Ethical Imagination: Broadening Laboratory Deliberations

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Usually ethicists of technology pass judgment on a technology when it is already developed and ready to be put on the market. But at that point it is often too late to change anything about a technology. As Collingridge (1980) showed in his well-known analysis The social control of technology, many parties –such as (public) research funding institutions, researchers, designers and producers – have invested time, effort and money in the development of the technology and when it is ready, they have an interest to put it on the market. At that point it is difficult for ethicists to prevent this from happening.

Collingridge's claim that attempts to change or steer technology often come too late, has been influential: it has lead to the engagement of social scientists –and since recently also ethicists – in an earlier phase: that is, during research and development. This early involvement of social scientists or ethicists offers the opportunity not only to try to influence the decision whether or not to implement the technology, but also to co-shape the development of the new technique. However, it has also been noted that it is not realistic to expect that this will lead to *control* over technology. (Rip et al. 1995) The construction of a new technology, as well as the process in which it is brought on to the market, are subjected to the decisions of many people and institutions; such as scientists, research funding institutions, producers and designers.[1] So the social scientist or ethicist who is engaged in the R&D phase will be just one party among others which influences the final shape that the technology will acquire and whether and how it will be sold and used.[2]

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[1] For example, the decision of a commercial producer not to invest in the further development of, say, a preventive medical technology for reasons of economic risks, may motivate researchers to search for a public research funding institution, which strongly influences the aspects of the technology that will have the chance to be investigated. And accordingly, the resulting technology will be different.

[2] These sociological insights have also been relevant to some forms of ethics of technology, in which case-studies take the form of a story about an individual or organization which faces an

S. Roeser (ed.), *Emotions and Risky Technologies*, The International Library of Ethics, Law and Technology 5, DOI 10.1007/978-90-481-8647-1_9,

This differentiated view of power and decision-making that sociological studies of the R&D phase have produced, is instructive if we want to understand the role that social scientists or ethicists could adopt, who are embedded in the research and development phase. They usually do not seek to “control” one single decision – for what decision should that be? – but take a role in the negotiation that takes place between the parties who influence the shape that the technology will acquire and its implementation in society. They could for example (1) study decision-making processes in the laboratory and mirror them back to the researchers, and contribute in that way to self-awareness and self-reflexivity of the participants (Fisher 2007), (2) invite new parties at the negotiation-table during the research phase such as citizens or patients, and understand the conflicts between their interests to be the relevant ethical issues (Zwart et al. 2006), or they can (3) engage in an imaginative anticipation of the effects that the technology that results from the research will have on the quality of human (social) life, based on conversations about the quality of life with different stakeholders, and bring those views into the conversation with scientific engineers about the future scenarios of the technology their research contributes to. (van der Burg 2009).

This contribution will follow this last approach, which focuses on quality of life issues, and which I developed during my own work as an embedded ethicist. It will offer a case-study, which is based on my embedded ethical work in a scientific engineering context and focuses on research into a medical technology called an acousto-optic monitoring device, which is intended for the non-invasive monitoring of chemical substances in the blood, such as oxygen, glucose and cholesterol. This technology is currently (2009) being researched by a small research group consisting of three people: a PhD student, a technician and a professor. These researchers are part of the Biophysical Engineering Group at the University of Twente (the Netherlands). Research into this acousto-optic monitoring device is still in an early phase: during the past 3 years it took place in the controlled environment of the laboratory. The technology, however, is an original version of a broad family of technologies, which includes optical sensing techniques for oxygen and glucose (See for example: Aoyagi 2003; Sieg et al. 2005) and acousto-optic and photoacoustic techniques for the non-invasive imaging of bowels or tumours in the body (See: Manohar et al. 2007; Xu and Wang 2006; Selb et al. 2001). Some of these technologies are already being used, and some are still in the process of being researched at different locations in the world. Because these technologies are related, they likely have some similar features, and in so far as these features are problematic, the different technologies might share these problems. I want to focus here especially on problems that these technologies likely have when they are used on people with dark skin.

After a brief introduction into this technology and its history in part two, in part three possible future ways will be anticipated in which this technology could affect the quality of human life when it will be used. Here, special attention will be paid to

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either-or decision; such as, should this technology be put on the market or not? Or, should I prevent the challenger-launch or not? (Lynch and Kline 2000) the way in which this technology could affect the emotions of people. Before I start the case-study, however, I want to explain briefly how I am going to approach "the quality of human life", and how it is connected –and not connected – to the concept of "risk" which is the main topic of this volume.

1 "Risk" and the "Good Life"

The term "risk" includes a broad variety of meanings, but ethicists most commonly take risks to refer to what I will call here "hard impacts".[3] Hard impacts refer to concrete *harms* that a treatment or technology may inflict, which can be counted in numbers of injuries or amount of losses of health or life. Usually ethicists talk about harms for human beings, but sometimes they include also harms for animals or nature. The term "risk" indicates only vaguely that there is a chance that this harm occurs, and sometimes attempts are made to be very precise as to how big a chance that is. In the context of quantitative risk assessment, for example, an attempt is made to be more precise as to how "probable" the risk is; in this literature "risk" is expressed in terms of a number that indicates the average annual probability that a fatality occurs, which is usually based on past experiences of fatalities in the same or a similar context, for example, the probability of the occurrence of a car collision is based on past car accidents in the same area.[4]

There has of course been a lot of debate within ethics about these characterizations of "risk". Classic questions include, for example, *by whom* risk is to be defined, and whether to assign it subjective or objective meaning (Teuber 1990); or there are authors who analyze the term "probability" and state that uncertain decisions are often treated as if they were decisions under probability (Hansson 1996; 2003). But the critique I am most interested in here aims at the interpretation of "risk" in terms of harms to bodies that can be counted, which are called here "hard impacts". In this article, I am interested in tracking the possible consequences that the use of acousto-optic monitoring will have for the quality of life, which depends on many more factors then life and health alone. I therefore side with authors who adopt a much broader view of "risk" and also include psychological harms, which refer to impacts on people's emotion, experience, relations to others and ways to deliberate and act, etc. (Such as Malek and Kopelman 2007) It is these impacts that will be called "soft impacts".

If "risks" can include hard as well as soft impacts, the term seems to be sufficiently rich to include the kind of impacts that technologies may have on the quality of human life. This interpretation of risks as a combination of hard and soft impacts would go together well with an approach to the "good life" which has been

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[3] With thanks to my colleague Tsjalling Swierstra to whom I owe the distinction between "hard" and "soft" impacts.

[4] In risk-benefit analysis a risk is also expressed in terms of a number, but here the number stands for monetary value assigned to a negative outcome such as an injury or loss of life.

developed by Martha Nussbaum and Amartya Sen, and is know as the "capability approach". (Nussbaum and Sen 1993) "Capabilities", according to these authors, are abilities that need to be developed and fostered in order to function well as a human being and reach a state of wellbeing, or of "flourishing". Examples of capabilities are life, bodily health and bodily integrity, but also the capability of the senses, imagination and thought, emotions, practical reason, affiliation with others, play etc. The aim of this capability-approach is to offer a measure for the quality of human life which is sufficiently rich, so that it can assess the way in which people can conduct their lives in a specific context. On the basis of this list of capabilities, questions can be asked about the life expectancy of people in a specific area, the availability and type of medical services of health care, the quality and availability of education and labour, the types of relations people have with employers, and the political affiliations they are able to engage in, the freedoms they have in conducting personal relations, but also how people in society are able to imagine, to wonder, feel emotions, and play etc.

Nussbaum and Sen do not pay specific attention to the kind of technologies that are available in a certain area. However, the availability of technologies are likely to make possible or help the development of some capabilities, and can also endanger or put obstacles to such development.[5] Similarly, it is possible to imagine how a *new* technology, which is not yet being used, could do that when it becomes useable. If "risks" are understood in a broad sense, and include hard as well as soft impacts, it seems proper to call an anticipated obstacle that a new technology could impose on human development a "risk": it refers to a way in which the wellbeing of human beings could be harmed *and* it is not yet certain that this harm will occur for the technology is still in the research and development phase.

However, looking at the riskiness of technologies in this respect also seems limited in two ways that have to be kept in mind in the remaining of this article. Firstly, it needs to be remarked that a term like "risk" is mostly applicable to individuals. Technologies, however, may have effects on groups of people, as Janet Malek and Loretta Kopelman show in relation to DNA diagnostics which concern genes which people share. DNA tests can show that a specific group is more susceptible to a specific disease, such as Native Americans are to alcoholism. This genetic knowledge can lead to stigmatization and discrimination of that group. But these effects are hard to qualify as "harms" since groups lack the body and mind that is capable of being harmed. (Malek and Kopelman 2007) Words such as "risk" and "harm" are thus more apt to distinguish impacts on individuals, than they are to talk about effects on groups of people.

This is also a relevant point for the technology discussed in this article. While part of the possible future impacts of this technology will be understandable at an individual level, such as influences on capabilities such as life, health, imagination emotion, practical reason etc, others can only come into view if people are perceived

[5]See Oosterlaken, Ilse (forthcoming). "Design for Development; A Capability Approach". In: *Design Issues* (accepted for publication on November 11th, 2008).

as *members of a group*. These effects are hard to understand in a risk-vocabulary; to do so demands an imaginative extension of the meaning of terms like "risk" and "harm".

Secondly, the term "risk" may simplify the view of *how* new technologies influence people's lives. Terms like "risk" and "harm" suggest that the relation between the introduction of a technology and its impact on human life is linear. But sometimes the relation between the introduction of a technology and its effects on people is not so straightforward. The stigmatization and discrimination that DNA-tests produce for Native Americans, for example, depend not only on the technology; rather, these effects are co-shaped by relations between population-groups prior to the introduction of DNA-tests in the US. DNA-tests are not the sole cause of stigmatization and discrimination of Native Americans; the availability of these tests *intensified and altered* a problem that was already there.

This will also be the case in the case-study that is presented here. Imagining the "impacts" that an acousto-optic monitoring device for blood may have on the quality of life of human beings also implies knowledge of the contextual characteristics in which this technology will be introduced. Without such contextual knowledge it becomes hard to imagine in a reliable way how people's lives will be changed, and how they are likely to evaluate that change. Contextual knowledge is therefore a prerequisite for the formation of an "educated imagination" about a technology's impact on the quality of human life.

These limitations have to be kept in mind in the discussion of this case-study, which will (1) imaginatively anticipate the changes in the capabilities that an acousto-optic monitoring device could produce, but will also (2) pay attention to possible group-effects, and (3) will try to come to grips with these changes by means of a study of the context for which the technology is intended.

2 The Acousto-Optic Monitoring Device for Blood

For an adequate anticipation of the interplay between a technology and a context, and the effects it will have on how human beings are able to conduct their lives, one needs to become acquainted with the technology first. Research into the acousto-optic non-invasive monitoring device for chemical substances in the blood, such as oxygen, glucose and cholesterol, is the most recent example of the search for a non-invasive monitoring method which began already in the nineteen thirties, when the first non-invasive instruments to measure oxygen in the blood were built. This research got accelerated during the Second World War; it was part of a project to investigate the oxygen level in the blood of pilots during fights at high altitudes, who frequently lost consciousness. After the war biophysicist E.H. Wood succeeded in constructing the first quantitative method to monitor oxygen levels in the blood, but this was only used in laboratories for it was not yet practical for use on patients. It took until 1972 when a simplification of Wood's instrument was developed, and it was ready for use in a hospital context by 1983. This instrument was called the "pulse oximeter", and is nowadays adopted into standard anaesthesia practice in many countries. (Aoyagi 2003) The pulse oximeter is the clip patients get on their finger when they undergo surgery, and which monitors the oxygen-level in their blood. Next to surgery it is also widely used in recovery, emergency units and in intensive care units. Outside the hospital it is used in aviation, or by mountain-climbers, who need to monitor the oxygen level in their blood at high altitudes.

The pulse oximeter is an optical technique: it uses a light beam of infrared laser light, which points at part of the human body, most often a finger or an earlobe. It aims especially at arterial blood. When that blood is rich with oxygen it has a light colour, but when it contains little oxygen it is dark red; accordingly, blood rich with oxygen absorbs a lower amount of light, than the dark blood that contains little oxygen which absorbs a lot of light. The absorption degree of the light indicates the amount of oxygen in the blood, therefore the pulse oximeter is able to notice a critical oxygen-level before clinical signs are apparent. Since the pulse oximeter focuses on the oxygenation of *arterial* blood which has a pulse, the instrument is called "pulse oximeter".

The pulse oximeter, however, is imprecise, because the light beam does not only go through the vessel –which is responsible for the measurement – but also through tissue, which strongly scatters the light. The pulse oximeter is unable to correct for this imprecision. This is one of the reasons why scientific engineers at the University of Twente engaged in research into a new technique, which uses sound as well as light, to overcome this problem. Research into this technology is still in a very early stage of development, meaning that it has only been researched *in-vitro* on a simulation of tissue, interestingly called a "phantom". In the test-set-up the phantom is made by repetitive freezing and defrosting of an intralipid solution, which by that procedure acquires the substance of a white pudding that has light scattering characteristics that are similar to human tissue. In this white pudding a tube is inserted with coloured ink, which is the stand-in for the blood vessel. On one side a light beam with a well-defined colour is pointed at the phantom with the ink-tube, but on another side an acoustic transducer is pointed precisely at the tube. The ultrasound manipulates the movement of the photons (the light-particles) that transgress the tube, and allows to distinguish from the totality of light that leaves the body again the photons that go through the vessel from the photons that are scattered by tissue, thus allowing to focus on the absorption-level of only those photons. (Bratchenia et al. 2008)

This acousto-optic technology carries with it the promise to improve the results of measurements with the pulse oximeter, but its uses may also be extended in the future so that it is able to measure non-invasively other chemical substances in the blood, such as glucose or cholesterol, using other appropriate light colours. With the future exploration of these broader possibilities for the technology, this research builds forth on a wide field of research into techniques which aim to monitor in a semi-invasive or non-invasive way the glucose level in the blood of diabetes patients. Among these techniques are optical techniques such as optical sensors, but also other acousto-optical techniques. (Sieg et al. 2005; Larin et al. 2002; Zhao and Myllylae 2002)

The acousto-optic monitoring device may or may not become a usable technology. That depends on how successful the research will be. It is possible that this technology will be very successful and will deliver its promises, but experience teaches that many technologies will not succeed to take the step from the controlled environment of the laboratory to the much more complex reality of human bodies. However, also when the acousto-optic monitoring device does not become useable, the technology may become operational in other ways. In the near future, for example, research is planned into a connection with another technology that is being researched at the University of Twente, called photoacoustic mammography and which is intended for the non-invasive detection of breast cancer. (Manohar et al. 2007) Photoacoustic mammography also uses sound as well as light, but it is an imaging technique: it images excessive growth of blood vessels around a lump in the breast, which is an indication that it is a tumour.[6] A connection between acousto-optics and photoacoustic mammography could make it possible to offer a more precise diagnosis to cancer patients. While photoacoustics is able to image extra vessel-growth around tumours, acousto-optics could determine the oxygenation of that blood. Blood with little oxygen indicates that the tumour grows fast, for it withdraws a lot of oxygen from the blood, while blood rich with oxygen is indicative of a slow growing tumour. Information about speed of growth could therefore make it possible to offer more precise diagnostic information than is available at present.

It seems worthwhile to anticipate the possible positive and negative ways in which an acousto-optic monitoring device could influence human life, for it may develop into a useable technique. But if it doesn't, it may become integrated into another technology such as photoacoustic mammography, which is already in a much more developed stage of development and will be tested on patients this year (2009). Furthermore, apart from the fact that it may be compatible with other techniques, there are also similarities between them. Its congeniality with other emerging sensing techniques and acousto-optic and photoacoustic technologies –which are researched all over the world[7] – is an indication that these other technologies may share some of the problems that the acousto-optic monitoring device has, and which I will discuss in the following section.

3 Acousto-Optics and Dark Skin

There are many ways in which the acousto-optic instrument could affect the quality of human life. Here I will focus mostly on one example; namely, the different ways it may function on people with different skin colours. I first thought about

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[6] This process of vessel-formation around tumours is termed "angiogenesis". (Carmeliet and Jain 2000). I provide for a more extensive case-description of photoacoustic mammography in van der Burg 2009.

[7] It is important to realize that the field of optical technologies is broad. See, next to earlier mentioned articles about photoacoustics: Tromberg et al. 2000; Pogue et al. 2001. Articles about acousto-optic imaging techniques: Wang 2003; Lev and Sfez 2003.

the possibility that this technology could function less well on people with dark skin –meaning dark African or Indian skin, not the lighter skin-tones seen in Arabic or Asian countries – in the first phase of my embedded ethical research when the scientific engineers introduced me to their research-topic and their laboratory set-up. They explained to me that the measurement of the technology depended on the absorption of light by colour; also, they explained to me that in order to find out whether this technology worked they simplified reality in the laboratory, thus keeping the substitute of human tissue – the phantom – white while allowing only the content of the vein to be coloured. In relation to these explanations, different skin colours seemed to pose an obvious problem at least in the initial phases of the research. But the scientific engineers convinced me that they could eliminate this problem in a later research-phase, for it had also been solved in recent versions of the pulse oximeter, the most successful ancestor of their technology. However, during conversations with anesthesiologists in hospitals I found out that the pulse oximeter does not always work well on dark skin. These remarks drove me to search for literature about the pulse oximeter regarding this problem.

Interestingly, articles that focus on the technology of pulse oximetry, which are published in scientific journals about optical techniques, rarely mention skin colour at all in relation to the technology. For example Takuo Aoyagi, who collaborated in the development of the useable pulse oximeter that was realized in 1972, and began to be widely used in hospitals in 1983, does not mention skin-pigmentation as a problem when he discusses the history of the device, nor does he mention it in his inventory of the problems for its future. (Aoyagi 2003) And of the many articles that report about tests of the pulse oximeter on patients, only few take dark skin into consideration. Some of them report no alarming results. For example, two large-scale studies on 380 dark and white skinned subjects reported no significant pigment-related errors at a normal oxygen-level; "normal" meaning that haemoglobin in the blood –which is the oxygen carrier – contains between 95 and 99% oxygen. (Adler et al. 1998; Bothma et al. 1996) Many smaller-scale studies, however, reported errors in pulse oximeter readings in cases when the skin is coloured. Some of these studies were not especially aiming to study the performance of the pulse oximeter on dark skin, but reported that nailpolish, ink, henna or meconium (in neonates) is able to interfere with the pulse oximeter readings (Coté et al. 1988; Battito 1989; Goucke 1989; Johnson et al. 1990). There were also other studies which compared the performance of different kinds of pulse oximeters, and reported casually –as if it were just a "side-effect" – that they also produced different measurements on dark-skinned patients compared to those on light-skinned ones. (Cahan et al. 1990 and Seweringhaus and Kelleher 1992).

There are also studies that concentrate especially on skin-colour differences, and noticed a variation in pulse oximeter readings that is significant to medical decision-making. Jubran and Tobin (1990), for example, tested 54 critically ill patients who were ventilator-dependent and found out that the measurements of the pulse oximeter needed to be read differently in dark-skinned patients than in light-skinned ones. In patients with a light skin tone a pulse oximeter measurement that indicated that the blood contained 92% of oxygen could be considered safe, but dark skinned patients with the same measurement suffered serious hypoxemia (lack of oxygen). In dark skinned patients the pulse oximeter needed to show an oxygen saturation of 95% to be considered “reliable”. Another test on 33 patients belonging to different ethnic groups – Indian (5), Malay (6) and Chinese (22) – by Lee et al. (1993) also indicates that the amount of oxygen is overestimated in people with dark skin, especially at low oxygen saturations in the blood. Misreadings in the dark-skinned Indian patient-group increased most when the oxygenation in the blood dropped.[8] Ries et al. (1989) reported similar findings from a study on 187 patients for the pulse oximeter used in the ear: this type of oximeter produced a lot of technical problems often resulting in no reading at all on the darkest skinned test-subjects, and if it did work on these patients, it produced less accurate measurements.

These studies are all somewhat dated. A newer generation of pulse oximeters may have overcome these difficulties. This is what Gerard Coté claims (Coté 2001, p. 3). He argues that while earlier monitors were frustrated by a large list of problems, among which skin pigmentation, this is no longer a problem for a new generation of oximeters: now pulse oximeters use two wavelengths, which allow to take the ratio of the pulse and the total transmitted red light, and divide it by the same ratio for infrared light. The result should be dependent only on arterial oxygen-saturation, which should make pulse oximetry independent of skin colour.

While this technological explanation seems sound to scientific engineers –it is convincing to the researchers at the University of Twente – two small more recent patient-studies which were carried out on six different new brands of pulse oximeters, report that they are still not working accurately, especially not on dark skinned patients whose oxygen level in the blood drops below the normal.[9] (Bickler et al. 2005; Feiner et al. 2007) Bickler et al (2005) report the results of a test on 21 test-subjects, 11 of whom had a dark skin colour (African American) and 10 a light Caucasian skin tone. During the experiment a measurement was taken with a “normal” oxygen level, and then the oxygen in the blood was lowered by means of breathing air-nitrogen-carbon dioxide mixtures through a mouthpiece. When the saturation of oxygen in the blood lowered, the bias in the pulse oximeter’s readings on dark skinned patients increased. In people with oxygen-levels beneath 80% a bias up to 8% was perceived, which can be significant in situations during surgery, in the emergency room, or for example in people with heart diseases who have a stable lower level of oxygen in the blood. In the study by Feiner et al. (2007) 36 test-subjects of different skin tones (ranging from white to Hispanic, Asian and African–American) were studied, among which were 19 males and 17 females. Next to skin colour this study also focused on gender differences in measurement, which affects finger-geometry. Here a deviation up to 5% was measured up until a saturation of 75% in dark skinned patients.

[8] The types of pulse oximeters checked here were Nellcore, Simed and Critikon.

[9] The pulse oximeters tested were Nonin, Masimo and Nellcor instruments in the last study (Feiner et al. 2007) The earlier study tested the Necor N-595 clip-on sensors and for Nonin Onyx and Novametrix 513. (Bickler et al. 2005).

In sum, while the skin-colour problem was thought to be technically solved, patient-tests give reason to think that this conclusion at least needs to be nuanced. Most pulse oximeters seem to be calibrated using light-skinned individuals, with the assumption that skin colour does not matter. But the studies mentioned above show that pulse oximeter readings need to be corrected by in vivo comparisons of oximeter readings in patients with different skin pigments. This is reason for several researchers who carried out such patient-studies to call for caution: some suggest that warnings about their bias on dark skinned patients should be printed on the instrument (Jubran and Tobin 1990, p. 1420), others argue that correction tables should become standard in hospitals or even that technical adjustments should be made which make it possible to adjust the instrument to the skin-tone of the patient. (Bickler et al. 2005, p. 717)

While all these suggestions are helpful solutions to the problem and could –if they would be communicated to technicians or anaesthesists, and would be taken seriously by them[10] – eventually solve the problem for pulse oximetry, it is striking that 37 years since its invention the pulse oximeter is still not able to function properly on dark skin *and* that the problem acquires so little attention in technical articles. The scientific engineers from the University of Twente explained to me that the reason for that could be that the pulse oximeter was created by mostly light-skinned Caucasian and Asian people, and is funded by institutions in countries where light-skinned people dominate and will thus be inattentive to skin colour problems. Next to that, they argue that skin colour cannot be paid attention to by scientific engineers because of the rigid phase-structure that technological research needs to respect if it is to be successful: this means that researchers first deal with simplified versions of reality in the laboratory and will only consider complications such as "skin colour" when their technology is tested on patients and turns out to have troubles on dark-skinned patients. Abandoning this phase-structure of research would mean, according to the scientists, that it is impossible to do research that is conducive to the development of an actual technology.

While these are both relevant and understandable explanations for the reluctance of scientific engineers to pay attention to literature about test-results in an early phase of their research, it also shows why a new technology –such as acousto optics – risks to have the same flaws as the pulse oximeter. If scientific engineers do not know about the pulse oximeter's poor performance on people with dark skin at low oxygen levels, they lack important knowledge that may be informative to their research-questions and test set-ups, including the set-up of the test phase on patients. Such patient-tests do not show by themselves that a technology performs

[10] This is not a matter of course. Communication between researchers and hospitals remains limited, as well as the communication between researchers and producers. Next to that, it is striking that a lot of information never leads to action: it is for example known that it is harder to withdraw blood from dark skinned people, because the vein cannot be found easily. This makes withdrawing blood for dark people a lot more painful and distressing (especially for children). While there are technological possibilities to solve this problem, there has to be a researcher who takes an interest in it, to be able to solve it.

poorly on dark skinned patients; tests can only offer that information if – prior to the test – information is gathered on the skin tones of the test-subjects, and performance on different skin colours is included among the research questions. Setting the patient-tests up in this way means that scientists need to hypothesize *beforehand* that there might be a skin-colour related problem. They are only able to do that if they have information, such as the information provided here about the pulse oximeter's problems with dark skin.

Of course, acousto-optics does not function in exactly the same way as the pulse oximeter, for next to light it also uses sound. Ultrasound is used to alter the amplitude with which the light goes through the vessel, and allows to distinguish the photons that traverse the vessel from the other light particles. This means that the measurement depends on the photons that go through the vessel. The rest of the light is ignored in the measurement. However, if part of the light is absorbed at the level of the skin, there are less photons left that go through the vessel. Furthermore, the measurement depends on the light-signal that comes back out of the body. So, the light has to go through the skin twice – in and out – meaning that the skin colour will absorb part of that light twice too, meaning that it is not sure whether a measurement will be possible. This seems especially so when the oxygen-level in the blood is low, for in that case the little light that succeeds to go through the skin and reaches the vessel may be absorbed by the darkly coloured blood, which leaves almost no light to go back out of the body, through the skin, and allow a measurement.

Whether it is more difficult, or impossible, to make a measurement on dark skinned people with an acousto-optic device, of course needs to be researched. But my discussion at least shows that there is a potential problem here that needs attention. The problem of skin-colour is especially relevant because acousto-optics also aims to bring about a non-invasive monitoring technique for diabetes patients. While this technology will probably use different wavelengths of light to study the glucose-level, which may alter its performance on dark skin, it is important to note that skin-colour is a relevant research-factor in the area of glucose-monitoring for diabetes. Information about contexts for which this technology is intended shows why that is so. In the Netherlands, for example, diabetes patients often have a dark skin. According to the National Compass for Public health, which gives information about the occurrence of diseases in the Dutch population, diabetes mellitus occurs more frequently among populations from Suriname, Morocco and Turkey, than among people of Dutch decent. Especially Hindu people from Suriname –who have a very dark skin – have a relative high chance of developing diabetes: 37% of the population older then 60 has the disease. The presence of diabetes among people from Turkey and Morocco also lies 3–6 times higher then among people from Dutch decent.[11] That means that at least within the Netherlands, diabetes patients will to a

[11] Reasons for this difference are hard to give, but it is thought to be explained by deprivation during youth, and the more frequent occurrence of obesity among these populations. English sources on which these findings are based are for example: Middelkoop et al. 1999; Weijers et al. 1998. For Dutch readers: see the site of RIVM http://www.rivm.nl/vtv/object_document/o1261n17502.html

large extent be people with a darker skin.[12] But studies outside the Netherlands have also pointed out that the amount of diabetes patients is high in certain areas where people with very dark skin colours live, the most well-know example being India. (Ranachandran et al. 2001) This empirical information shows why it is important for researchers and developers of non-invasive monitoring techniques for glucose to pay attention to skin colour.

4 Possible "Risks" of the Acousto-Optic Monitoring Device

The role I am proposing for embedded ethicists is to imagine the "risks" that new technologies might bring about in the future for people's quality of life, and bring that information to the laboratory so that it can inform research decisions. This imagination, however, needs to be an "educated imagination": it is formed on the basis of information about the new technology, as well as other related technologies. It also needs information about the contexts for which the technology is eventually intended. This information allows to imagine in a reliable way what types of hard and soft impacts this technology is likely to have on human (social) life. Here I will give an example of such an imaginary endeavour.

If acousto-optics succeeds to make possible a more precise and adequate non-invasive measurement of oxygen than the pulse-oximeter is able to deliver, it is clear why it would be desirable to have such an instrument. It will improve the means to monitor the life and health of patients during surgery. If the acousto-optic monitoring device turns out to be able to measure glucose too, it would even have more attractive impacts. In that case, it would offer a less painful and less inconvenient way to check glucose than the invasive check-ups that are currently the standard for diabetes patients. Also, it enables diabetes patients to check their glucose level frequently, which allows them to keep it more balanced and that may lead to the development of fewer complications. If research into the acousto-optic monitoring device is successful, it could therefore contribute to "hard impacts" such as the diminishment of pain during the glucose-checks, as well a decrease of the amount and seriousness of the complications that are frequent symptoms in people with diabetes, such as problems with eyesight, kidneys, peripheral nerves, heart and blood vessels. This of course fosters the capabilities of life, bodily integrity and health.

Furthermore, the acousto-optic device could also deliver soft impacts, which depend on specific characteristics of the context for which it is intended. During a focus group that I organized twelve Dutch diabetes patients pointed out how their life is affected by the frequent invasive glucose-checks at this moment, which helps to imagine what changes will occur if the check-ups become non-invasive. These diabetes patients check themselves between 4 and 10 times a day, which is a painful and troublesome procedure. A student describes, for example, how she had to overcome a fear of needles to be able to carry out her daily glucose-checks. While

[12] People from Morocco and Turkey usually have lighter skin colours than Hindu people from Suriname who generally have dark brown skin.

she handles her fear now, she describes always feeling repulsed when she has to insert the needle. This fear is not shared by the other interviewed patients, but they all report that they often feel unwilling to interrupt their activities to check their glucose, and express regret at missing things: such as courses, part of a lively conversation during lunch with colleagues, or even part of work. A man, who works as a sculptor, says he fails to check his glucose when he is working, "because it is too much of a hassle to get clean and perform the check-up." Another man who works in construction agrees with him and explains that the time-consuming procedure to clean his fingers adequately and do the glucose-check has lead to tensions between him and his colleagues. "I know it is good for my health", he explains. "But not all of my colleagues understand: they feel I abandon them and they have to do the hard work."

These experiences indicate that a non-invasive acousto-optic monitoring device could bring about "soft impacts" such as liberation from the fear of needles and the inconvenient interruption of daily activities, but it would also enable people to engage more thoroughly in their work or studies and enjoy and sustain more adequately relationships with colleagues and friends. The technology would thus help to develop capabilities of affiliation with others, and of emotions, and likely also of practical reason. Practical reason is the capacity to form a conception of the good and to engage in critical planning of one's life: since the acousto-optic monitoring device liberates people from the burden of frequent time-consuming invasive tests, it could enable people to plan their life and actions more freely. Having to take frequent invasive tests could mean that a patient will not choose a career that involves getting dirty hands; and it puts constraints on what actions an individual is able to do in a day. If the test is non-invasive, diabetes patients could have more freedom to deliberately plan their lives, instead of having to organize it around their disease.

This catalogue of hard and soft impacts that an acousto-optic monitoring device could deliver is attractive. However, the skin-colour story points out that these impacts may be realized only for light skinned people. The above mentioned capabilities as life, bodily integrity, health, emotion, affiliation and practical reason may therefore be fostered in white skinned patients, and not in people with dark skin. This would mean, of course, that dark skinned patients are not enabled to realize their "good life" as well as light-skinned people are.

Thus, the technology is likely to produce an inequality between the lives of light skinned diabetes patients and dark skinned ones, which was not there before. This could make dark skinned patients vulnerable in new ways. It would mean, for example, that dark skinned patients – unlike white ones – have to continue to interrupt their daily activities for the time-consuming tests, while white skinned people with diabetes manage to check glucose quickly. This offers more freedom to whites to form their lives and relationships in the way they desire than blacks. Tensions that can come about between people, such as colleagues, because diabetes patients have to regularly retreat from their activities to perform their invasive tests, will then be reserved exclusively to people of dark skin colours. And it is quite possible that the outside world of people without diabetes will have more difficulty understanding the time and effort that dark skinned patients have to invest to keep their glucose at an even level, if their white skinned fellow-patients fulfil the same task much quicker.

This likely also affects the emotions. In a more extensive explanation of the catalogue of capabilities that Nussbaum gives in a later work, she pays special attention to the emotions. Here she identifies emotion as a capability "(..) to have attachments to things and people outside ourselves; to love those who love and care for us, to grieve at their absence; in general, to love, to grieve, to experience longing, gratitude and justified anger."(Nussbaum 2000, p. 79) The capability to have emotions here refers to a capacity to relate to other people, and to express the emotions that one experiences. If we imagine the impacts of an acousto-optic instrument which works on light skinned people, but not on people with dark skin pigment, we see that it affects emotions in precisely this way: it makes relations between people more difficult. If dark skinned patients, unlike light-skinned ones, remain tied to invasive tests, they have less control over their life-plan and their day-planning. And this may elicit irritation of other people, who fail to understand why they have to retreat so frequently.

In addition, relations between diabetes patients may alter, because they no longer share the same experiences with the disease. The difficulties dark-skinned patients experience because they have to take the invasive tests are no longer the same experiences as white skinned patients have. This drives the two groups apart. It will demand an extra effort for light-skinned patients to be able to notice that their dark-skinned fellow diabetes patients are vulnerable in other ways then they are. And of course it is very common that people do not take the effort to imagine themselves in someone else's shoes.

Altered emotions are also likely to impact on people's value judgments. In her book about emotions *Upheavals of thought* Nussbaum defends the view that "Emotions (..) involve judgments about important things, judgments in which, appraising an external object as salient for our own wellbeing, we acknowledge our own neediness and incompleteness before parts of the world that we do not fully control." (Nussbaum 2001, p. 19) Nussbaum here states that emotions are forms of evaluative judgment that ascribe to things and persons outside of a person's control great importance for that person's own flourishing.

In the imaginative exploration of the future that is offered here we have seen that a new technology such as the acousto-optic monitoring device is able to alter vulnerabilities: it takes some vulnerabilities away. And it probably takes them away for some people, but not for others. This means that different people are likely to experience different emotions, since they are in differing ways "incomplete". The needs of blacks will not be the same as the needs of whites, and consequently blacks and whites will judge differing objects to be salient to their wellbeing. This difference has of course effects on how people choose to lead their own lives, but it also is able to affect society. People who have difficulty imagining the lives of others, will often fail to consider the difficulties of others when they deliberate about their own decisions. It is in such a way that for example the pulse oximeter got calibrated on light-skinned people; the engineers who did that simply did not sufficiently imagine difficulties that could arise on dark skin. Because of the decisions of many individuals, technologies are produced that affect the society in which individuals live their lives.

5 Concluding Remarks

In this imaginary anticipation of the future of the acousto-optic monitoring device for oxygen and glucose in the blood, I have tried to track its possible effects on human capabilities. I have attempted to show that there's a reasonable risk that this technology does not work, or that it works less well, on dark skinned people. This difficulty is likely to produce many effects on people, the most important one being that it will make it more difficult for dark and white skinned patients to relate to each other's vulnerabilities. This is bound to affect their judgments about what is valuable and worth pursuing in their personal, as well as professional or public life.

This "educated imagination" about the possible ways in which an acousto-optic monitoring device could affect people can be used as input in conversations with scientific engineers. The purpose of that would be to broaden the scope of scientists' deliberations about their research. Usually the imaginations of scientific engineers about the future of their technology depend largely on their technological knowledge, which gives them a broad and complicated field of research-questions to study. However, the more "ethical imagination" explored in this article could raise some additional research questions, or alter research priorities, or it could offer alternative views on how part of the research –such as the testing phase – should be conducted. While it is understandable that scientific engineers have to limit the scope of their attention to be able to acquire the level of specialization that is needed to do their research, they do contribute to technologies that potentially change people's lives. It therefore seems worthwhile that others – such as ethicists – do the extensive work that is needed for the development of a broader view of the future, which includes also the effects on a rich variety of users. Such an "ethical imagination" offers insights that are hopefully able to draw the scientists attention to some aspects of their technology that are worth their attention, and that they previously did not consider.

Acknowledgments With thanks to Sabine Roeser for the invitation to contribute to this book, as well as for her comments on the first draft of this article. I am also thankful to the Biophysical Engineering Group at the University of Twente for their generous and open cooperation with the embedded ethical research that lead to this article, and to the volunteers from the Diabetes Association Netherlands (Diabetesvereniging Nederland) who participated in the focus group. I also want to thank Rob Kooyman for his comments on an earlier version of this article. Finally I would like to thank NWO for funding the embedded ethical research that resulted in this article.

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