Increasing comfort on long-haul air travel in an economy class environment

Rick van de Westelaken

Report Final Master Project

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Department of Industrial Design
Eindhoven University of Technology

Assessment Panel
Prof. Dr. G.W.M. (Matthias) Rauterberg - Coach
L. (Lucian) Reindl - Assessor

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Introduction

Almost 2 billion people are traveling by airplane every year. A large group of passengers experience discomfort or stress in some degree during a flight. This is not surprising because on the one hand humans have not evolved naturally to fly and are better suited to terrestrial travel. On the other hand airlines try to fit as many chairs in a plane as possible to keep the ticket prices low with limited seating space in economy class as result.

In 2006 an European funded project entitled “SEAT” (smart technologies for stress free air travel) was set up to investigate and develop new innovative ways to improve comfort in air travel. The final master project described in this report is executed as part of the SEAT project and has the objective to improve the perceived level of comfort in air travel. Because the term “comfort” is quite broad it was further defined as reducing psychological stress and supporting passengers with their activities during a long-haul flight.

The structure of this report is overall similar to the process of the project. The project was started with a literature research about state of the art developments in the field of air travel regarding comfort. With the new insights an idea generation session was held with goal to explore different areas that could lead to improvements in comfort on long-haul flights. Mapping these solution areas on the schedule of a regular flight gave a concept direction as result. This concept direction can be described as a system that provides a rhythm to the passengers with goal to improve the flight experience and to reduce the experienced jetlag after the flight as much as possible. To reach this goal on the one hand it is desired to influence the mental state of passengers by letting them believe the time of day is different than the actual time. On the other hand it is desired to influence the biological clock of passengers. By delaying or advancing the internal circadian rhythm the passengers are prepared for the new day –night rhythm on their destination.

After defining the rough outline for the concept a second literature study to human

circadian rhythm was conducted. The insights gained with this literature study contributed to the final concept that was proposed in this project.
A prototype has been built with goal to conduct a user test to proof the principle of the concept. The result of this test can be read in the conclusion and discussion part of this report.

2

Problem & context

Air travel business has been rapidly expanding during the last thirty years and is approaching a number of 2 billion passengers every year. Despite the large number of passengers and long history of air travel a majority of passengers still experience some degree of stress or discomfort (World Health Organization 2003). This fact in itself is not surprising because humans are not evolved naturally to fly and are better suited to terrestrial travel. The causes of stress and discomfort related to air travel are mainly a result of the typical characteristics of flying. First of al there is a group between 10% and 40% that have a fear of flying. The fear of flying is not a single, unitary problem, but comprises several underlying fears, including a fear of crashing, heights, confinement, instability and lack of control (Bor 2007).

Secondly the physical behavior of aircrafts can result in physical discomfort such as motion sickness as result of vibrations and turbulence, pain in the inner ears as result of the relative low air pressure and irritations due to engine vibrations, noise and relative low humidity.

A third source for discomfort and stress has to do with flying as way of public transport. This category contains factors such as a small amount of seating space, long duration of a flight, annoying neighbor passengers, loss of day –night rhythm, a flight that doesn't match passenger's expectations, delays or worries about connecting flights.

It is difficult to address most of these stressors in a solution, while for some of the stressors already a solution exists. 'Simply' by buying a business class ticket the discomfort caused by the limited amount of seating space and neighbor passengers is resolved. For many passengers however traveling business class is not an option or the advantages are considered insufficient in proportion to the extra costs for the ticket.

Airlines are well aware of the experienced discomfort in economy class during long-haul flights. Since the public air travel market is highly competitive airlines try to differentiate their selves to strengthen their position towards the competition (Alamdari 1999). An obvious way for airlines to differentiate their selves in this market is to provide products or services during a flight that increases the level of perceived comfort. For this reason aircraft manufacturers, airlines and research institutes are continuous searching for ways to make air travel more comfortable. In 2006 a European funded project entitled "SEAT" (smart technologies for stress free air travel) was started with objective to take passenger comfort to a new level. A consortium of companies and research institutes including the faculty of Industrial Design at the University of Technology Eindhoven are trying to develop smart responsive seats and an interior environment with the capability of detecting physiological and psychological changes of passenger's condition in real time. The overall goal is to create an environment that responds to the individual requirements and desires and is not centrally controlled or manually adjusted (SEAT 2006). The project described in this report is executed as part of the SEAT project and aims at contributing to an improvement of comfort.

Comfort

Comfort is not a one dimensional concept, but a rather complex one. It contains objective ergonomic requirements as well as subjective impressions including feelings, perception and mood. This subjective nature makes it also very difficult to measure comfort on a simple way.

Many scientists make a distinction between comfort and discomfort. Comfort in this case is more associated with emotional experiences while discomfort is more related to physical aspects. This implies that an absence of discomfort not automatically results in comfort (Dumur 2004, Vink 2005 and 2007). Because every individual has his/her own subjective experiences and opinion about comfort it is very difficult to improve the perceived level of comfort. What for one passenger is important may not be relevant for other passengers. For example passenger A finds the leg space important while passenger B is more concerned about the chair width. Comfort on air travel is not only determined by space allocated to each seat, but implies all activities performed by passengers in the context they are in (Han 1997). According to Dumur et al (2004) the comfort in an aircraft cabin can be described by four different models:

"1) The passenger bubble, in which the passenger is isolated from disturbances and can pursue his/her own activities; 2) The health model, where the focus is on absence of discomfort, potential health dangers and annoyance, and on physical well-being; 3) The community model, in which passengers belong to a public-transport group, who communicate and share common experiences; 4) The aesthetic-economical model, in which comfort is perceived as being in an interesting, advanced and beautiful environment, for a reasonable price."

The measures to improve comfort for the different models can be contradictive (for example if the passenger bubble is made so comfortable that the passenger does not feel any necessity to leave his/her seat, this may cause medical problems). Besides the difficulty to create non conflicting solutions also factors like standards, safety regulations and economy feasibility plays an important role. This makes the design process very difficult and requires an iterative approach at the same time.

Current developments

Aircraft manufactures are trying to improve future planes from a mechanical point of view, with goal to decrease the noise and vibrations and increase the air pressure and humidity inside the cabin. This would already contribute to a better perception of comfort by passengers. Besides the mechanical improvements also airlines and research groups are developing things to improve the level of perceived comfort. Most research is focusing on different arrangements inside the cabin and on improving the chair from an ergonomic point of view (Aircraft interiors 2005, Tan 2007, vink 2007).

Another important area for improvements has to do with the in-flight entertainment. This has already evolved rapidly last decade, but here are still a lot of improvements to make (Liu 2007a). One potential development in this area is to make the in-flight entertainment system context aware, (Liu 2007b, Baldauf 2007). A last major area which becomes more important nowadays in aircraft cabin design is to create a certain atmosphere to improve the experience of flying and to decrease the tension that some passengers experience.

Overall it is clear that a lot of research is performed and developments are made to improve the quality and comfort in air travel. Although I believe there are many other potential areas in which major improvement can be made towards increasing the perceived level of comfort in air travel, which will be the goal of this project.

3

Idea generation

3.1. APPROACH

One of the things that became clear after a first literature study is why many people experience stress and discomfort and what type of activities are carried out by passengers during a flight. This understanding served as starting point for an idea generation session. Four master students of industrial design cooperated in an idea generation session. During this session the volunteers were asked to combine one or two discomfort factor(s) with a specific activity and to think of a solution that would improve comfort in relation to the chosen activity. This procedure was repeated a number of times with a total result of over 30 ideas. A selection of these ideas is shown in appendix A.

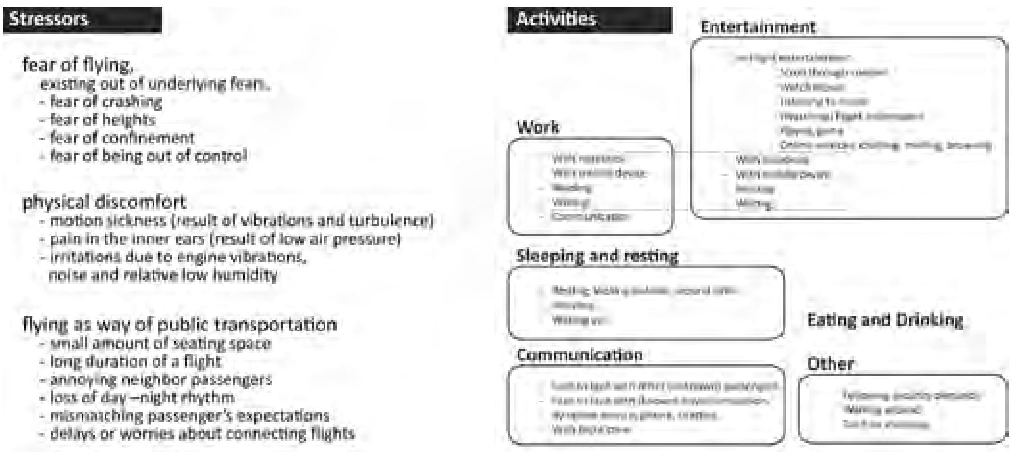


Figure 3.1, list of stressors and activities used during the idea generation session.

3.2. RESULTS

The original project objective is quite broad and a specific concept direction had not been chosen. For this reason the created ideas were not used as direct input for a concept, but the ideas were clustered to define possible directions for a concept. Six possible solution areas were the result after clustering the ideas. These solution areas are summarized below.

1. Private bubble to support work; isolate passengers in a way that they are less disturbed and more focused on their work related tasks.
2. Private bubble to support resting and sleeping; isolate passengers in a way that they are less disturbed while they try to rest or sleep.
3. Support and stimulate social interaction; establishing interaction among passengers (for example talking, chatting, multiplayer games etc) will distract them from the fact they are traveling by airplane.
4. Provide information /infotainment; a large group of passengers do not understand why an airplane can fly. Explaining fundamental principles and facts about the safety of flying could take away doubts and worries concerning air travel.
5. Create stress reducing cabin atmosphere; a cabin environment that changes according to the mental state of passengers could reduce the average experienced level of stress.
6. Arrange cabin in activity dependent zones; create an area especially intended for certain activities. For example an area for watching entertainment, an area for sleeping and resting, an area for talking and chatting, etc.

Two of the mentioned solution areas are disregarded as potential solutions for this project. The first one is the idea of a “private bubble to support work”. According to Alamdari (1999) a group of only 26% of the business passengers say they like to work during the flight and “there is some anecdotal evidence that while business passengers state that they would like all the business facilities possible in the air, in reality they prefer to relax and watch movies.” This means the potential user group of such system is relative small compared to the group that is served by developing one of the other solution directions. Second the idea of arranging the cabin into different zones would implicate that the current concept of public air transportation should change considerably. This doesn’t match with an initial requirement that a solution should be based on current airplane cabin lay-outs.
The remaining four solution areas will be used towards developing a concept that should increase comfort and support passengers during a flight.

3.3. CONCEPT DIRECTION

Besides the four solution directions that focus on only one activity during the flight I have been looking to the flight as collection of activities. Every flight starts with a take off period and ends with a landing period, in which it is not possible to use the in-flight entertainment system, or to use “detached” objects like a notebook or mobile music player. During the remaining part of the flight the timing of specific actions is controlled by the crew. For example the timing of serving meals and the timing at which the crew asks to close the windows and to be quiet (in order to give other passengers the possibility to rest or sleep) cannot be changed towards your own preference. This means there is more or less a schedule for every flight (fig. 3.2). The problem is that the passengers don’t know this schedule with the exact timing of the different events.

Figure 3.2, General scheme of long-haul flight.

The described solution directions in chapter 3.2 are in fact only applicable to a part of the flight. Ideally you only want passengers to sleep, being social or using in-flight entertainment on specific times of the flight. This means creating a solution based on one of the suggested solution areas would only offer a “solution” during a period of the flight. This does not even include the discomfort and stress caused by the flight after being landed on your destination location.

This analysis of the different solution areas in relation to a normal flight with its specific schedule resulted in a new potential solution area: provide a rhythm to the passengers during the flight to emphasis the transition from the local departure rhythm towards the new local destination rhythm and reduce the discomfort and stress after the flight (the jetlag).

After thinking through the different potential solution directions the most promising and most challenging direction in my opinion was the last one. For that reason I decided to continue with this direction and to make a solid concept to provide passengers a certain rhythm during the flight and to reduce the symptoms of a jetlag after the flight.

4

Concept

The main focus of the concept is to provide passengers a rhythm during long-haul flights to emphasis the transition between the local departure rhythm and local destination rhythm. This rhythm should on the one hand improve how the passengers perceive the duration of the flight and on the other hand minimize the results of jetlag after the flight.
The concept description created at this point was a reason for literature research into human daily rhythms and the phenomena called jetlag. Insights into this matter should lead to a well funded development of the concept.

4.1. LITERATURE RESEARCH

4.1.1. Jetlag

People may experience a “jetlag” when they go through several time zones in a relative short period of time. Jetlag is a condition characterized by various psychological and physiological effects including fatigue, headache, irritability, loss of concentration and the inability to sleep at the new night-time. These symptoms are a result of a de-synchronization of the human body clock with external environmental clues. The human body clock is synchronized with environmental clues like the light/dark cycle and timing of meals. After crossing more than three or more time zones in a short time the body clock is desynchronized with the “new” environmental clues. This can result in the above mentioned symptoms and it takes some time before the body clock is adjusted to the new rhythm.
The severity of jetlag depends on the number of crossed time zones and direction. Flights to the east are typically experienced worse than westwards flight. Besides external influences there are individual differences in the symptoms and severity of the

symptoms experienced. Age for example seems to have influence on the severity of the jetlag symptoms. Older travelers appear to have more problems than younger travelers (Waterhouse 1997, Waterhouse 2007, Revel 2005). The reason for this however is unclear. Fripke et al. (2007) tested the hypothesis that older adults have absent or weaker phase-shift responses to light. Although the results of his experiments showed similar phase shifts between young and older adults.

Advice given by airlines and specialist to travelers regarding jetlags includes to remain in the old rhythm (rhythm at departure) when the stay in a country is 3 days or less. Another common advice is to start adjusting to a new time zone by changing the sleep wake rhythm in combination with exposure to light starting a few days before the flight (Revell 2005) or slightly different to take light therapy the first days after the flight.

These are good recommendations but the problem is only very few people know about this and it requires considerable effort from the passengers.

4.1.2. Human biological clock

The key function of the biological clock is to provide the body with an internal estimation of the environmental time. The biological clock is responsible for regulating daily and seasonal dependent cyclic bodily processes. These cyclic processes (fig. 4.1) include regulation of core body temperature, production of the hormones cortisol (stress hormone) melatonin (sleep hormone), blood pressure, attentiveness and timing of sleep (Beersma 2006). All these different rhythmic processes explain for example why humans are better in mental tasks in the morning and physical performance in the afternoon (Smolensky 2000) (fig. 4.2).

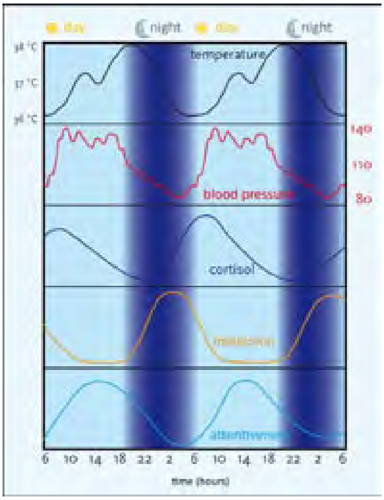


Figure 4.2, daily biological rhythms. Source: "Chemische feitelijkheden" edition 58, nbr. 252.

The main body clock is a paired group of nuclei at the base of the hypothalamus entitled the suprachiasmatic nuclei (SCN). Normally one period of the SCN, also referred to as Free Running Period (FRP) would be longer than 24 hour if it wasn't adjusted. The exact length of this FRP is different for every individual but for the majority this length is more than 24 hours. According to Duffy and Wright (2005) there is evidence from forced desynchrony period assessment studies that indicates an average FRP in humans of about 24.2 hours (24 hours and 12 minutes). The difference between the environmental period and the human FRP introduces the process of entrainment. This process makes the length of your biological rhythm more or less equal to the length of the environmental rhythm (Johnson 1999, Johnson 2003). "Entrainment" is not the same as "synchronization", which implies

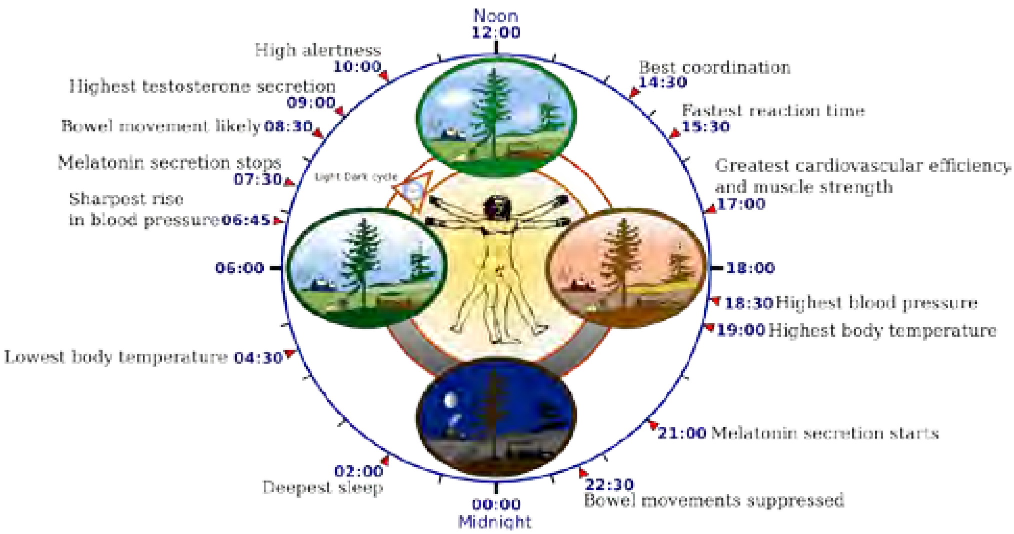


Figure 4.2, effects of biological clock on human daily rhythm. Source: WikiPedia

that the waveform of the environmental rhythm coincides with the waveform of the rhythm of the biological clock. A person with a FRP of 24.2 hours needs to entrain daily a 12 minutes phase-advance shift.

The entrainment process is controlled by so called zeitgebers ("time-givers"), which are rhythms resulting directly or indirectly from the environment (Gornicka 2008, Revel 2005, Rimmer 2000, Waterhouse 1997 and 2007). These rhythms include the daily cycle of light /darkness, temperature, food availability, activity/inactivity and social influences. The effect of most zeitgebers depends highly on the time at which it is presented. The phase shift of the biological rhythm can be plotted as function of the circadian phase that a zeitgeber is presented to a person. The plot of this relation is called a phase-response curve (PRC). The best known PRCs are the one for lighting and for melatonin intake (fig. 4.3).

As you can see in figure 4.3 it is not possible to make phase advance or phase delay shift larger than a few hours. Even when for example light pulses and melatonin intake is combined and given at the exact right time the maximum daily shift is only a few hours. For this reason it takes a number of days before jetlag symptoms are passed away and your body clock has synchronized with a new daily rhythm. This also explains that a jetlag is more severe when more time zones are crossed.

Also the difference in jetlag symptoms between westward and eastward flights can be explained. Since humans have an average FRP of more than 24 hours this would mean a phase advance in body clock is more difficult than a phase delay. This gets clear with an example of a person with a FRP of 24.2 hours. To get a phase advance of 1 hour this person should actually have a phase shift of 1.2 hours (72 minutes); 1 hour plus 0.2 hours

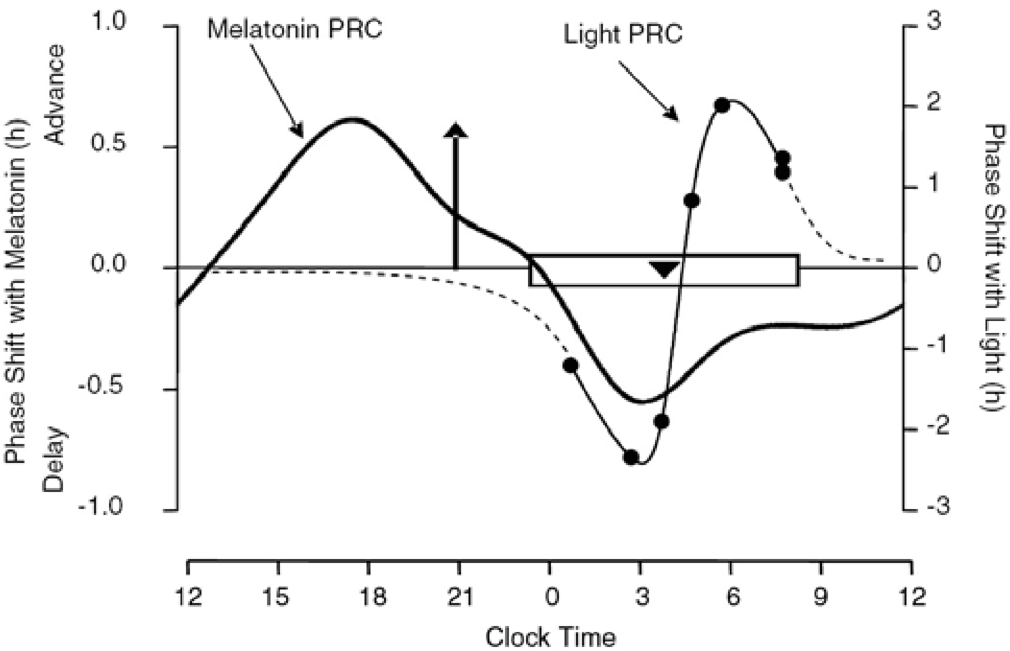


Figure 4.3, Human phase response curve to bright light and melatonin. Source Revell 2005

to entrain to the 24 hours daily rhythm. For a phase delay of one hour the shift only has to be 0.8 hours (48 minutes); 1 hour minus 0.2 hours. For this reason it is advised to treat an eastward flight crossing 10 or more time zones as a westward flight (10, 11, 12 hours eastward can be treated respectively as 14, 13, 12 hours westward)(Waterhouse 2007). It may be clear that the more time zones crossed, the longer it will take before a person's body clock is synchronized with the new environmental time. There are situations known where people are still experiencing a jetlag after more than 13 days after being in a new environmental time (Boulous 1995). This extreme long period of being de-synchronized is especially a risk associated with eastward travel and is caused by antidromic re-entrainment (Revel 2005, Boulous 1995). Antidromic re-entrainment is phase shifting in the wrong direction and is caused particularly by exposure to light at the wrong moments. This is possible after crossing 7 or more time zones to the east. The period in which people delay their body clock by exposure to light is shifted towards day-time, while a phase advance is required after an eastward flight.

4.1.3. Light/dark cycle as main zeitgeber

The most consistent and influential environmental time cue is the daily cycle of light and darkness. For already a long time it is clear that light has a large influence on the biological clock, but until 2002 scientist could not explain why. For more than 150 years we only knew rods and cones as photoreceptors in the human eye. Humans are capable of generating a visual image of our environment by the signals from these photoreceptors.

In 2002 David Berson et al. (Berson 2002) discovered a third type of photoreceptor, ganglion cells that are responsible for regulating biological effects in the human body. Light perceived by these photoreceptors is converted to electric pulses that go directly to the SCN by a direct nerve-connection (Bommel 2004, Bommel 2006).

The spectral sensitivity of the photoreceptors that influences biological effects of the human body differs from the spectrum sensitivity of the photoreceptors that are responsible for human visual perception. The visual system is sensitivity for light between 400nm and 700nm and has a peak around 570 nm. The biological system on the other hand is most sensitive for light around 464nm. (Brainard 2001) (fig. 4.4) . In order to make a phase shift as large as possible it seems obvious to use blue light (with wavelengths around 464nm). Studies that have been conducted to test this assumption proved that it is possible to cause a large phase shift with a relative low intensity of blue light (Glickman 2006, Brainard 2008).

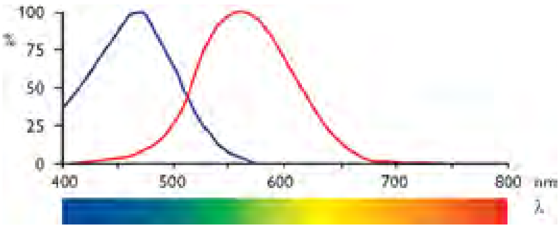


Figure 4.4, biological sensitivity for light based on melatonin suppression (in blue) and sensitivity of visual system (in red) Source Bommel 2004

Unfortunately exposing humans to blue light introduces a risk on so called blue light hazard (Roberts 2006, Smith 2005). These scientists believe chronic blue light may be toxic to a large group of people and can result in retinal injuries. Since the group of people traveling by airplane every year is very large and diverse, usage of blue light is strongly discouraged.

4.1.4. Conclusions

It is possible to make a shift in the human biological clock by exposing humans to light or to take away light at the right moments. The phase shift depends on the human's FRP, timing, intensity and wavelength /color of the light. An indication for the expected phase shift can be retrieved out of the phase response curve for light (fig. 4.3). The relation between expected phase shift and the color and intensity of light can found in dose response curves (Zeitzer 2000, Brainard 2001). The timing is crucial and as you can see in the PRC there is a turning point from phase delay to phase advance somewhere in the middle of the night. This exact point can be found by monitoring the core body temperature, because this turning point is reached at the same time as when your body temperature reaches its daily absolute minimum.

Keeping this all in mind a maximum phase shift of about 2.5 hours is the maximum that could be achieved with a certain system during the flight. For many people a shift of 2.5 hours is a considerable advantage. Furthermore you should not forget that such system would prevent or at least minimize a chance on antidromic re-entrainment. This makes the added value of such system even better.

4.2. CONCEPT DESCRIPTION

The idea generation session and the literature review resulted in a good overview of the possibilities and details for a concept. For this reason a general description of the concept was made to act as guideline for working out the detailed and precise description of the concept.

The objective of the concept is to provide passengers a rhythm that that should serve as a transition between the local departure time and the "new" destination time. Important aspect of this rhythm is that is should do this in such a way that it will also minimize the jetlag after landing. Minimizing a jetlag should be done by phase-advance (eastward flights up to a maximum of 9 crossed time zones) or phase delay (westward flights and eastward flights crossing 10 or more time zones) the biological clock by controlling the light in the cabin. This means absence of light in periods where a negative shift could occur and providing lights when a desired shift could occur. Parts that should be considered for controlling the overall lighting conditions in the cabin are:

- Main cabin lighting
- Light coming through the windows
- Reading lights, indication lights and other light (for example light on toilet)

Important to keep in mind here is that not all passengers have the exact same circadian rhythm and that there is a large difference between people that are on a direct flight, or having a stopover. This means there should be a method to determine the rhythm of the body clock of individual passengers. The possibility to have lighting directed to one person could be very helpful.

Besides influencing the biological clock, another part of the concept is to provide a certain rhythm to make the time gradually change from local departure time to local destination time. Further on in this report this will be called "transition time". Providing a rhythm to the passengers is partly done by the lighting, simulating a sunset or sunrise but this could be strengthened by subtle clues integrated in the in-flight entertainment system. The main focus of these subtle clues is to make people belief that the transition time is the "real" time.

In the remaining part of this chapter the concept is worked out in more detail with corresponding reasoning behind these details.

4.3. TIME TRANSITION CALCULATION

The transition time as stated before is the lapse of time from local departure time towards the new destination time. Variables that are important for this transition time are: local departure time, local destination time, flight duration, the number of crossed time zones and the direction.

An obvious way to divide the time over the flight duration is to do this linear. For example for an eastward flight of 11 hours that crosses 6 time zones this would mean that one minute in real-time would be 1:33 minutes in transition-time (fig4.5).

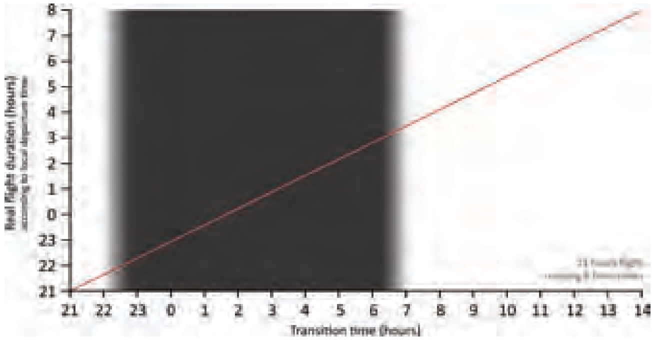


Figure 4.5, Linear relation between flight duration and transition time

For some flights this single linear curve is all it takes. This is the case for flights on which the optimum moment for exposure to light is actually not during the flight. In cases where an optimum moment for light exposure is situated during the flight a different approach for calculating the transition time is required.

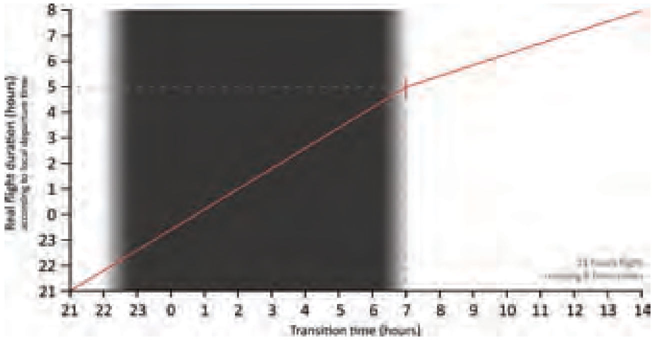


Figure 4.6, Relation between flight duration and transition time with moment to start light exposure

The optimum time for exposure to light and darkness is reasoned based on the local departure time. For an eastward flight light exposure on average should start around 5 a.m. and for westwards flight light exposure is desired until 3 a.m. Ideally this moment of light exposure should match with a point in transition time that makes sense to the passenger. For example when simulating a sun-rise at 5 a.m. local departure time it would make sense to make the passengers believe that is around 7 a.m. instead of 10 a.m., which feels quite unnatural. This has as result that the earlier described linear curve is split into two linear curves (fig 4.6). In these cases it is important to keep the slope of the two lines (in other words the transition-hours to real-

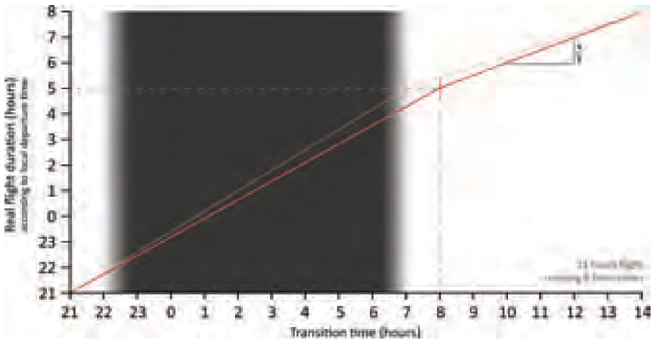


Figure 4.7, Relation between flight duration and transition time where moment for light exposure is shifted to keep slope in-between boundaries

hours ratio) in-between certain boundaries. The reason to keep it in-between boundaries is important because a too steep or too flat slope would feel unnatural. For example when the transition time goes 3 times faster than real time (1 minute in real time would be 3 minutes in transition time) is would be hard to believe. When the transition-hours to real-hours ratio is outside the determined values the light exposure point regarding to the transition time needs to be shifted as far as required to keep the transition-hours to real-hours ratio between boundaries (fig 4.7).

The process described above is focused on calculating the transition time for one individual person. In an airplane cabin this calculation should be based on the biological rhythm of all passengers in one row of connected chairs. The reason for this is because first of all it is strange when the transition time on the screen of a neighbor passenger is different from the transition time on your own screen. Secondly it is possible to simulate a sunset or sunrise per row of connected seats (see chapter 4.7.1).
More specific for an eastward and westward flight it means the passenger in a row of connected chairs with the latest optimum moment for light exposure is leading for this calculation.

Finally a last remark regarding the transition curve is whether this should be linear or maybe more complex in a way that the transition-hours to real-hours ratio gradually changes from 1:1 to the desired ratio. During a literature search to the perception of time no information was found regarding this subject. In order to give an answer on this question, extensive research is required. For this reason in the scope of this project there are no recommendations regarding this subject.

4.4. ARRANGEMENT OF PASSENGERS IN AIRCRAFT

Making the right arrangement of passengers inside the aircraft is crucial for the effectiveness of the concept. Passengers that are continuing a flight after an intermediate landing have a fundamental different biological rhythm compared to travels on a direct flight or who have an intermediate landing after the flight. Ideally the passengers should be arranged in such way that the people with approximately the same biological rhythm are placed close together.
The determination whether passengers are on a direct flight or having intermediate landings as well as the question if passengers' stay are longer than three days or if they have shifted their circadian rhythm already before the flight could be retrieved at the moment that people book their flight in the form of a short questionnaire. With this information it is possible to make a rough division of the passengers regarding their seat in the aircraft cabin.

The more accurate the data concerning the biological rhythm of passengers the more precise arrangement could be made, which results in a more efficacious system. In order to get more detailed information about the passenger's biological rhythm some solutions are proposed:

Online questionnaire

A passenger can get a reminder (by mail or text message) a few days before a flight to fill in an online questionnaire. This questionnaire is intended to retrieving the sleep/wake cycle of a passenger the week before the flight. This sleep /wake cycle could be used to get a better estimation of the passenger's biological rhythm. It should be possible to fill out this questionnaire in about 5 minutes and include questions about the sleep/wake cycle on workdays and free days.

Application for mobile phone

You can offer people to download an application for their mobile phone when they book a flight. Depending on the type of mobile phone this application could be more intelligent and require less user involvement. On some devices the application will ask everyday (for a certain period) explicit what time a person went to bed and woke up. When a mobile device is more sophisticated it can try to retrieve the sleep/wake cycle based on settings made in alarm function and on movement registered by an integrated accelerometer. In all situations the required data is automatically sent to airline that needs this information.

4.5. DETERMINE PASSENGERS' LIGHT EXPOSURE SCHEDULE

Crucial for the system is to know the exact timing for light/darkness exposure for every individual passenger. It is preferred to have a "context aware" system that excludes explicit user input. To realize a context aware system an indication for the human biological rhythm is required. There are a few solid ways to measure the human biological clock. This can be done by measuring the cortisol or melatonin levels in the human body or by measuring the core body temperature.

The cortisol or melatonin levels are not suitable as input for a context aware system because it is not possible to retrieve these hormone levels without user effort. Besides determining these levels is a complex process which takes quite some time, while values in real time is preferred. Furthermore stress has a large influence on the cortisol production, so this would not be a valid measurement method because a lot of people experience stress during a flight.

This leaves the core body temperature as last option for input in a context aware system. Measuring core body temperature can be done in several ways, but since comfort is a very important aspect of this project, oral, rectal and axillary measurements are excluded. This leaves otic (in the ear) measurements as last accurate way to retrieve the core body temperature. Using in ear measurement is doable when the IR sensor to do this is integrated in the in-ear headphones that normally are handed out by the stewardesses in the beginning of a flight.

To test whether in ear measurement is a reliable option a consumer in ear thermometer (Braun Thermoscan IRT 3020) was bought and adjusted (fig 4.8) to measure a daily temperature curve of a person.

Figure 4.8, photo of adapted in-ear thermometer used to investigate the option to use this type of measurement to retrieve a human core body temperature curve.

The conclusion of this test is that the positioning of the sensor in the ear is very important. With the slightest changes in position of the sensor the measured temperature varies. This difference in measured temperature is even too large to get a usable temperature curve that could serve as input for the system. Furthermore being dependent on headphones as sensor device has a big disadvantage, because in fact most passengers do not use the headphones during the entire flight or do not use them at all. Finally measuring skin temperature by infra red sensors was considered as input. It turned out that there is not a good relation of skin temperature related to the biological rhythm, which excluded this way of measurement as well.

This means that as long as there is no accurate way to measure the biological rhythm in real time in a comfortable way a short questionnaire at the beginning of the flight is necessary to get an indication of individual passenger's biological rhythm. Passengers that have filled in this questionnaire before the flight or used a special application on a mobile device could off course skip this questionnaire at the beginning. Because this type of input is less accurate than a sensor system it is highly desired to eventually find a way to measure the biological clock by a smart sensor system.

4.6. PASSENGER'S MENTAL STATE

Part of the concept is to make people believe that the transition time is the real time. This is useful as stimulation for people to rest or sleep at the right times. An important part of this believe is result of the sunrise and sunset simulated by the lights in the cabin. Furthermore the in-flight entertainment (IFE) system can serve as a perfect platform to trick passengers. An enumeration of small clues on the IFE system could form a convincing way to trick passengers. Some examples are:

Time indication
By showing a clock on the IFE screen that actually shows the transition time people might think this is the actual real time.

IFE menu
The appearance of the IFE menu could indicate the time of day according to the transition time.

Flight information
The appearance of the flight information could indicate the time of day according to the transition time. In comparison with current flight information clues like the day/night rhythm projected on a map of the earth should be removed

Available content
The movies offered by the IFE system could dynamically change according to the transition time. For example in the evening hours action movies are offered while during the night documentaries and late nights shows are offered. Also the duration of the movies can differ for eastward and westward flights. On eastward flights relative short movies are preferred because during these flights transition time goes faster than real time and on westward flights this is the opposite.
Finally also the music should change dynamically. In the evenings the music should be more relax, supporting people to rest and in the morning it may be more active music to prevent people to fall asleep again.

There could be more ways to emphasis the transition time, but the above described ways are considered as the most persuasive ones. How such dynamic IFE system could look can be seen in the prototype part of the report (chapter 6).

4.7. PASSENGER'S BIOLOGICAL CLOCK

Part of the concept focuses on creating a shift in passengers' biological rhythm. This shift should be achieved by controlling the lighting conditions inside the cabin.

4.7.1. Cabin lighting

On present day aircraft the lighting is basically realized on two different ways. This is by indirect lighting integrated in the walls and/or ceiling (fig. 4.9) or by illuminated surfaces in the ceiling directly above the aisle (fig 4.10). Furthermore the direction of the lights is always longitudinal. When it is tried to influence the biological clock with this lighting it will only have limited effect because of its relative low brightness. Besides it is not

Figure 4.9, Indirect lighting on present day aircrafts

possible to use this lighting to address parts of the cabin.

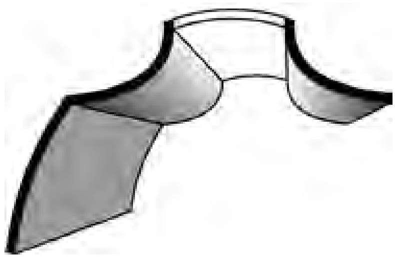


Figure 4.10, illuminated surfaces on present day aircrafts

Both of these shortcomings can be solved. First the positioning of the lights should be in the same direction of the chairs. Secondly indirect lighting should be used to illuminate the cabin's wall and ceiling per row of chairs and produce bundled light directed to the head area of the passengers per row of chairs (fig 4.11). This way it is possible to illuminate parts of the cabin with higher intensities of light. Besides if the arrangement of passengers is done in a way that the back row should be exposed to light first it can start in the back and gradually illuminate the cabin to the front.

A last remark, it is important that the light intensity can be controlled. This is necessary to simulate a sunrise or sundown on a convenient way towards the passengers.

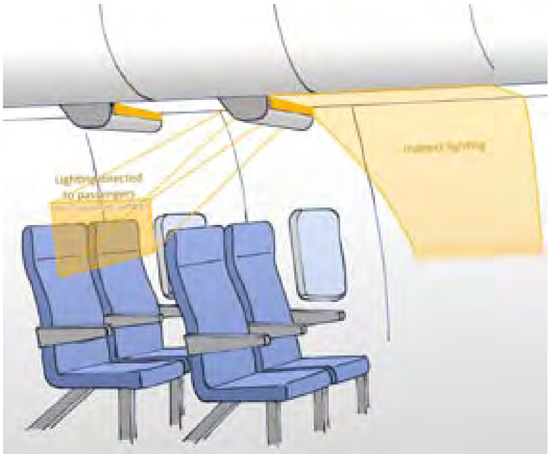


Figure 4.11, proposal for cabin lighting

4.7.2. Individual directed lighting

To solve the problem that the biological rhythm of individual passengers will never be in phase with each other it is desired to expose individuals to light without exposing surrounding passengers. By locating a light source in the chair in-front of a passenger it is possible with help of lenses, directional light or polarizing filters to direct this light to the "head" area of the passenger. When the light is well direct it should not influence the biological clock of other passengers.

It is advised to use monochromic light with a wavelength between 500nm to 530nm. Light with a wavelength around 464 nm is more effective, but also introduces a risk on blue light hazard which should be prevented at all costs. The desired intensity of the light depends on the exact wavelength of light (Brainard 2001), but for wavelengths in the range of 500nm to 530nm an intensity of 10^{14} photons/cm^2/second is enough for an effective system.

4.7.3. Other lighting

Reading lights

The effectiveness and therefore the success of the concept is highly dependent on the control over the entire lighting condition in the plane's cabin. A disadvantage of this desire to have full control is that passengers might feel even more out of control than they already are. This could even lead to annoying feelings. For this reason just disabling the reading lights at certain moments is not really an option. When exposure to light is interfering with the desired phase shift the reading lights can just give bright or warm white light, as it is today on airplanes. For the moments that exposure to light should be prevented there are actually two variables that can be tuned towards a possible solution; light intensity and color. The wavelength (color) of the light should be preferable as high as possible and the intensity of the light as low as possible. It may not be forgotten that the visual (reading) conditions should be on a reasonable level, which means a certain color and intensity is required.

Based on individual passengers it is possible to change the wavelength and intensity of the reading light. Normally this light may be bright white with a considerable intensity, but when absence of light is preferred the color could shift more towards orange or red light in combination with a decrease in intensity. This way reading a book for example should still be possible, although it has less to no effect on the biological rhythm of the passenger.

Indication marks

In the entire cabin lighting is used to show the pathway and safety exit. There is no doubt about the importance of these marks, so they should absolutely be well visible. Regarding the relative low intensity of light used in these types of indication marks the color of light has not a very large effect on the passengers' biological rhythm. Nevertheless the usage of blue light is strongly discouraged.

Lighting in toilet

The lighting in the toilet might interfere with the preferred lighting exposure schedule of passengers, but a certain light intensity is preferred here. Therefore it is advised to filtering out the lower wavelengths in the light, to reduce at least partly the negative effect on passengers.

4.7.4. Aircraft windows

To control the lighting conditions in the cabin it is important to rule out uncertainties regarding user interference. This can be reached by using smart glass, which is glass with the capability to change its translucency. Currently there are two promising smart glass techniques available; SPD (Suspended Particle Device) and ECD (ElectroChromic Device). From these two SPD is currently the most suitable technique to implement in an aircraft.

SPD is a technology where microscopic light absorbing particles are dispersed in a liquid suspension, which is enclosed between two glass or plastic plates coated with a transparent conductive material. By applying a voltage on the plates the particles are forced to align, which results in a change of translucency of the material. The translucency can be regulated by changing the applied voltage.

There are different translucency ranges available for SPD technology and the switching speed is even by -40 degrees less two seconds for a complete tint change. The weight and energy consumption should not be a problem for usage on a plane. The weight of this technique is negligible compared to the weight of the window itself. The power consumption is maximal 0.64 watts per square meter in full translucency state and the technology doesn't require any power in full opaque state. Since the SPD film is not hazardous or flammable it has passed stringent FAA flammability tests for use in aircrafts.

The translucency of the windows is determined and set based on the light/dark cycle according to the transition time in combination with the data from one or more light sensors measuring the lighting conditions outside the plane. An impression of applying this technology in an aircraft is shown in figure 4.12.

Figure 4.12, The effect that can be reached by SPD technology

5

Market potential of concept

Providing products or service on a flight that increases comfort can influence people in buying a ticket. According to Brauer (2004) airliners can increase their financial margin by 1% if they manage to get 1% more passengers onboard. Brauer (2004) has also studied selection behavior of passengers. It appears that passengers first select on point to point transport, time and price. Then aspects like marketing followed by comfort, past experiences and delays are important. Especially for long-haul flights the comfort aspect plays even a more important role.

Like the concept all products and services related to (long-haul) air travel can be divided into four categories (fig. 5.1). These categories are core, expected, augmented and potential products and services. Nowadays aspects of scheduling, safety and reliability are typical core values. Features that could be considered as additional to core values but nevertheless expected by passengers such as provision of food and drink, seat comfort, frequent flyer program and in-flight entertainment are typically expected values. The features described in these first two categories are widely applied by all airlines worldwide. The airlines have to provide these features in order not to be outdated by the competition.

The third category entitled "augmented" contains products and services provided by some airlines but not typically expected by passengers. These features are for example

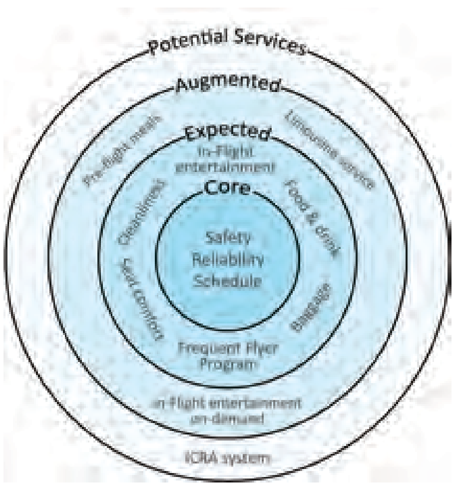


Figure 5.1, Four categories related to products and service used by airlines.

pre-flight meals, limousine service or on-demand in-flight entertainment. The airlines that provide these features try to differentiate their selves from the competition with goal to strengthen their market position in the already very competitive market of air travel. Some specific airlines known as innovators (Singapore airlines, Emirates airlines, Virgin Atlantic, Malaysian airlines and Swissair) look for new product and service innovations that could be integrated in their fleet. These potential products and services can be classified in the fourth category entitled “potential services”.

Sometimes a feature introduced by airlines as augmented can become expected by the passengers and therefore shift from the augmented to the expected category. A clear example of such feature is in-flight entertainment. Back in the nineties only offered by a few airlines but nowadays available in almost all long-haul flights. On-demand movies on the in-flight entertainment system is nowadays still an augmented feature, but this will most likely become an expected feature as well in the near future.

When a feature is classified in the augmented category an airline tries to generate more revenue by implementing this specific feature. This revenue should be a result of an increased number of passengers. When a feature makes a shift towards the expected category the question is not how much revenue it will make, but how much loss of revenue is made as result of the lack of the feature.

Currently the concept could be classified as a potential service. Extended user tests should be done to find out the effectiveness of the system. If it can be proved that the system has a significant advantage regarding the experienced jetlag symptoms an airline might decide to introduce it in their fleet. At that point it would become an augmented feature. When it also proves to be effective in real practice and when passengers could really appreciate the system it might become more expected, with as highest goal to be implemented by more airlines.

Before the system will be classified in the “expected” category there is still a long road ahead. Improvements need to be made, but more important the reliability of the system should be guaranteed. Without a stable system it will be less likely that people accept such system. Maybe an even bigger concern is whether people are willing to accept the system in general. For example the choice of blocking the ‘outside vision’ to create a dark cabin might be unacceptable for a group of passengers.

Depending on the effectiveness of the system, the acceptance by potential users and the willingness of airlines to integrate such system in their planes will eventually determine whether this system could become a success and help a large number of passengers to reduce their jetlag after a long flight. Until further experiments with the system it is hard to predict what will become of the concept.

6

Prototype

It is assumed that the concept presented in chapter 4 could lead to a phase shift in biological rhythm and that the transition between local departure time and local destination time with the concept is preferred above current situations. Especially the first part of this assumption is based on a literature study, but not tested in a real economy class cabin environment. In order to get these answers a prototype of the system was build into the simulation lab (a detailed copy of a part of an aircraft for user-testing purpose) for an extensive user test at the end of the project.
The starting point for this prototype is a long-haul eastward flight, because eastward travel is related to more severe jetlag symptoms than westward travel. For this reason the prototype is made for a simulation of a flight from Amsterdam to Shanghai, which means an 11 hour flight crossing 6 time-zones. Furthermore it may be obvious that the prototype should approach the described concept as much as possible. The prototype can be divided in two main parts; the in-flight entertainment system (software only) and the hardware (lighting, casing and control software).

6.1. IN-FLIGHT ENTERTAINMENT SYSTEM

The in-flight entertainment (IFE) system is a system that broadcasts flight information, movies, music, games, etc on a screen in front of every passenger in an airplane. In case of the prototype all the content is broadcasted on-demand, which implies that all individual passengers can access their preferred content whenever they want. The in-flight entertainment system as part of the concept is a software application viewed and controlled by the users by means of a touch screen interface.
The IFE system has two functions. First providing a graphical user interface to the

passenger and second controlling this interface and logging the actions performed by a passenger (fig. 6.1).

The interface for the passengers can roughly be divided in four parts; calculating transition time, menu appearance, flight information and available content dependent on transition time.

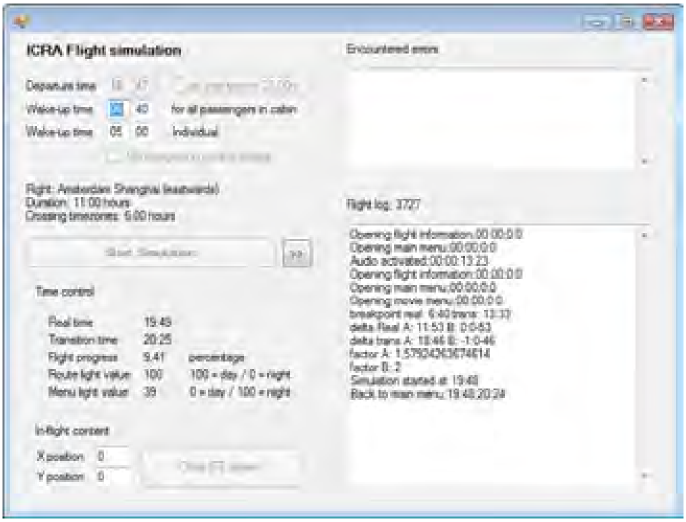


Figure 6.1, Screenshot of control and logging part of IFE application

The control and logging part of the software is made with Microsoft's .NET programming language C# (pronounced as 'C-sharp'). The graphical user interface for the passengers is realized by using Adobe's Flash. This choice is made because Flash was in this specific situation a better tool for creating the interface and since there are good ways in C# to set-up a link with a Flash file to share variables and functions this choice is made. Finally a Microsoft Access database was created to store the log data and to retrieve data that was necessary for dynamic movie system.

Calculating transition time

The transition time is calculated as described in chapter 4.3. This transition time is used as guideline for all the other components in the IFE system.

Menu appearance

The menu should give passengers an indication that it is day, night, dusk or dawn outside. This is not necessarily the real situation since the transition time is leading in this. To achieve this persuasion an image of the skyline of shanghai was taken as a background of the IFE menu. This image is built up out of three layers; a background layer, skyline by day layer and skyline by night layer (fig. 6.2). The first two layers change in brightness and the last one in transparency as function of the transition time. The use of these three layers result in a realistic transition from day to night view and the other way around corresponding to a convenient timing regarding the transition time. The exact timing and corresponding changes of the different layers is shown in figure 6.3.

On top of the background indicates an analogue clock the transition time and are links available to the flight information, movies and music. The final appearance of the IFE menu is shown in figure 6.4, where you can clearly see differences in appearance on different times.

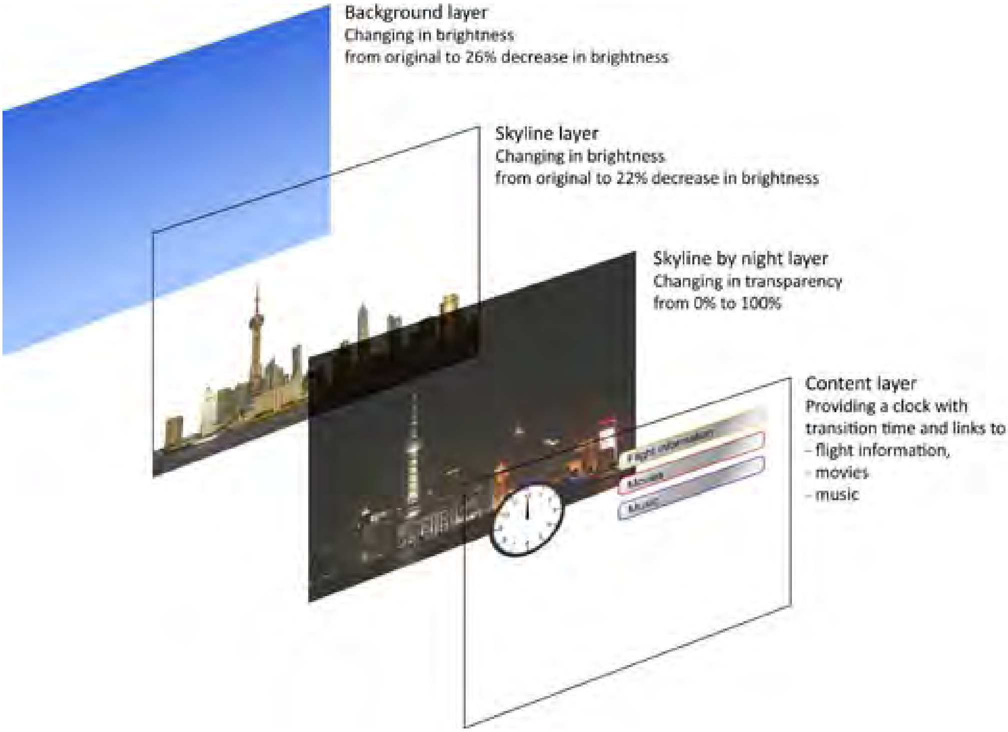


Figure 6.2, the layers used to built the IFE menu

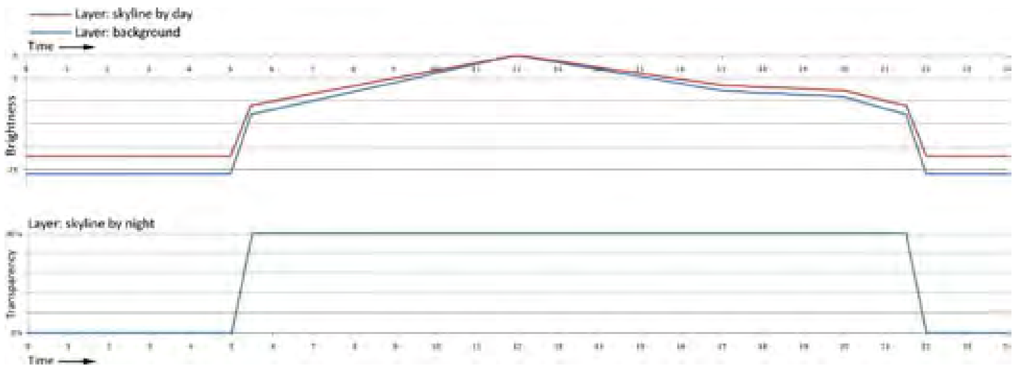


Figure 6.3, exact timing of changes made to the individual layers

Figure 6.4, Final appearance of the IFE menu on four different moments in time

Flight information

The flight information is an overview of the current status of a flight. This includes the position of the plane in relation to the world, ground speed, altitude, distance to destination and outside temperature. The background of the flight information screen is a map of the world on which a small airplane is projected to indicate the real position of the plane

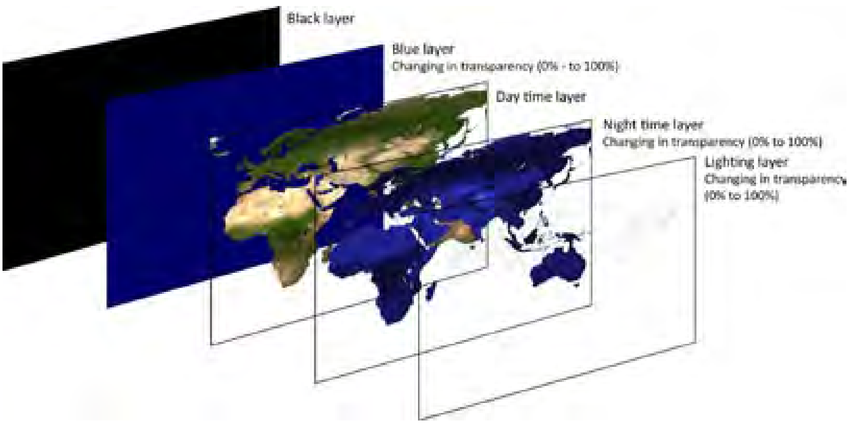


Figure 6.5, the layers used to form the background of the flight information screen

in relation to the world. This background is built up by five layers which can dynamically change its transparency as function of the transition time (fig 6.5). The use of these layers result in a realistic transition from day to night view and the other way around corresponding to a convenient timing regarding the transition time. The transparency of the different layers regarding the transition time is shown in figure 6.6.

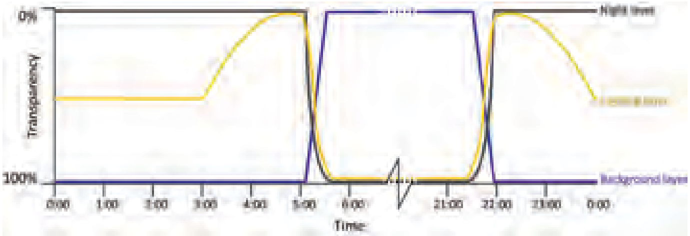


Figure 6.6, exact timing of changes made to the individual layers

The plane is moving over the screen from departure location towards the destination location according to the curve a real airplane would fly from Amsterdam to Shanghai. To make the flight information screen more interesting for the user the possibility to zoom is integrated. When a user zooms in more details appear on the screen.

The indicated ground speed, altitude, and outside temperature are comparable to a real flight. The values are randomly fluctuating around a defined value to make this information more convincing for the users.

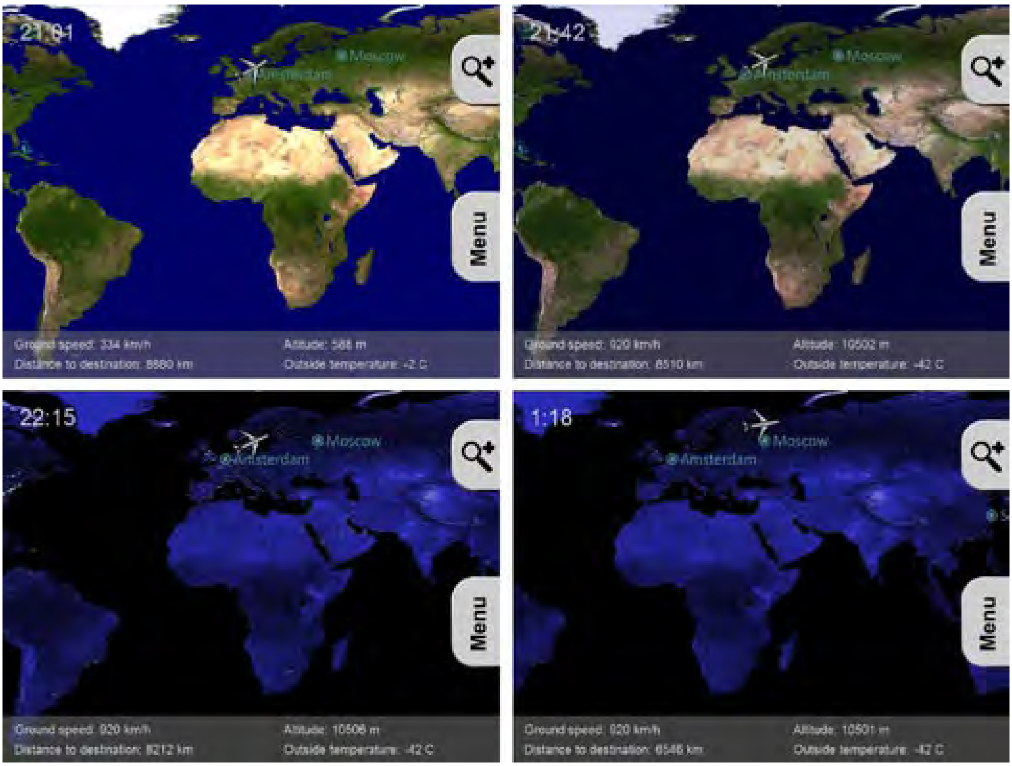


Figure 6.7, Final appearance of the flight information screen on four different moments in time

The final appearance of the flight information screen is shown in figure 6.7, where you can clearly see differences in appearance on different times.

Available content

In the prototype the selection of offered movies is changing along with the transition time. The names of the available movies together with the range in time that it may be offered to the passengers are saved in a database. The main part of the program takes care that the list of movies shown to the user is updated once every minute.

Movie title	Genre	Available from	Available till
Kungfu panda	animation /comedy	9:00	14:30
How to lose friends...	comedy	15:00	15:00
White Oleander	drama	20:00	24:00
Layer cake	Drama /Thriller	22:00	24:00
future by design	documentary	0:00	1:30
Madagascar 2	animation /comedy	9:00	21:45
Sweet home alabama	comedy / romance	20:00	22:30
Wall-e	animation /comedy	20:00	22:30
Zeitgeist	documentary	0:00	3:00
Time: daytime	documentary	1:00	9:00
future by design	documentary	23:00	24:00

Figure 6.8, movies with timing offered by IFE system

In the evening movies of the genres comedy, action, thriller and drama are offered. During the night only documentaries are offered and the number of documentaries is decreasing towards the morning. In the morning only animation movies are offered. The complete overview of movies and exact timing for offering is shown in figure 6.8.

6.2. HARDWARE

The concept is based on having full control over the lighting conditions inside the aircraft's cabin. For testing purpose the simulation lab was equipped with the hardware to do this. A number of components have been made to have this control. The hardware is connected to an ATMEL ATMEGA 168 microprocessor which then is connected to a computer by a serial interface. On the computer a control and logging application (made with Microsoft's C# .NET) is running to control the lighting and to log specific user actions (fig 6.9).

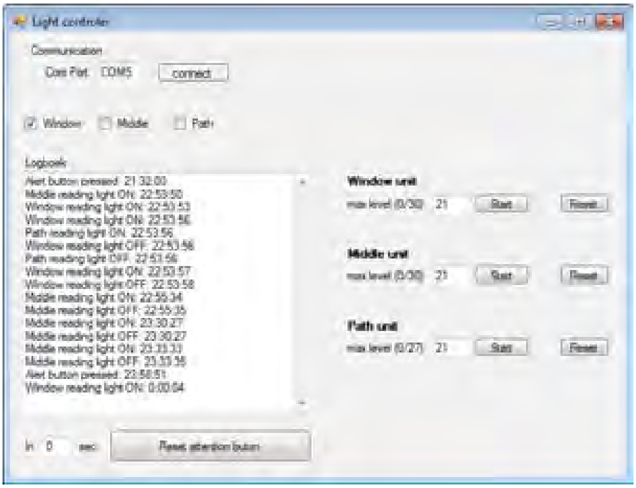


Figure 6.9, control and logging software for the hardware

Cabin lighting

For the cabin lighting a unit was made that is positioned above a row of seats in the simulation lab. This unit contains reading lights for the passengers that can change in intensity and change from bright white color to orange/red color. The usage of reading lights is per individual logged by the control software. There are also buttons available in the unit to call a steward or stewardess. This is also logged by the control software.

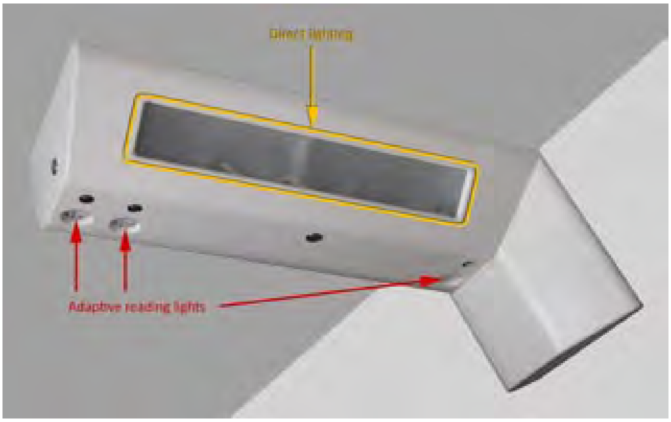


Figure 6.10, back view of cabin lighting unit

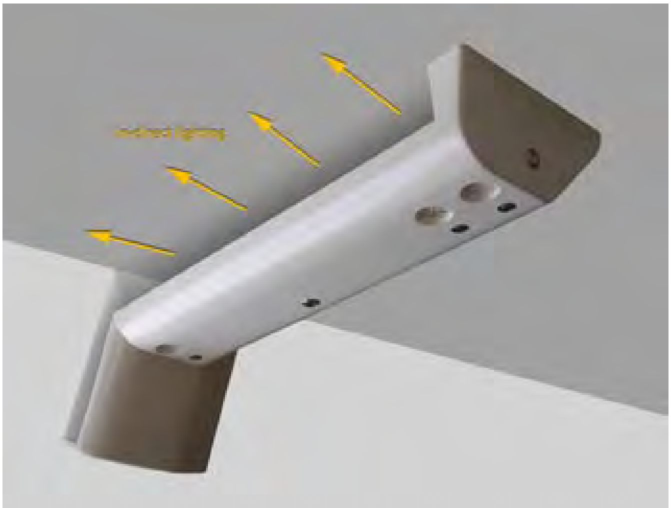


Figure 6.11, front view of cabin lighting unit

Furthermore this unit can provide indirect cabin lighting as well as direct lighting to passengers in one single row by an illuminated surface (fig 6.10 and 6.11). Because the indirect lighting and illuminated surface both address a different row an extra direct lighting unit was created to reach the desired light intensity in the cabin (fig 6.12).

Figure 6.12, cabin lighting units placed in the simulation lab

Individual lighting

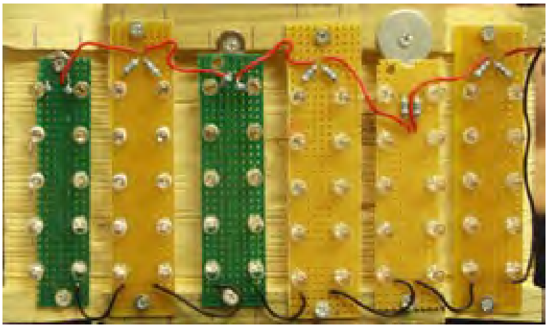


Figure 6.13, arrangement of LEDs in individual lighting units

Three individual lighting units are built to expose individual passengers to light without exposing other passengers to it. Every unit is equipped with 60 LEDs that illuminate 4000 mcd of light with a wavelength of 525 nm per LED. The LEDs are arranged in a way that the light is directed at the head area of a person (fig. 6.13). Measurements proved that the units are capable of emitting monochromic light of 60 Lux into the face of passengers. 60 lux corresponds to an intensity of 2.96×10^{13} photons per square centimeter per second, which according to Brainard et al (2001) should results in a 40 percent (control-adjusted) melatonin suppression.

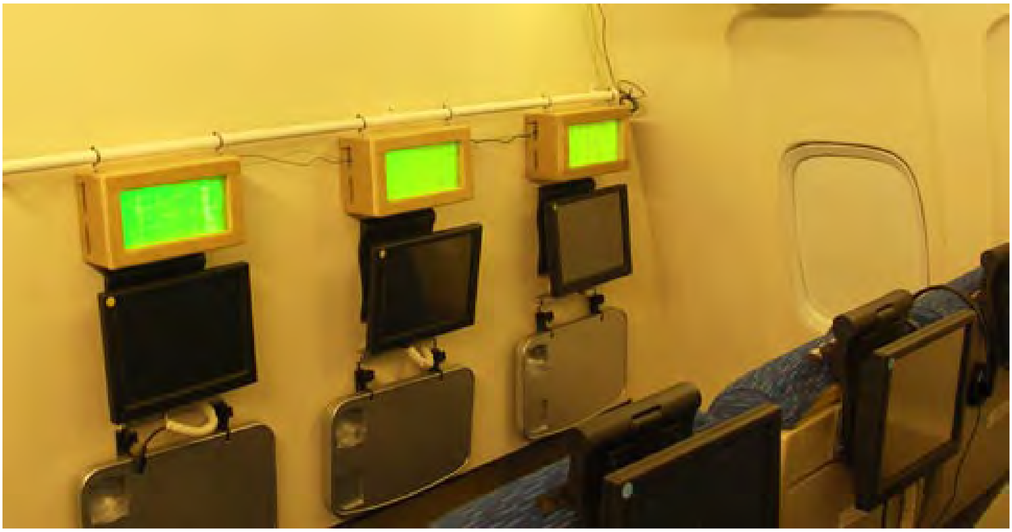


Figure 6.14, the LED units in the simulation lab

Toilet light

Because the standard toilet light has a too big influence on passengers biological rhythm this light was adjusted in a way it only produced indirect light instead of direct lighting and the light source was equipped with a Rosco e-color 105 filter to filter out the lowest wavelengths of light (see appendix B for the filter's characteristics). Figure 6.14 shows an image of the adjustments.

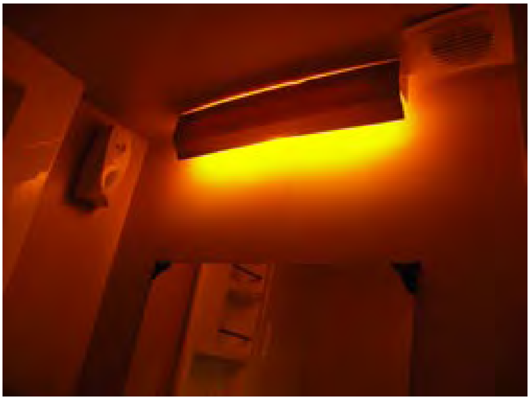


Figure 6.15, Adjustments made to the light in the simulation lab's toilet

7

Scenario

The scenario describes how businessman John experiences his flight from Amsterdam to Shanghai. His plane is equipped with a system as described in the concept chapter.

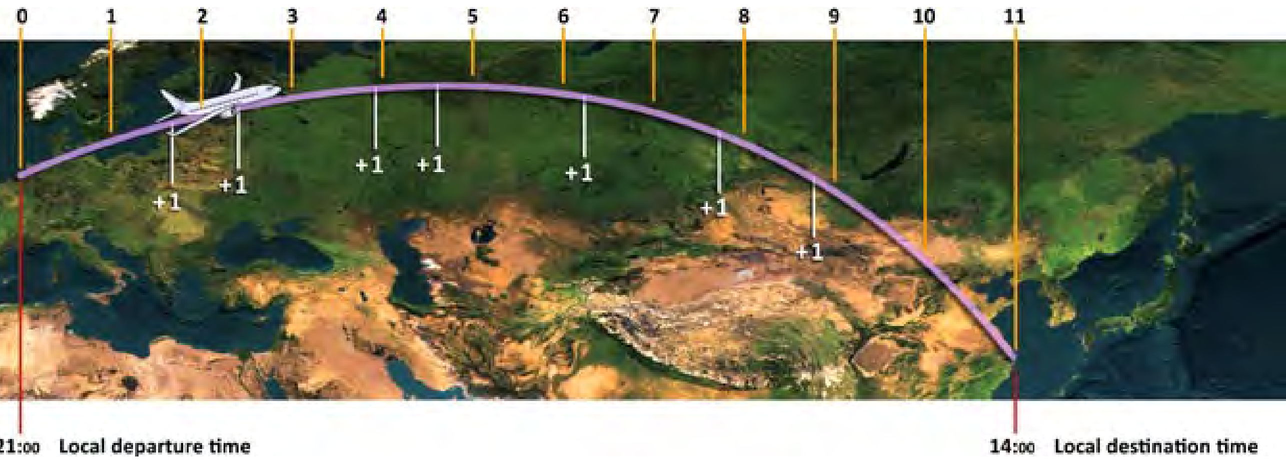
John's plane depart from Amsterdam 21:00

Flight duration (hours)

Time on departure location: 21:30
Transition time: 21:44
John has watching to the flight information and decides to watch a movie.

Time on departure location: 23:00
Transition time: 23:55
The movie has ended and John notices that the IFE menu has changed. It has changed according to the environment outside. Also the cabin lighting has dimmed while he was watching the movie.

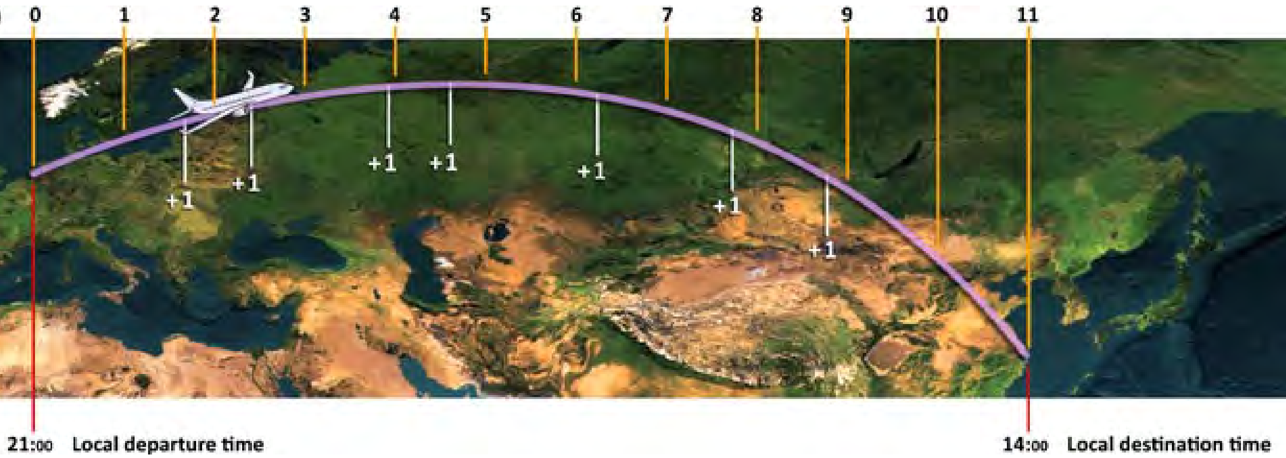
Time on departure location: 23:01
Transition time: 23:56
When John turns to the flight information he notice that this is has also changed according to the outside environment.

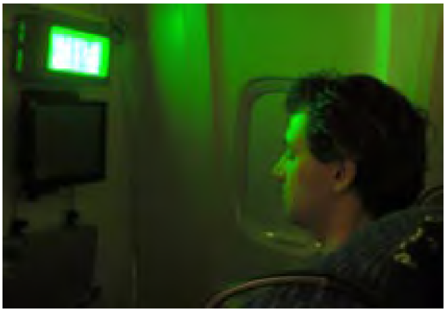


Time on departure location: 23:10
Transition time: 0:10
John decides to watch another movie and sees that only documentaries are offered by the IFE system.

Time on departure location: 23:30
Transition time: 0:38
John decides to rest for a while and finally falls asleep.

Time on departure location: 23:11
Transition time: 0:11
Since John prefers to read the book he brought with him above watching a documentary he turns on the reading light. The light has a reddish color, but this is not a limitation to read.





Time on departure location: 5:54
Transition time: 10:00
John just got awake and notices that the chair in front of him is illuminating a green light towards him.

Time on departure location: 6:50
Transition time: 11:41
John is sees that the appearance of the menu has changed again.

Time on departure location: 6:15
Transition time: 10:30
The cabin lighting slowly starts to get brighter and there is also some light coming through the windows.

Time on departure location: 6:30
Transition time: 11:00
Breakfast is served by the stewardesses.

Time on departure location: 8:00
Transition time: 14:00
The plane lands as planned right on time in Shanghai.

8

User research

During the project a concept and prototype is realized mainly based on a literature study. A next step in the project is to validate the system. The main question that needs to be answered during this user test is:

Can the system create a phase shift in the human biological clock?

The goal of the test conducted in the scope of this project is to deliver a prove of concept. Therefore the test is done with only three participants. The outcome of this test could then be a reason for a more extensive user test in the future.
Another interesting question is to find out how the system is experienced by potential users. After the test a small interview was held with the participants to get a qualitative impression of how they experienced the system.

8.1. APPROACH

The user test includes actually two tests; a control test and a test with the prototype. During the control test a flight from Amsterdam to Shanghai will be simulated in a way you could expect it nowadays on a real flight. This means the lighting inside the cabin is regulated like on a real flight and there are no dynamic changes in the IFE system.
The test with the prototype will also simulate a flight from Amsterdam to Shanghai, only than according to the described concept in chapter 4. In summary this means the lighting is controlled with goal to shift the participants' biological rhythm and the IFE system changes dynamically according to the calculated transition time. The lighting schedule for the two tests is show in table 8.1.

Control test

time	action	average light intensity seen by participants	Max. light intensity seen by participants
21:00	Cabin lighting is set to normal brightness	70 lux	140 lux
23:45	Cabin lighting dimmed	< 10 lux	n/a
6:30	Cabin lighting to normal brightness	70 lux	140 lux

Light in toilet ~200 lux

Concept test

time	action	average light intensity seen by participants	Max. light intensity seen by participants
21:00	Cabin lighting is set to normal brightness	70 lux	140 lux
23:30	Cabin lighting dimmed	< 10 lux	n/a
6:40	*individual unit participant #3 is activated*		
6:50	individual unit participant #3 is at 100%	15 lux (only #3)	25 lux (only #3)
6:55	*individual unit participant #2 is activated*		
7:05	individual unit participant #2 is at 100%	15 lux (only #2, #3)	25 lux (only #2, #3)
7:08	50% of original cabin lighting is activated	20 lux	60 lux
7:09	*individual unit participant #1 is activated*		
7:10	100% of original cabin lighting is activated	70 lux	140 lux
7:13	Indirect lighting for row of seats is activated	200 lux	400 lux
7:15	Direct lighting for row of seats is activated	450 lux	800 lux
7:19	individual unit participant #1 is at 100%		

Light in toilet ~30 lux

Table 8.1, the lighting schedule for the control and concept test

Method

Normally you would expect two groups of participants. One group for the control test and one group for the concept test. Because of the small group of participants in combination with the fact the free running period of these participants is not known it was advised to use the same participants for both tests. The reason for this is clarified by a possible scenario where different participants are used for both tests. Participant A in the control group and participant B in the concept test group both seems to have no shift in their biological rhythm after the test, so it seems like the concept had no effect compared to a normal situation. Actually the real outcome of the test could be different. Because person A has a FRP of 24:01 hours there is no significant shift. On the other hand person B has a FRP of 24:35 hours which means that the rhythm of person B has shifted 35 minutes.
By using the same participants for both tests a comparison with a normal day rhythm can be made as well as a comparison between the effect of the control test and the effect of the concept test.

Measuring biological rhythm

The way to get an indication of the participants' biological rhythm for the test is done

by taking saliva samples of the participants. Later on the melatonin levels are retrieved out of the saliva samples. All the melatonin values of one night are a good indication for someone's biological rhythm.
In total there a three nights on which saliva samples are collected. The first night (before both tests) is used to get a control curve of the participants' melatonin levels. Than the first night after both tests are the other two nights where saliva samples are collected. With the melatonin curves of these nights it is possible to compare the effect of the test with the control curve or to compare the effect of the control test with the effect of the concept test.
The collection of these saliva samples is done in a light regulated environment, because light intensities above 10 lux could start suppressing melatonin production. During the saliva collection nights the "context lab" (a home environment with living room and bedroom within the faculty of industrial design) is used as place to spend the night. During these nights the light intensities in the entire room is kept below 8 lux.
Collecting the saliva samples is done by a strict protocol formulated in a European research project entitled EUCLOCK (see appendix C for the protocol). On all saliva collecting nights the participants were asked to join the context lab (with dimmed light) one hour before the first saliva sample was taken. On the first night samples were taken every hour from 7 p.m. until 1 a.m. and from 1 a.m. on one sample every two hours until 9 a.m. The sample period after the tests started two hours earlier, because the hypotheses is that in a best case scenario the biological rhythm of the participants could be advanced by two hours. This means the samples during these nights were taken every hour starting at 5 p.m. until 1 a.m. and from 1 a.m. until 9 a.m. one sample every two hours.

Participants

Three participants were found willing to spend five nights on the test. All three participants are male industrial design students with ages of 19, 23 and 24. All participants satisfied to the requirements for participating in the test. These requirements are: 1) not being involved in shift work in the last three months for the test, 2) non smoking and 3) a mid sleep on free days between 4:21 a.m. and 6:50 a.m. Mid sleep is a term that means literally the midpoint of sleep. For example someone who falls asleep at 11 p.m and wakes up at 7 a.m. the mid sleep is at 3 a.m.

Determine individual time for exposure to light

The most effective time to produce a phase advance by light according to the literature is around 8 hours after the moment the body starts to produce melatonin (DLMO). On average this point lays two hours before people fall asleep. This means the optimum time for light exposure is two hours after the point of mid sleep on free days assuming that people sleep on average 8 hours per night.
The participants were asked to fill in a Münchener Chronotype Questionnaire (MCTQ).

This questionnaire is used to determine the mid sleep on free days and on work days. The optimum timing for light exposure would be two hours after the mid sleep point on free days, but because the difference between mid sleep on free days and work days for the participants is quite large it was decided to correct the light exposure time based on the difference in sleep duration. The final optimum timing for light exposure per individual is shown in table 8.2.

Participant	Free days sleep duration	Free days Mid sleep	Work days sleep duration	Work days Mid sleep	timing for light exposure
1	8:55	5:33	7:15	3:44	7:19
2	9:00	5:15	7:35	4:18	7:05
3	9:55	5:03	8:10	4:10	6:50

Table 8.2, information of the participants regarding mid sleep and best time for light exposure

Instructions given to the participants

Some instructions were given to the participants regarding the days before and after the tests:

- Remain your normal sleep/wake rhythm for at least two days before the sample and test nights.
- Don't go to sleep during the day after the test in the airplane.
- Try to be exposed to similar lighting conditions after the control and concept test.
- Eating bananas and chocolate on the collection day should be avoided
- The use of Aspirin or aspirin and ibuprofen containing drugs (Algifor, Brufen, Dismenol, Dolocyl, Ecoprofen) is prohibited on the collection day.

8.2. RESULTS

The saliva samples were brought to the University of Groningen on Monday 8th of June for analyzing. The results of this analysis are expected in week 25. This chapter will be completed as soon as these results are available.

Experiences of the participants

After the concept test the participants were asked how they experienced the test in general. They were also asked if they noticed the differences between the control test and concept test and what they thought about that. The conclusions are summarized below.

- The clock indicating transition time is a strong clue to fool your mind.
- The day/night appearance changes in the IFE system were notice by all participants,

although they all believe that these changes in itself do not really influence their perception of time.

- The green light emitted by the individual lighting units was not experienced as too bright or annoying.
- One participant noticed the similarity of the changing movie selection with the normal programs offered on television. He didn't mind that he could only watch documentaries during the night, although he actually preferred to watch a movie.
- According to one of the participant the music offered was too active to fall asleep.

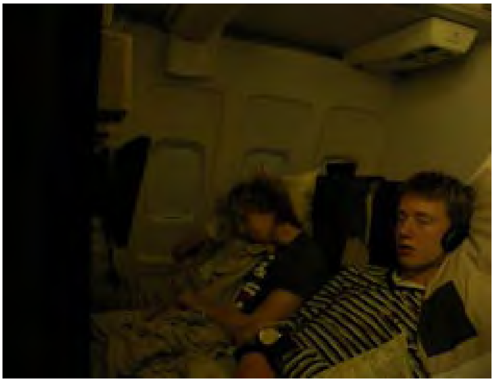


Figure 8.1, Photo made during control test in simulation lab

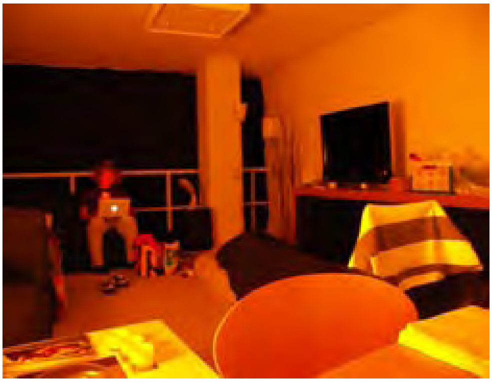


Figure 8.2, Photo made during saliva collecting night in context lab

9

Conclusion and discussion

During this project a "service" has been created that influences the biological clock of passengers to minimize jetlag symptoms after the flight. According to Dumur et al. (2004) comfort in an aircraft context can be divided into four different models of comfort (see chapter 2). The solution proposed in this project would fit in the health model, because it is mainly concerned about the physical well being of passengers. Dumur et al also correctly argues that improvements in one comfort model often lead to conflicts in other models. I believe this is also the case for the concept proposed in this project. The concept could indeed contribute to physical health improvements of passengers, but at the same time it conflicts with the aesthetic-economical model. By removing the control of blinding the windows away from the passengers and by changing the amount and type of movies and music during the flight it is possible that the actual flight experience doesn't match the passengers' expectations. These type of conflicts needs to be investigated and if necessary adjustments need to be made.

I would have liked to say here something about the results of the user test. Unfortunately the results at the time of writing are not known. This does also mean that this version of the report will updated as soon as when the results are returned from the laboratory.

I believe this project is a good starting point for a solution towards jetlag minimization during the flight, but there are still a lot of things that needs further investigation and some design iterations are absolutely necessary before it can really be integrated on a plane for the first time.

Future work

The concept described in this report is on some areas still quite superficial. This means more work is needed to take the concept one step further. In my opinion developing an accurate real-time method to measure the biological clock of passengers without explicit

user input is a great challenge, but a solution for this would be a great contribution to the system. Also in the area of the individual and cabin lighting a lot of fine-tuning is required. Finally further investigations to the influence of the clues in the IFE system and to the user acceptance of such system during long-haul flights is important. Answers to these questions largely determine the further development of such system and if it makes a chance to be introduced in the market.
There is still a lot of work to do, but a first step towards minimizing jetlag during the flight is made by this project.

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List of used abbreviations and terms

DLMO	Dim Light Melatonin Offset. The time of day that the human body in dim light starts to produce the hormone melatonin.
FRP	Free running period. The endorgenous time of the biological clock when it would entrain.
IFE	In-Flight Entertainment. A system that every passengers have to con sult flight information or to watch or listen to entertainment.
PRC	Phase response curve. The phase shift of the biological rhythm plotted as function of the circadian phase that a zeitgeber is presented to a human.
SCN	SupraChiasmatic Nuclei. Paired group of nuclei at the base of the hypothalamus that is considerd as human main biological clock.
Simulation lab	A detailed copy of a part of an aircraft for user-testing purpose. This copy contains a business class with one seat, an economy class with six seats (2 rows of three seats) a kitchen and toilet.
Transition time	Time lapse between local departure time and local destination time. This could be seen as a function of flight duration and the number of crossed time-zones.

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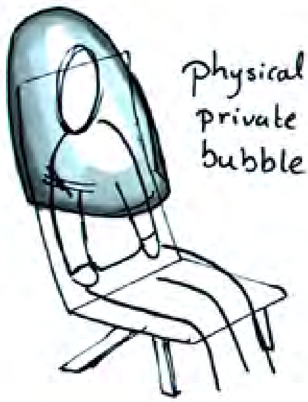
Appendices

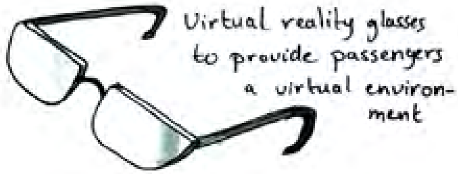
A SELECTION OF IDEAS

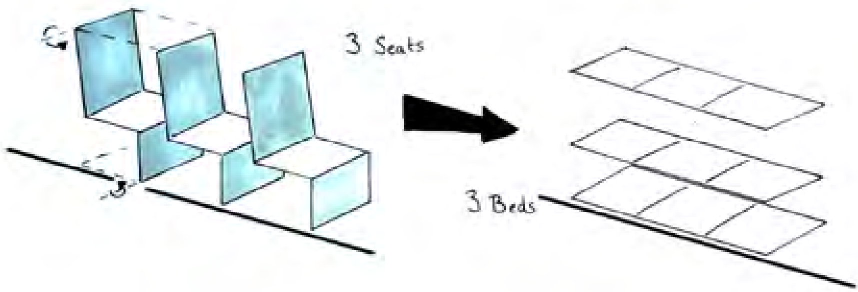
B ROSCO FILTER CHARACTERISTICS

C SALIVA COLLECTING PROTOCOL

A selection of ideas generated during the idea generation session







* "Do not disturb" sign, So other passengers and crew know when they can disturb you.

* Individual (directional) sound, so headphones are not needed.

* Massage function in the chair

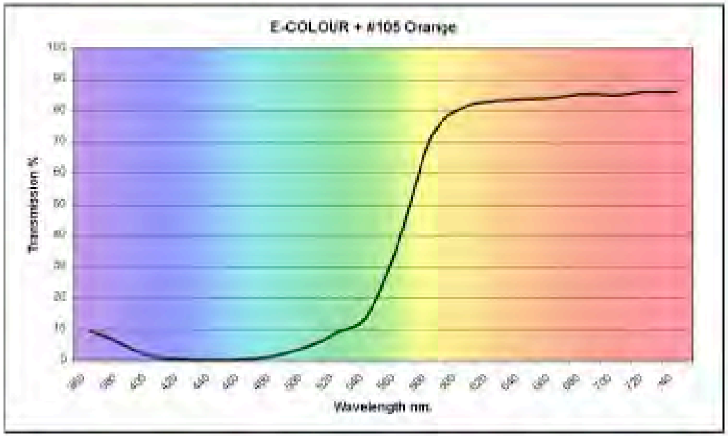
* Possibility to watch real-time images / video of cities you are flying above.
  or possibility to interact (chat) with people on the ground.

The characteristics of the Rosco e-color 105 filter

rosco COLOR FILTER TECHNICAL DATA SHEET

SWATCHBOOK: E-COLOUR +
COLOR FILTER: #105 Orange
DESCRIPTION: Color Effects Lighting Filter.
TRANSMISSION = 41% or -1.3 stop loss
MIRED SHIFT = Not Applicable.
CC EQUIVALENT = Not Applicable.

COLORIMETRIC DATA
OBSERVER: CIE 1964 10°
SOURCE: • 'A' (turgsten)
° 'D65' (daylight)

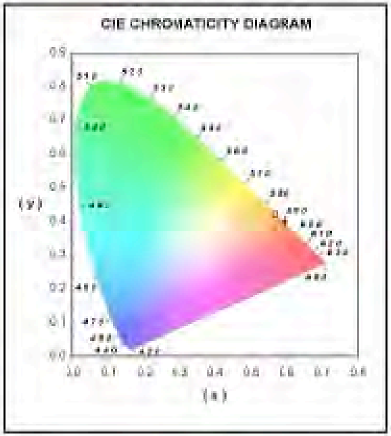


HUNTER LAB SOURCE A	
L'	75.694
A'	42.372
B'	112.969

HUNTER LAB SOURCE D65	
L'	67.533
A'	43.893
B'	103.471

CIE 1964 SOURCE A	
Y	49.391
(x)	0.597
(y)	0.400

CIE 1964 SOURCE D65	
Y	37.342
(x)	0.567
(y)	0.423



nm	360	380	400	420	440	460	480	500	520	540	560	580	600	620	640	660	680	700	720	740
trans %	10	6	1	0	0	0	2	4	9	15	39	77	81	83	84	84	85	85	86	86

MATERIAL SPECIFICATIONS:
General Description: Dye-Coated Polyester Film
Substrate: PET (Polyethylene Terephthalate)
Thickness: 3.0 mil (.003" or 75 micron)

Manufactured in: U.K.

AVAILABLE SIZES:
20 in. x 24 in. sheets (50cm x 60cm)
21 in. x 24 in. sheets (53 x 60cm)
24 in. x 25 ft. rolls (60cm x 7.62m)
48 in. x 25 ft. rolls (121cm x 7.62m)
60 in. x 20 ft. rolls (152.4cm x 6.10m)
13.5 in. Diameter Glass (34.3cm) - Cut to order

Protocol for collection saliva samples

Prepared by: Marijke Gordijn	SOP – TAKING SALIVA SAMPLES FOR MEASUREMENT OF MELATONIN
Revised by:	**March 5th, 2007**

PURPOSE:

The following procedure contains the minimum requirements necessary to take saliva samples for measurement of melatonin levels.

EQUIPMENT:

Labelled collection tubes (e.g. Salivette® **51.1534** with cotton swab, no citric acid, Sarstedt AG & Co).

RESPONSIBILITY:

The collection of saliva is a simple non-invasive method. Subjects can do this by themselves. If correctly instructed, this could even be done at home. However some precautions are needed (see procedure).

PROCEDURE:

a) The period starting 1h before sampling until the last sample is taken is further called the "sampling period".
b) Environmental lighting needs to be maintained at < 8 lux throughout the sampling period. In the home environment subjects should be instructed to keep light levels as low as possible, not to sit near a lamp, not closer than 3 m in front of the T.V. and to close the curtains. Light levels and the intensity/contrast of computer screens should be decreased as much as possible, so that reading is just possible.
c) Subjects are required to minimise their movement during the sampling period.
d) During the 10 min before each sample is taken, subjects are required to remain in their designated, controlled posture position. For example, subjects may be in a sitting position during waking hours and in a recumbent position when they are sleeping.
e) Subjects should refrain from eating during the sampling period as much as possible and at least finish their meal or snack 30 min prior to the collection time. Eating bananas and chocolate on the collection day should be avoided.

f) During the sampling period, subjects are allowed to drink beverages without artificial colorants, and without caffeine, only when finishing it 30 min prior to the collection time. Drinking coffee, cola and alcohol is prohibited throughout the sampling period. Drinking water is allowed until 10 min before collection of each sample.

g) Subjects should rinse their mouth with water 10 min prior to collection of each sample. No toothbrushing with toothpaste is allowed during the sampling period.

h) Subjects should not stimulate saliva flow e.g. by chewing gum.

i) The use of Aspirin or aspirin and ibuprofen containing drugs (Algifor, Brufen, Dismenol, Dolocyl, Ecoprofen) is prohibited on the collection day.

j) The number and timing of collecting the samples depends on the protocol of the study. Some general rules: (1) To measure melatonin onset a sampling interval of maximal 1 h is required starting 5 hours prior to habitual sleep onset until 1 hour after habitual sleep onset. (2) When a 24-h curve is needed, sampling during wake time should have an interval of 1h, during sleep a 2-h interval is allowed.

k) In the lab: centrifuge saliva samples and store them at -20◦C. At home: keep the samples in the refrigerator (2-8◦C) for a maximum of 3 days and send them in a special box to the lab. If they are not send within 3 days they should be placed in a freezer. Samples should not be send just before a weekend. Bühlmann tested the stability of melatonin in saliva using their RIA (RK-DSM) as well as their ELISA (EK-DSM) using samples either kept at -20°C or room temperature for 7 days, without observing an effect on the melatonin concentration.