



Science and Technology Committee

Corrected oral evidence: The effects of artificial light and noise on human health

Tuesday 7 March 2023

11.20 am

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Members present: Baroness Brown of Cambridge (The Chair); Lord Borwick; Viscount Hanworth; Lord Holmes of Richmond; Lord Krebs; Lord Mitchell; Baroness Neuberger; Baroness Neville-Jones; Baroness Northover; Lord Rees of Ludlow; Lord Sharkey; Lord Wei; Lord Winston.

Evidence Session No. 3

Heard in Public

Questions 27 - 39

Witnesses

Professor Stuart Peirson, Professor of Circadian Neuroscience, University of Oxford; Professor Kenneth Wright, Director of the Sleep and Chronobiology Laboratory, University of Colorado Boulder.

USE OF THE TRANSCRIPT

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Examination of witnesses

Dr Stuart Peirson and Professor Kenneth Wright.

Q27 The Chair: I welcome our witnesses to the committee's third evidence session of its inquiry into the effects of artificial light and noise on human health. Today we are focusing on light, and we have in person professor Stuart Peirson, professor of circadian neuroscience at the University of Oxford, and virtually joining us from the United States we have Professor Kenneth Wright, professor of distinction and director of the Sleep and Chronobiology Laboratory at the University of Colorado Boulder. Thank you very much to both of you for joining us.

I will kick off with a very introductory question. Can you give us a quick overview of some very basic issues? What are the main sources of artificial light that humans are exposed to, and do we have a formal definition of when that light constitutes light pollution?

Professor Kenneth Wright: Good morning, everyone, and thank you for the invitation to be here. The main artificial sources of light in humans that we are exposed to today are primarily light-emitting diodes, and fewer and fewer people are exposed to incandescent light bulbs, compact fluorescent light bulbs, et cetera, as we replace those. However, another driving factor of this exposure is our use of electronic devices: our laptops, computer monitors, smart phones, TVs and tablets. Then, especially in urban areas and disadvantaged populations, street lighting can enter the house and the bedrooms at night.

In terms of what is considered light pollution, there are some definitions out there. For example, the United States Department of Energy defines light pollution as any artificial light that is not needed. If we take an astronomical point of view, the International Astronomical Union, which is composed primarily of professors and professional astronomers from all around the world who hold PhDs, has a recommendation for the maximum tolerable light threshold for light pollution as 10% above the natural background levels.

Professor Peirson, who is with us here, as well as Professor Spitschan, who was in your last session, were part of a scientific consensus for recommendations for daytime, night-time and evening lighting for maintaining human health. If we use those as a proxy for a definition of light pollution, we have provided recommendations for what the light should be in the home environment at night prior to bedtime as well as during sleep. We can talk about that later in more detail, but those cut-offs would be less than 10 melanopic EDI lux for the evening and less than 1 EDI lux in the bedroom at night.

Professor Stuart Peirson: Professor Wright has covered that very clearly. You have the external light environment, which as regulators is probably what we would think about as light pollution, but we also have the artificial light in our homes that we generate. Just think of your home environment: it is full of everything that emits light. As Professor Wright

said, it is that light that is unnecessary and that may have unexpected health effects.

The Chair: Thank you. There are requirements in various places to map noise pollution. Do you know of any places where it is a requirement to map these sorts of exposure patterns to light pollution?

Professor Stuart Peirson: Light pollution is certainly measured by a lot of satellite approaches. Again, I do not know how accurate the metrics of that are from the perspective of on-the-ground illumination. I do not know whether there is one standard for light pollution that is used across the whole field, and that is mapping only the external light environment and not the internal light environment, which is the biggest source of our artificial light exposure.

Professor Kenneth Wright: I agree. Most of the science that has been done in this area has used the Defense Meteorological Satellite Program to assess light. There is a citizen science campaign now, which is supported by the National Science Foundation and the National Optical-Infrared Astronomy Research Laboratory here in the US, that is an international effort to measure light in the environment from the ground using personal devices and things like that to try to capture better what Dr Peirson was talking about—something that is closer to the exposure that people would get.

Q28 **Lord Sharkey:** Good morning. What are the major impacts of artificial light on human health that we know about and are most confident about, and do we have any sense of how serious these are in their impact on human health?

Professor Kenneth Wright: First, I would like to highlight that electrical lighting was not available to the masses in North America and Europe until the 1930s, which is when the electrical power grids were created. If we clock human evolution as one 24-hour day, the use of artificial lighting has been around for less than a few seconds of our evolution. Today, we are exposed to lower levels of light during the daytime, because we spend more time indoors, which makes us more sensitive to electrical lighting at night.

Large epidemiological studies now show that many of the major health problems that we see in developed countries today are associated with light at night, such as insomnia, prescription of hypnotic drugs in older adults, obesity, type 2 diabetes, heart disease, elevated blood pressure, depression and cancer. In a more recent study, that looked at more than 40,000 women, having a light or a TV on while sleeping was associated with the risk of gaining weight over time, so it is a prospective study. Other experimental studies in laboratories show that light at night can increase our heart rate and blood pressure, as well as impair our body's ability to regulate our blood sugar levels, for example. It impacts a whole host of health problems.

Professor Stuart Peirson: There is certainly strong laboratory evidence that light exposure will shift our circadian clock, impair hormone production, suppress pineal melatonin specifically, and alter our levels of

alertness and subsequent sleep. As regards direct health effects, perhaps some of the best evidence comes from long-term shift-work cohorts, who show elevated rates of specific forms of cancer. There was a large study on nurses with an increased risk of breast cancer. More recently, there have been UK Biobank studies using those data sets that have shown long-term health effects that are related to light exposure.

We know that there is the potential for light exposure to affect our circadian phase—the melatonin—and there are even datasets that show that the one-hour shift of the clocks in springtime is enough to lead to a link between cardiovascular events and road traffic accidents. We may think that just a brief exposure to light may shift our clocks slightly—so what?—but actually, even a one-hour shift in our light/dark cycle is seen to have measurable impacts on risks of accident and disease.

Baroness Neville-Jones: I can see that with accidents.

Lord Sharkey: Are there any other potential impacts where the quality of evidence is currently low but where you feel that more research is likely to change that?

Professor Kenneth Wright: Science is always progressing, refining and expanding our knowledge. There is an opportunity to improve the quality of evidence—especially when I think about policy decisions—by trying to have better assessments of exposures. We talked before about satellites being a primary method of assessing exposure to light at night. We have new opportunities to use wearable technologies to allow us to get a better assessment of that exposure on an individual and population basis.

The flip side is to test some of the recommendations that the expert consensus panel I mentioned before made. For example, how much can we enhance exposure to light during the day in order to reduce the negative impacts of light at night? That is an opportunity that could help us to change overall recommendations. Overall, the things that are being added will refine our assessments of what should be done.

Professor Stuart Peirson: I reiterate the point that a lot of the historical light measurements that we have were done using photopic lux, which is a measurement of how bright our environment is to our visual system, so it is not appropriate for the non-visual effects of light. That is why you need to use metrics that have now been accepted by the international lighting commission for the measurement of melanopic lux and melanopic EDI as a measurement of weighted sensitivity, which is related to the non-visual effects of light and the role of melanopsin photoreceptors.

Q29 **Lord Krebs:** I have a very brief question for Kenneth Wright. When you talk about the health effects of light exposure and circadian disruption, can you give us a sense of what percentage of the variance in risk is explained by these factors?

Professor Kenneth Wright: If we look at the epidemiological studies and a variety of different health problems, the relative risk or odds ratio associated with measured light exposure at night from satellites ranges

anywhere from 5% up to 20% higher odds for a variety of the different disorders that I mentioned.

The Chair: If I could add a quick rider, we have heard a lot of mention of melatonin. Could one of you say precisely what melatonin does?

Professor Kenneth Wright: I would be happy to. The release of melatonin is controlled by our central circadian clock, which receives the light input that we have been talking about. No matter what species we are, including nocturnal species, melatonin communicates to the body that it is biological daytime or biological night-time. During the biological daytime, melatonin levels are low. During the biological night-time, melatonin levels are high.

Our physiology and biology are very different in biological daytime and night-time. When we are exposed to light during that biological night-time, we are exposed to a lot of the risks associated with the health problems that we are talking about. So melatonin communicates the time of day, but it also helps to prepare the body for sleep. As it is released, it causes a variety of physiological changes that allow us to have sleep and the associated functions.

Professor Stuart Peirson: I would just add that melatonin is basically a biological marker of night-time for the body. That is the same for nocturnal and diurnal species. However, there is a common misunderstanding that melatonin drives sleep—that melatonin levels go up at night and that is why you sleep. That is a correlation. For nocturnal species, melatonin levels also go up at night, which is when they wake up. There is some nice data that shows that individuals whose pineal gland has been removed do not produce melatonin, but their sleep is largely unaffected.

Q30 **Lord Borwick:** Various people sell artificial melatonin as a supplement for people who travel. Has that been proved to be helpful or not? Is it quack medicine?

Professor Stuart Peirson: Just quickly—Professor Wright is probably far better qualified than me to answer—I would say that it can be useful if taken in the right dose at the right time. Most people do not do that.

Professor Kenneth Wright: I agree. There is good evidence that we can use it to help with things such as jet lag and sleeping during the daytime. All the clinical trials that have been done show that taking melatonin at night basically shortens sleep latency, but that is about it. There is no large effect otherwise. However, there is the exception of some developmental disorders, as well as some neurodegenerative disorders that cause sleep disturbances, where taking melatonin may be useful. There is some evidence of melatonin helping there.

Q31 **Viscount Hanworth:** How good is the evidence that artificial light is causing disruption to sleep or to the circadian rhythms in humans? How well do we understand the physiological mechanisms that are involved in this?

I would like to interpolate some comments of my own. We have been talking almost entirely about melanopic illumination or the ambient light that we experience, but how do light flashes affect us? My own testimony is that they affect one greatly when one should be sleeping. When I wake up at 3.30 am and want to get back to sleep, even if I stumble in the dark I do not think of turning the light on, because that would be the light flash that would destroy the sleep thereafter.

I have another question to interpolate. Professor Foster has told us that, of all animal species, human circadian rhythms are the least affected by light. Do you have evidence for this and a plausible explanation of why that might be?

Professor Stuart Peirson: To take the first point, we understand the mechanisms involved very well—the photosensitive melanopsin retinal ganglion cells, their projections to the brain, and some of the aspects of physiology that they regulate. They have been characterised in animals and have been shown to mediate similar responses and be involved in the same processes in humans as well.

As for light flashes, certainly even a very brief duration of exposure is able to exert an effect on the circadian system. Effectively, we often think about these as photon counters. If you provide a large amount of photons in a very short period of time, it will have the same effect as fewer photons over a longer period. So even relatively brief flashes can have an effect. There is published data on even millisecond-long flashes of light being enough to drive circadian and non-visual responses.

On the second point about the relative insensitivity of the human circadian system, this is certainly something I consider to be unusual. The photoreceptor mechanisms are not wildly different—rods and cones and melanopsin cells in humans do not differ dramatically in their physiology from those in rodents. One potential explanation of why there seems to be that difference is the way we do experiments in humans. We do not keep them in complete darkness and then expose them to light, which gives you a very high contrast. Instead, we keep people under dim light and increase the light level, so the relative change in the light exposure may be different in those kinds of studies. The noise in human studies means that resolving those differences can be more challenging than in controlled animal work.

Viscount Hanworth: Professor Wright, perhaps I will take a different tack. How good is our qualification of the problem of the disruption to sleep? Do we have any sort of economic assessment of how much we are losing via this disruption and damage?

Professor Kenneth Wright: I agree with everything that Professor Peirson said, although there are differences in sensitivity between species. We and others have shown that candlelight is sufficient to impact circadian rhythms in humans, so we are sensitive. It is not that we are insensitive; we are just less sensitive.

In terms of economic assessments, there are no direct estimates regarding the economic costs of the health impacts of artificial light that I am aware of. However, we know that artificial light contributes to insufficient sleep. According to a 2016 analysis by the RAND Corporation, the US, for example, sustains a yearly economic cost of \$411 billion, or 2.3% of our GDP, due to insufficient sleep. For the UK, that is a loss of \$50 billion, or about 1.9% of GDP. We know that artificial light at night contributes to insufficient sleep, so even if we are talking about a fraction of those costs, we are talking about billions of dollars as potential economic estimates of the health impacts of artificial light. I note that the RAND report highlighted that limiting the use of electronic devices before bedtime is one strategy to reduce insufficient sleep. This is certainly part of the insufficient sleep problem that we have worldwide.

Viscount Hanworth: Do you have anything to say about light flashes?

Professor Kenneth Wright: Yes, I think Professor Peirson mentioned the light flash data that has been published. A couple of studies from Stanford University highlight that light flashes could even pass through the eyelids while we sleep to impact our circadian system, and findings from studies at Northwestern and others show that if the lights are on in the bedroom during sleep, they can also be disruptive to sleep and to our metabolic health.

Q32 **Lord Holmes of Richmond:** Good morning, and thank you for being with us. Do we understand how the intensity of light and the duration of exposure and wavelength of light factor into the impacts of artificial light on human health? Are these types of light exposure currently measured?

We have heard a lot about blue light. Can you define blue light for us and perhaps also say something about its impact at sleep time and devices claiming to be beneficial when they flip into night mode?

Finally, from some of the evidence we have discussed on noise pollution, there are subjective annoyance metrics on noise. Is there any such thing when it comes to light?

Professor Stuart Peirson: That is a very good question. Perhaps the easiest way to think about the intensity effects is that in many ways it is like a drug dose response curve. Basically, with the log dose of the drug on the X axis you get a sigmoid curve, with an increasing response up to a point of saturation. In fact, colleagues at Harvard have suggested that we could probably consider light as a drug—it exerts effects, so the timing and the amount are critical metrics when you are thinking about the effects of light on human physiology.

The wavelength of light shifts the position of that curve. Effectively, blue light will shift it to the left, so you need less light to get the same effect. You need less light to get any effect, less light to get a half maximum effect, and less light to get 100%—a saturating response. When you shift to other wavelengths of light such as red light, it just moves the curve further along. You can get a full phase-shifting response—a saturating physiological response—to a lot of these non-visual responses with red

light, but you just need more of it. That is the issue of the sensitivity curve.

It is interesting that studies from the expert working group that has been mentioned several times, which was hosted in Manchester, note that when the replotting of data from pineal melatonin suppression, human circadian phase shifting and the alerting effects of light are put on to a melanopic lux scale, they all superimpose, so it looks as though these responses can be described quite well. Between background and saturation, you are probably looking at about 1,000-fold—so a three-log unit—change. The effects of different wavelengths of light are basically relatively small compared to that; you may at most have a log unit difference. Therefore, the intensity of light depends upon how bright it is; the intensity has a much bigger effect than wavelength.

If you are thinking about blue light blocking, which has often been suggested as an approach to try to avoid these effects, typically when we talk about blue light we are thinking about below 500 nanometres, because the circadian system—the melanopsin photoreceptors—are maximally sensitive to 480 nanometres. If you cut out all light below 500 nanometres, you will reduce the activation of melanopsin by about threefold. On a log scale, that is pretty small, so if you are at exactly the steepest point of that dose response curve, you may have an effect, but in a large number of studies using blue-blocking glasses to try to look at the effect on sleep, around half of them show an effect and around half show no effect. The likely reason for that is because nobody reports the incident light levels, which is a bit like doing a study with a drug where you do not report the dose.

In the same sense, what people refer to as blue blocking is often poorly defined. Typically, it can be below 500 nanometres. Some studies use 550 nanometres or below, or even further, which is effectively light blocking: you are cutting out a lot more light, and that may have effects. For a lot of those studies the key parameters are not particularly well defined. The same applies to the apps on phones: they will have an effect, but they change the colour of the screen and drop the intensity. The intensity has a bigger effect than the colour, but we notice the colour more. Our eyes work over about a nine-log unit range—a billionfold range between starlight and bright sunlight—so dropping the intensity would probably have a much bigger effect.

Lord Holmes of Richmond: What about anything on a subjective annoyance metric? Have you come across anything like that for light?

Professor Stuart Peirson: I am not familiar with it. Certainly we know that subjective annoyance depends upon the source and the sensitisation to it—you are more tolerant of irritation from certain sources than others. So no, I am not familiar with annoyance factors in that regard.

Professor Kenneth Wright: I agree with everything that Professor Peirson said. I will add that those metrics of light also interact with our biology. The biological timing in which we are exposed to light, as well as our prior light history, will impact and interact with everything he said.

On blue light, I would like to highlight that it is not always bad. In fact, we want to enhance exposure to sunlight during the daytime, and sunlight has a lot of blue light, whereas we want to avoid or reduce exposure to all light at night, especially light in the blue and green wavelengths, as Professor Peirson mentioned. If the light is bright enough, it can impact our circadian rhythms regardless of spectrum, which is why dimming at night is critical and why I want to emphasise that. If we look at the research on the potential health benefits of computer settings and so forth, I agree that the intensity is most likely to be important there, because findings from some studies have shown that even at dim levels green light is more impactful on our system than blue light.

Regarding electronic devices and sleep, it is also the content on the electronic media, not just the light that we are being exposed to, that is disruptive. So removing the electronic devices prior to sleep is another key factor here, not just the light itself.

There are questionnaires out there that aim to evaluate different qualities of light and people's experiences—how it makes them feel, and so forth—but there is no standard with regard to the relationships with the health effects of light. It is more about rating "How do I feel when this light is on? Is it more businesslike, arousing to me, or pleasant?"—those types of things.

Q33 Lord Krebs: In a way, we have heard the answer to my question, which was: do we have the scientific evidence base to make guidelines for recommended levels of artificial light exposure to avoid human health impacts? We have heard about the meeting in Manchester that seems to have developed the guidelines. I would like both of you to confirm that my interpretation of that is correct. Leading on from that, however, if the Manchester meeting produced guidelines, have any of the health bodies, either national or international, such as the WHO, picked that up and run with it?

Professor Stuart Peirson: I should say that the meeting you refer to with regard to the recommendations was the second circadian photometry meeting held in Manchester. The first one introduced the idea of using the melanopic measurement, so a couple of meetings have defined that measurement system and have tried to provide actual recommendations. I am not aware yet of whether that has been implemented at the level of the World Health Organization and the like. I do not think so. It has certainly been implemented and taken up by architects and building designers, who are now starting to pay a lot more attention to it.

Before those kinds of guidelines, the basic science was there and the genie was out of the bottle. There was a bit of a wild west when it came to human-centric lighting and the incorporation of the idea of building better environments where we could integrate our understanding of the circadian effects of light into building design, so there was a lot of bad science and bad building design. So it has been quite good in the sense that it has provided guidelines on how buildings are already considered to

be built. I do not know whether it has been really implemented in the form of health recommendations at that level, though.

Lord Krebs: Is architects picking it up in deploying the guidelines in building design a voluntary action from the point of view of the industry rather than a response to some regulatory pressure?

Professor Stuart Peirson: A lot of it has been done according to the WELL Building design standard, and the recommendations from that meeting have largely been incorporated wholesale into the WELL guidelines.

Professor Kenneth Wright: I agree. The World Health Organization recognises that light exposure at night is one factor that might influence the effects of nightshift work on cancer. When the World Health Organization's International Agency for Research on Cancer said in 2007 that shift work is a likely carcinogen, it talked about light at night as a potential factor contributing to that. The American Medical Association has also published reports on the health and safety effects of light.

So some international organisations have paid attention to this, but nothing that has incorporated the new recommendations that were made in the meetings that we have discussed.

Q34 **Baroness Neville-Jones:** Can I take the issue of intervention a bit further into the possibility of regulation? There seems to be very little regulation, although my question indicates that government in the UK has issued guidance on lighting in the planning context, which I suppose is something of a start.

Do you believe that we have reached the point where we have enough evidence to issue valid regulation, and do you believe that we need to? If you do, in which areas? I do not know whether there is any evidence of any countries that have done that, so it would be interesting if you could talk about that.

I suppose the bigger issue is whether it is useful to explore the possibility of formal legally based regulation. If so, in which areas would you consider that to be interesting, useful, important, urgent?

Professor Kenneth Wright: Governments, policymakers, have an opportunity to go ahead and do something with light exposure. It is something that we can mandate and regulate in our work environments, in our healthcare facilities, in our school environments, and with designers so that they can make healthier lighting in homes. This is an opportunity, based on the evidence we have, that artificial light at night is not health promoting.

If we look at a variety of countries, yes, a number of efforts are being made worldwide to reduce light pollution at night. Slovenia, for example, has passed a national law requiring outdoor lighting to be shaded and not to reach certain levels of brightness. Porto Rico has legislation. France just adopted, in 2019, a national light pollution policy; it is one of the more comprehensive ones that can be looked at.

Baroness Neville-Jones: Are these regulations health-based? What is the inspiration for them? Is it economic?

Professor Kenneth Wright: I was not privy to the discussions and why some of the recommendations were made, but the new policy in France, for example, restricts the emission of blue light at night and has reductions in illumination levels. I think these are health-based in part, but they are also based on safety and trying to balance the safety of people in the environment at night with, for example, the safety of driving at night, as well as having the overall perspective of trying to reduce light pollution as a general rule beyond human health—for other species, for example.

A number of other countries do this. Mexico has a new law that is about how light at night is considered an environmental pollution, if you will. Even in the United States, if we look at the National Conference of State Legislatures, 17 states and the District of Columbia have some form of light pollution legislation, because again we are recognising more and more the impacts of light at night. Even the city I live in has its own outdoor lighting ordinances. So we see it at the local level, the state level, the national level and in a variety of different places around the world.

Professor Stuart Peirson: I do not have a great deal to add to that, other than the fact that there will always be a conflict between the non-visual health effects of light and the visual effects. Why do we have outdoor street lighting? It is for people to be able to see. Those visual effects are also critical, and there will always be a conflict between what we need for vision and what we need to do to minimise unexpected, unwanted health effects on the non-visual. From a circadian biologist perspective, having dark all night would be great, but some people have to walk around at night and do their jobs.

So there is always a balance, and context is also critical, particularly in the context of things like shift work, where light at night will clearly be necessary for people to do their jobs. If people are working in a factory using machinery, for example, you want them to be alert, but there will be consequences for their circadian systems as a result. Similarly, you want people to be alert when they are driving home from shift work. So in many ways you can almost think of light like a drug: it has an alerting effect and non-visual effects. Sometimes, having those effects is also really important for safety—you do not want to be driving tired—so light exposure during shift work is a positive thing.

The context in which light exposure happens is therefore also critical. That may be important on the regulatory side, because you could legislate to reduce light levels, but there are certain contexts where that may be inappropriate.

Baroness Neville-Jones: So it will be very difficult to strike balances.

Professor Stuart Peirson: There are possible ways of striking a balance between the two. It is just about being aware of the knowledge that there are non-visual effects of light, and balancing that against the visual and

working requirements of specific populations. That comes back to things like socioeconomic factors, such as people involved in shift work being predominantly from a lower socioeconomic class. So there is a bias in those exposure risks.

Baroness Neville-Jones: One of the things that seem to emerge from all this is that it matters a great deal, and people are moving from one intensity of light to another. Doing that sharply seems to be a problem.

Professor Stuart Peirson: It is also the timing of light exposure, in particular. When the general population is exposed the artificial light, it is typically at the start of the night, which is when our circadian system is most sensitive to the phase-delaying effects of light.

Q35 **Lord Rees of Ludlow:** This question may overlap a bit with what we have heard before, but I recall that, back in 2009, there was a report by the Royal Commission on Environmental Pollution on artificial light in the environment. Since that time, there has been the introduction of widespread cheap LED lighting, instead of incandescent lighting. Could you summarise what difference that has made to the issues?

Professor Stuart Peirson: Just to take that from a dosage perspective, yes, LEDs contain blue light, but the actual proportion of blue light is relatively small. Compared to an incandescent lamp, a typical cool white LED may have about 40% more melanopic lux for the same photopic lux. Against a compact fluorescent light, it is only about 20%. Measuring that on a log scale would require huge sample sizes in humans. If we measure that over the long term—over exposure durations of days, weeks or years—we do not know what the biological effects would be.

Lord Rees of Ludlow: But has this not allowed much brighter car headlights and things like that, which may have separate effects on safety, et cetera?

Professor Stuart Peirson: Certainly. I think it was alluded to in the last session that if you make light cheaper and more flexible, people just use more of it. However, the technology for LEDs is very good. It is very flexible and tuneable, and there are a lot of opportunities to use that more sensibly to optimise our light environment in a better way. I do not think that has happened necessarily very well.

Lord Rees of Ludlow: Professor Wright, do you have any comments on that, and perhaps on any foreseeable developments that might affect the light environment in the future?

Professor Kenneth Wright: In the United States, the National Highway Traffic Safety Administration regulates the brightness of motor vehicle headlights. There are some examples of where it required a number of motor vehicle companies to replace the lights because they were too bright. There has not been any systematic analysis of access that I am aware of, but that is certainly recognised as a concern.

In terms of where we are going and developments, we have the capability to install highly tuneable LED lights. That way, when we have a better understanding of what dose, spectrum, duration, intensity, et

cetera, is best, we will be capable of controlling that and changing it across the day in places where we want to do this, such as the home environment, healthcare centres and places like that.

Again, on the future, we are now coming out with LEDs that more closely mimic sunlight during the daytime, instead of having these peaks in specific areas of the spectrum. That will be an opportunity for us to have better lighting relative to health, and we can adopt many of the principles we have been talking about.

Lord Rees of Ludlow: Looking further ahead, do you think that will be worthwhile?

Professor Kenneth Wright: Yes. I think we will have improved LED technology that will be able to simulate sunlight during the daytime. That is what we were always exposed to. If we can bring more sunlight indoors—and, where we cannot do that, if we can use LEDs to provide an exposure that more closely mimics sunlight during the daytime, and then remove that and have it tuneable so that at night we can get rid of blue and green light, have dimmer light and things like that—that will be to our health benefit.

Q36 **Lord Winston:** Thank you. Much of my question has been answered, I think, on where we ought to try to focus research. Clearly, we have to make recommendations for the Government; that is what we are here for. Starting with Dr Peirson, you have published extensively in animal research, particularly using mice. How valuable are those studies in translating them to human physiology? I wonder if you would like to talk about that specifically. There are a number of areas that you might want to elaborate on.

Professor Stuart Peirson: Absolutely. As you will all be aware, all models are wrong, but some are useful. Mice are not small humans, but the physiology of the circadian system and the melanopsin photoreceptors were first discovered in mice. Recent papers using human post-mortem retinas have shown that the diversity and responses of those cells are remarkably comparable in humans and mice. There are some small and subtle differences in retina structure and function, but the mouse data has been very important on the basic photoreceptor side.

Clearly, there are limitations of studying a nocturnal species and extrapolating that to a diurnal primate, particularly in the alerting and the effects on sleep. For example, light exposure at night makes a mouse go to sleep, whereas it increases alertness and prevents sleep in humans. However, the effects on the circadian clock in the SCN—the master circadian pacemaker in the hypothalamus—in terms of electrical activity and the molecular mechanisms seem broadly the same between nocturnal and diurnal species. The SCN is more electrically active during the day and less so at night. That is the same independently of whether a species is nocturnal or diurnal.

There are a lot of things that can be extrapolated. We must always bear in mind that our models are just that. They are not, of course, perfect representations of human physiology. At the same time, they are

certainly valid. One thing I have been an advocate for is trying to get human and basic scientists to work together to integrate our data better so that we can study the mechanisms and then extrapolate and translate that to human physiology.

Lord Winston: Would that be a basic area that you would recommend?

Professor Stuart Peirson: Certainly. Studying the detailed underlying physiological mechanisms in humans, as Professor Wright would probably attest to, is very challenging. Overall, the field has worked quite well in terms of the basic physiology, which generates experimental ideas that are then tested in detail as to whether they extrapolate to human physiology.

Q37 **Lord Winston:** I see that Professor Wright is nodding his head—I am sorry that we have disturbed your circadian rhythm this morning by asking you to get out of bed so early. Would you be kind enough to tell us more about the human issues? We have been talking a great deal about a number of areas. My own particular interest is in reproduction. I do not know of any proper study in humans, but I think this is a very important area to look at. What important areas of public health do you think we might want to look at?

Professor Kenneth Wright: Since you mention reproduction, I am familiar with one published study looking at artificial light at night and the impact on outcomes in labour, where prolonged labour and some potential negative or adverse effects were associated with the prior history of light exposure at night. There are some signals there, as well as everything we know about shift work and reproductive health, which light at night may contribute to.

On overall health, a lot of what we know scientifically—in the laboratories, for example—is assessed in healthy adults. We need more science targeting vulnerable populations, including young children, who are much more sensitive to light than adults are. So the recommendations we are making may have to be different for them, for example. We may have to have even tighter regulations and dimmer lights for children at night. Older adults are another part of the population to target, including those who are living in assisted care—in nursing homes, for example—so that we can get a better understanding of where light exposure or the lack thereof contributes to the risk of health disparities, including in shift workers themselves.

In order to help make policies, another thing that is key—we have alluded to this a bit—is that we need new assessments of exposure. We need to get beyond the satellite exposures and deploy technologies that can measure light using the metrics we are talking about here, looking broadly at spectral and intensity differences as well as personal exposure. So when we are talking about epidemiological or population health studies, we should look at personal light exposures to better quantify what timing, duration, spectrum, et cetera, contribute to the risk of health problems but also to the health benefits of light during the daytime. That is key here. We do not want to lose the opportunity to say

that we can enhance daytime lighting as part of our strategy to improve health and not talk about removing light at night. If we look at the human studies, both are important in determining the impact on our circadian rhythms, and they may both be very important in determining our outcomes for health.

Lastly, we also need to think about implementation research in order to translate the scientific advances that we have here into effective health messaging for the public—for example, the enhanced daytime lighting and what they can do in their home environment with these new tuneable lighting technologies. Again, this additional science will help guide policymakers, such as you, who are trying to help us to consider how to create healthier environments.

Q38 Viscount Hanworth: Dr Peirson, you were talking about animal studies. Does the presence or absence of colour vision have any effect on the interpretation of these studies and their relevance for humans?

Professor Stuart Peirson: That is a very interesting point. Mice have a slightly different visual system. They have two cone classes, rather than the three that occur in humans. The melanopsin system is tuned to 480nm in humans and in mice. Professor Rob Lucas in Manchester has recently been involved with a study—I do not think it has been published yet—looking at the spectral sensitivity of melanopsin across a broad range of species, expressing those pigments in vitro and characterising that sensitivity. It does not vary very much—we do not know why. To return to an earlier point about different sensitivity between individuals, there are polymorphisms in the melanopsin gene that occur in humans. That may be related to the differences in light sensitivity between individuals that have been described.

In terms of colour vision, we can take into account the differences in colour vision between animal models and humans. In a lot of the animal studies that we can do now, we can use animals—we can put the human red cone into a mouse, for example, so that it has the same red sensitivity as us anyway. So we can get around those kinds of issues with the genetic tools that we have.

There are issues here. One other key point is that a lot of the laboratory-based exposure studies have been done with full-field illumination over quite long durations, which does not necessarily reflect how we experience the world around us in the real world—for example, the fact that we move our heads around, there are different sources of light in our environment, or one area of our visual field is brighter than another. Under those natural conditions there may be more contribution from other photoreceptors as well as the extrinsic input into the melanopsin system.

Those are all research-based questions that we still do not really know the answers to at the moment.

The Chair: Professor Wright, do you have anything to add?

Professor Kenneth Wright: Not on that, thank you.

The Chair: Before we finish, I have to ask both of you: should we stop changing the clock twice a year?

Professor Stuart Peirson: Until I started looking at the evidence more, I was quite blasé about it. However, certainly in the springtime, we see that there are measurable rises in the rate of road traffic accidents and things like myocardial infarction. That does not occur in autumn—as my wife says, everyone likes an extra hour in bed.

The Chair: So you think we could make an economic case that we should give up doing this.

Baroness Neville-Jones: Or a health case.

Professor Kenneth Wright: A health case and an economic case. Absolutely we want to get rid of the time change, but it then becomes a question of what we do next. All the evidence points to permanent standard time being the healthiest choice, not permanent daylight saving time.

One of the things we have not highlighted as much in this session is that our exposure to light, especially in the evenings, delays our circadian rhythm. For us to have a delayed or later timing of our sleep in our circadian rhythm as a society is more unhealthy. That would be seen to a much greater extent if we went to permanent daylight saving time, versus permanent standard time.

There could be a whole other discussion to get into the details, but, absolutely, there are efforts happening in many places worldwide to pursue this. We need to have an in-depth discussion with everyone, so that way people will understand the risks if we choose permanent daylight saving time versus permanent standard time.

Q39 **Baroness Neuberger:** We have talked a bit about children and teenagers and their particular sensitivities. We also know that teenagers tend to sleep half the morning, if not all the morning. Should we think of very specific time ranges for sensitive groups? Would that apply to teenagers and children, and to older people? Should there be particular restrictions on light for those groups? We have covered bits of that question, but not all of it.

Professor Kenneth Wright: Certainly children are a group for whom we want to remove those electronic devices. We want to dim the lights in the house hours before they go to sleep. Those electronic devices are often used as babysitters and opportunities for parents to spend time with each other instead. We know that children are supersensitive to that light, so just a little light exposure to them is much more impactful than it is on adults. That is something we have to be concerned with.

We know that, for adolescents, getting up later is part of their biology. We also see that in non-human species—a delay in the timing of the circadian rhythm. When they go to bed later, they get more light exposure at night, which delays them even more. Then they have to get up early for school. There is a mismatch there, which leads to insufficient

sleep. Again, that is a major issue for health, mental health and substance use, which are certainly concerns among that population.

These general guidelines of enhancing light during the daytime and reducing light at night apply to all, but we also have to take into consideration the higher sensitivity of these groups compared to adults.

Professor Stuart Peirson: I totally agree with Professor Wright. The other thing is that that delayed phase and the consequences for attention and performance at school can have long-term effects on career prospects: if you do not perform well at school, that has knock-on effects.

Secondly, there is good evidence that daytime light exposure is particularly important in the development of myopia during eye development. I think this was discussed briefly in the previous session, but I would add that short-wavelength light and blue light exposure have been implicated strongly in that development, in terms of exposure and daylight exposure. Myopia is not just a case of being short-sighted. If you talk to clinical ophthalmologists and paediatric ophthalmologists, it is also a risk factor for the development of things such as age-related macular degeneration in later life, which is a major problem in eye health in most developed countries.

The Chair: Thank you very much to both our witnesses in this session, particularly for getting up so early in Boulder, Colorado. We have really appreciated it. I hope you have realised from the questions and follow-on questions that it has been a fascinating session. I remind you that you will get the transcript of this session soon, and you can come back quickly with any minor corrections that you want to make. If there is anything that you think of, or any data that you think would be useful to us, we would be delighted to receive that as additional evidence.