying to get out, even when encouraged by test monitors and parents to look for some escape.

Heather Paul, head of a federal panel on trunk entrapment, reviewed the GM tests and commented, 'Children's behavior is not predictable or intuitive.'

GM's final solution was to offer GM car owners an inexpensive, dealer installed child-resistant trunk kit for most of its 1990 and newer US-engineered family cars [15]. The kit has three main features:

a) a trap resistant latch that requires manual resetting (easy for adults but very difficult for young children) before the trunk lid will close;
b) a visible escape handle inside the trunk;
c) a strap to prevent children from entering the trunk through the back seat access.

Thus, a much more complicated solution was required than GM engineers anticipated. Is this solution adequate? It at least promises considerable improvement. However, it may be worth noting that, although access through the back seat is prevented, trunk release levers inside newer cars still make it possible for children to gain access to trunks without keys. Also, it seems possible that other kinds problems (e.g., trunk lids flying open while driving) may result from adults who forget to operate the manual lever in shutting the trunks. Whether or not these are serious problems, as in all areas of consumer safety, it is unlikely that current efforts for improvement will be the last efforts.

CONCLUSION

In the end, engineering ethics must address questions about ethical principles, rules of practice, justification, good judgment, and decision making. However, as this paper illustrates, it must also address questions about perception and imagination, including the underlying dispositions and skills of engineers. When it does, it becomes clear what is required is the *integration* of ethical values and engineering expertise, such that, in the midst of engineering practice, the perceptions, imaginings and, finally, judgments of engineers are blended into responsible engineering practice. There are times when it is important for engineers to pause and ask reflectively whether what they are contemplating doing is ethically justifiable; as a subject of study, engineering ethics needs to examine ways in which such questions might best be answered. However, equally important for engineering practice are the dispositions and values reflected in the very ways engineers come to perceive problems and possibilities in the first place. As this paper suggests, engineering ethics also needs to pose for engineers the questions Lawrence Blum poses for all us: 'How do agents come to perceive situations in the way that they do? How does a situation come to have a particular character *for* a particular moral agent?'

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