

Z³: Advice and Suggestions Component Design

Julia Booth

Abstract—The Z³ system uses a mobile phone application to provide users with advice individually tailored to what affects their sleep. The system analyses information about the environment in which the user sleeps and their lifestyle to identify factors that have a significant impact on their sleep and provides suggestions to the user to make simple changes to improve their sleep. This report outlines the high-level design of the advice and suggestions component responsible for choosing the appropriate advice to give the user.

I. INTRODUCTION

Many people experience some form of sleep problem, whether serious or minor, over the course of their lifetime [1]. Most people do not see sleep problems as an illness but as an inconvenience and many take no action, considering it as a normal problem that everyone experiences [2]. However sleep can be improved significantly simply by making small changes to lifestyle [2].

The z³ system is composed of a mobile application and a hardware component containing a number of sensors. Before going to sleep the user answers a short survey concerning their actions throughout the day which might affect their sleep, for example how many cups of coffee they drank. Over the course of the night the sensors in the hardware component measure the level of light, humidity, noise, temperature and accelerometer readings from the bed and surrounding environment. On waking the user will be asked to rate whether their sleep was good or bad. Using the information gathered from the user and their environment, the recommendation engine analyses what factors have the greatest effect on the user's sleep, giving each factor a weight indicating to what degree they have an effect on the user's sleep. These factor weights will be analysed to give the user personalised suggestions to help the user improve their sleep.

The advice and suggestions component makes up one part of the recommendation engine. The suggestions displayed to the user are the most important form of feedback they receive from the app, giving personalised advice on what the user needs to do to improve their sleep. When choosing advice to give the key factors that affect the user's sleep, the ability of the user to follow the advice and the willingness of the user to follow to a given type of advice, must all be taken into account.

II. BACKGROUND

A. Related Work

Projects using this direct advice giving approach include the Fit4Life project [3] which is aimed at reducing obesity in adults by encouraging healthy behaviour. The system monitors the actions of the user, such as eating or exercising,

and uses this information to advise the user what they should and should not do via both direct and indirect routes. This project particularly focuses on the persuasion of other individuals via social networks. The system publishes messages to the user's social network wall with information about their progress, either congratulating them on their success or posting about any failures in order to get their friends to give them encouragement. The system also gives direct advice and feedback to the user about how healthy their actions are via an earpiece.

Another example of persuasive technology is the EnergyLife system [4] which uses an app to encourage the user to reduce their household power consumption. The advice the product provides is a combination of 2 different types of information, the actual power consumption readings from household devices and energy conservation tips given by reputable sources such as environment agencies.

Persuasive technology has also been applied to the improvement of sleep. The CubeSensor [5] detects levels of noise, temperature, light and other environment factors in the bedroom. The Cube itself notifies the user when it is time to go to bed and the web app displays the data collected during the night to allow the user to identify why they did not sleep well and provides daily advice about improving the sleep environment such as "you should really turn up the heat".

Another example of a product advising a user about their sleep is Beddit [6]. Beddit monitors the user's quality of sleep, their heart rate and breathing and their environment. The app analyses what the user has done during the day and compares this information against their measured sleep quality to identify trends to improve the user's sleep. It summarises its finding on the user's sleep quality as a sleep "score" and displays previous nights' sleep alongside corresponding data, such as sleep time, to allow the user to identify behaviours that result in a good night's sleep. It also displays the data from the sensor measurements in graphical representation along with identified activities that improve or negatively impact the user's sleep and to what degree they have an effect.

B. Sleep Improvement

Most people will experience some kind of mild sleep disorder at some point with around one third of people developing insomnia [1]. A bad night's sleep can have many adverse effects on health such as reducing the efficiency of the immune system, encouraging weight gain or increasing the risk of depression [7]. Common problems that people experience with sleep include waking during the night, sleeping fewer hours than necessary and difficulty getting

to sleep, also known as sleep latency. Many different factors can effect how well we sleep including stress, distracting environments and the food you eat [1].

The lack of hours spent sleeping is often cited as a significant cause of tiredness, the NHS advises that most adults should sleep between 6 and 9 hours a night [8]. The number of hours slept, both too many and too few, can have an effect mental health, a study undertaken in Japan found that subjects who slept fewer than 7 hours a night or more than 9 hours a night had a poorer mental health status compared with those who slept for between 7 and 9 hours per night [9].

Medicalization has long been a widely used solution to sleep problems. However their use is dropping, indicating that people want to find alternative ways of improving their sleep [2]. People now have more interest in attempting to improve their sleep by making changes to their lifestyle after it has been shown that behaviours that improve health such as exercising and eating a healthy diet may result in better quality sleep [2] [9].

1) *Exercise*: Exercise has an significant positive effect on sleep, improving sleep depth and decreasing sleep latency [10]. The NHS advise that regular physical exercise can help to promote sleep. However it should be avoided in the 2 hours prior to going to bed [8] as this raises the heart rate and causes the release of hormones into the blood that promote alertness. The ideal time to exercise is the late afternoon as the body temperature reaches a high, causing better muscle performance and improved cardiovascular function[11].

2) *Diet*: Diet can have a major effect on a person's sleep. The most common diet-associated factor disrupting sleep is the consumption of caffeine. Caffeine is a stimulant and causes difficulty in getting to sleep, delaying the production of melatonin. Although caffeine is most often associated with preventing a person getting to sleep it also affects sleep quality. Throughout the day the chemical adenosine builds up in the bloodstream which helps your body to sleep. However caffeine affects the receptors in the brain blocking to from being absorbed, this prevents the brain from entering a deep sleep [12]. Different people can have very different tolerances, some people are affected by coffee they consumed in the early afternoon and should not be drunk within 4 hours of going to bed [11][8].

Other stimulants include sugar which, when consumed in substantial amounts results in a spike in energy levels [11]. Nicotine should be avoided as it is also a stimulant, the NHS advise that it should be avoided within the hour before going to bed.

Many people believe that drinking alcohol, which is a relaxant, in the evening can help to reduce the time taken to get to sleep. However, alcohol in fact tends to reduce sleep quality and depth by disrupting the sleep patterns and reducing the number of REM cycles.[1]

Many people consume non-decaffeinated teas to help promote sleepiness. Popular teas include Chamomile, which increases the levels of nerve relaxant in the bloodstream, and Valerian and Passionflower, which may increase the levels of

gamma aminobutyric acid (GABA) in the brain which helps to regulate the nervous system [1].

An ideal evening meal contains a mix of carbohydrates and proteins in a smaller portion to prevent discomfort associated with being too full. Not only the food that you eat, but the time at which you eat it is important. An experiment into the effect of meal regularity in mice found that irregular mealtimes can affect sleep [1]. Regular meal patterns during the day and in the evening makes it easier to fall asleep. It is advised that the final meal before bed should take place about 4 hours before sleep.

3) *Routine*: The NHS cites a bedtime routine as one of the most important factors in getting to sleep, keeping regular sleeping hours[8] as well as establishing a bedtime ritual that you do every night before bed such as drinking a caffeine-free tea [1]. The aim of building a bedtime routine offsets potential sleep distribution and over a lifetime become necessary to help the onset of sleep. Common bedtime rituals include taking a bath, consuming a snack or hot drink and brushing teeth [2].

4) *Relaxation*: One of the most common problems with sleep occur from stress. The NHS provides advice about a number of different methods to promote relaxation before bed including taking a warm bath, not hot, to help the body reach its optimum sleeping temperature, relaxation exercises to relax and stretch the muscles, for example yoga or progressive muscle relaxation (PMR) [13] or listening to the radio [8] work well to reduce sleep latency. In fact in an experiment conducted by Simeit et al., the use of relaxation techniques saw a reduction of a halve in sleep medication [13].

5) *Environment*: The environment in which a person is sleeping has a great impact on how well they sleep. The two primary environmental causes of bad sleep are attributed to light, which reduced the amount of melatonin produced [7], and noise, which disturbs the brain [14]. The ideal sleeping environment is a dark, quiet and tidy bedroom with a comfortable mattress and bed and the temperature kept between 18 degrees celcius and 24 degrees celcius, with an optimum of around 18.5 [12][8].

6) *Device Use*: About 78% of people in the UK use their smart phone, laptop or tablet immediately before going to bed. These devices emit bright blue light which stimulates the brain, reducing the amount of melatonin produced and causing sleep latency [12]. Advice to combat this is to reduce the brightness of the device screen or not to use them at all in the two hours before going to bed [12].

III. REQUIREMENTS

Health applications are one of the most obvious uses for persuasive technology as, in general, people agree that anything that improves their physical and mental health is positive [15]. As a result users are more likely to embrace persuasive technology and to follow advice, within their ability, that they believe will improve their wellbeing. Personalised advice is particularly important in a health

application as different advice works for different people [16].

The clarity of advice is a particularly important factor in getting the user to follow the instructions given to them as well as the information given being applicable to their needs [17]. In fact users often prefer to receive detailed and specific information [4]. Contradictory suggestions will lead to confusion as to whether to carry out the advice and will often result in the user doing what they usually do. Advice can be difficult to interpret when it only states degrees of intensity rather than specifics, for example the meaning of moderate exercise is difficult to quantify [17]. Therefore any suggestions given to the user should be clear-cut using a quantitative measure rather than qualitative, such as advising the user to do 1 hour of jogging rather than suggesting that they do moderate exercise.

Giving context or describing the information in a more intuitive way can improve the clarity of the advice given. For example the Fit4Life system [3] gives information to the user in the context of what they have already done today and give a suggestion based on that behaviour enabling the user to understand the reasoning behind the suggestion, such as Dave, the scone you are about to eat probably contains 400 calories. Youve already consumed 300 calories today. There are 9 hours remaining in your wake period. After eating the scone, you will have consumed 45% of your total nutrition needs for today. You have free time today from Noon to 2 pm. Would you like me to schedule a long run?. Sometimes information that the system records is abstract, making it difficult to interpret and so needs to be described in a different way to help the user understand the meaning of the information. An example of this is the way in which the EnergyLife system [4] gave carbon dioxide readings to the user in a way that was easier to understand, for example This week 134 trees had to absorb the CO₂ produced by your PC. Help the environment by changing the energy saving setting of your PC.

Using friends and family as sources of advice and encouragement can be particularly effective [17]. This was utilised in the Fit4Life project [3] which used interaction via the user's social network to congratulate them on their successes, providing public praise to a user whose actions have followed the advised healthy behaviour. The Fit4Life system would also post on the user's negative actions in an attempt to encourage their friends in their social network to support the user and help them get back on track, although this post will be negative it also provides constructive advice in advising the user what they should do which, in turn, can encourage their friends to offer to help the user.

IV. IMPLEMENTATION

Personalisation of suggestions is important, not only for providing people with advice that will help them but also to produce more persuasive advice [15]. The suggested changes in behaviour need to be relatively simple as anything that is too difficult will be more likely not to be followed by the user. By displaying the weightings of the factors that

affect the user's sleep they will be able to see how much following a particular suggestion could improve their sleep. Sleep behaviour tends to be accumulated throughout life, becoming a permanent habit. In helping people to improve their sleep over a number of weeks we hope that using the app to analyse their sleep will become part of their permanent sleep behaviour [2].

The suggestions will be determined by the intervention model, using the weightings of the factors identified as having an important impact on the user's sleep. The model will take as input the measurements and information for those factors considered to be having a large effect and from that data make suggestions that maximise the effect they will have on the user's sleep but being easy to carry out. For example, if caffeine consumption has been identified as having a large negative impact on the user's sleep and the information gathered from the lifestyle survey shows that the user drinks 3 coffees per day, the suggestion should advise the user to drop the number of coffees they consume to 2 per day, this piece of advice is helpful but achievable.

Not only will the given advice attempt to give incremental changes to make it easier but it will also offer the users the option to reject suggestions as they may concern a factor that they cannot control, for example if the system identifies that noise in their environment is affecting their sleep but the user lives next to the railway or a busy road and so is not able to change this factor then the user can reject this suggestion and the app will no longer give them suggestions concerning noise. In the case when users do not reject advice but appear not to follow it the suggestion may be repeated a set number of times before it is considered rejected by the user. Although this repetition of the same advice could be considered unhelpful a study conducted by Gamerini et al. found that repetition of advice was noted by the users but this in fact strengthened the users' belief in the importance of the suggestions [4].

For the prototype of the Z³ system there are 2 different phases of data collection. The first stage has collected both environment and survey data from a number of different test subjects and each factors is analysed using support vector machines toolbox in MATLAB in order to find the threshold which, in general, are considered to be the difference between a good and bad night's sleep. This information is used to calculate generalised factor weightings which will be used as the default for the app on installation by a user.

The advice and suggestion component takes as input the calculated factor weights, identifying the most significant factor or factors having a negative effect on the user's sleep. For these identified factors, suggestions are given to gradually change that aspect of the user's behaviour towards the advised behaviour shown in the table below. As advice is followed by the user the weighting of this factor should decrease as it begins to have a positive effect on their sleep and so other factor weights will be identified as the most significant.

The suggestions are grouped by the factors that they aim to tackle, within each group are multiple different suggestions

Sleep duration	between 6 and 9 hours of sleep per night, if the user normally wakes between 06:00 and 09:00 then they should go to bed between 21:00 and 00:00
Exercise	if the user currently does no exercise then advise 20 minutes of jogging 3 times a week working up to 40 minutes jogging 4 times a week if the user currently does some exercise then advise 30 minutes of running 5 times or 1 hour of running 4 times a week, preferably undertaken in the late afternoon
Caffeine	reduce coffee/caffeine intake by the cup drunk latest in the day
Evening meal	balanced meal with a mix of carbohydrates, protein and at least one portion of fruit and vegetables, low in sugar. Medium sized portion eaten about 4 hours before going to sleep
Nicotine	no smoking in the hour before going to sleep
Alcohol	avoid consuming alcohol in the hours preceding sleep
Relaxation	take a warm (not hot) bath, drink decaffeinated tea, such as chamomile, or follow a relaxation technique, such as PMR
Light	room should be as dark as possible
Noise	room should be as quiet as possible
Temperature	the temperature of the room should be between 18 and 24 degrees celsius
Humidity	low humidity
Device use	if device use before bed has only a minor impact on the user's sleep they should reduce the brightness of their screens, if device use has a great impact on their sleep they should refrain from using devices for the 2 hours before sleep

that may help the user. A suggestion is chosen randomly from the group identified by the factor weightings and will be given at a time when it is useful to the user, for example suggestions to reduce caffeine intake would best be given in the morning as giving this advice in the afternoon might be too late. This part of the module will be written in Python.

When the advice is displayed to the user they will be given the opportunity to reject the advice, this allows the user to dictate what types of advice they are unable to follow for example the user may not be able to make the room quieter or may not be able to fit a 1 hour run into their day. If the user rejects a piece of advice the suggestion will be removed from the group and not given to the user again, this informs the component of the factors that cannot be changed by the user and so other suggestions giving similar advice will also be removed.

V. FURTHER WORK

Further work to be done at this stage includes the handling of repeated suggestions in order to judge whether the user has followed the advice given. If a piece of advice has been given but no apparent change has been made to that factor, the conclusion can be made that either the user has not followed the suggestion, because they are unable or do not want to follow the advice but have not rejected the suggestion, or that the suggestion does not work for that individual. In this case the suggestion will be repeated a maximum of 3 times in a row before it is removed from the suggestion group.

The other part of the component still to be implemented is the front-end of the component, a screen of the app displaying the both the suggestions given and a graphical representation of the factor weights to enable to user to easily see what effect each factor is having on their sleep. This part of the component is part of the iOS app and so will be written in Swift.

VI. CONCLUSION

The advice and suggestion module of the Z³ forms a major part of the feedback given to the user in order to help them improve their sleep. This report outlines the way in which personalised suggestions will be chosen using the identified factors that affect that individual's sleep and how to alter suggestions given the ability of the user.

REFERENCES

- [1] B. iWonder, "What should i eat for a good night's sleep?" <http://www.bbc.co.uk/guides/z282p39>, 2017. Online; Accessed: 2016-02-17.
- [2] J. Hislop and S. Arber, "Understanding women's sleep management: beyond medicalization-healthicization?," *Sociology of Health & Illness*, vol. 25, no. 7, pp. 815–837, 2003.
- [3] S. Purpura, V. Schwanda, K. Williams, W. Stubler, and P. Sengers, "Fit4life: The design of a persuasive technology promoting healthy behavior and ideal weight," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '11, (New York, NY, USA), pp. 423–432, ACM, 2011.
- [4] L. Gamberini, A. Spagnolli, N. Corradi, G. Jacucci, G. Tusa, T. Mikkola, L. Zamboni, and E. Hoggan, *Tailoring Feedback to Users' Actions in a Persuasive Game for Household Electricity Conservation*, pp. 100–111. Berlin, Heidelberg: Springer Berlin Heidelberg, 2012.
- [5] CubeSensors, "Cubesensors - feel better." <https://cubesensors.com/>. Online; Accessed: 2017-01-31.
- [6] Beddit, "Beddit." <http://www.beddit.com/>. Online; Accessed: 2017-01-31.
- [7] B. iWonder, "Which five things ruin a good night's sleep." <http://www.bbc.co.uk/guides/zsspn39>, 2017. Online; Accessed: 2016-02-18.
- [8] NHS, "How to get to sleep." <http://www.nhs.uk/Livewell/insomnia/Pages/bedtimeritual.aspx>, 2016. Online; Accessed: 2016-02-18.
- [9] T. Ohida, A. Kamal, M. Uchiyama, K. Kim, S. Takemura, T. Sone, and T. Ishii, "The influence of lifestyle and health status factors on sleep loss among the japanese general population," *Sleep*, vol. 24, p. 333338, May 2001.
- [10] S. D. Youngstedt, "Effects of exercise on sleep," *Clinics in Sports Medicine*, vol. 24, no. 2, pp. 355 – 365, 2005. Sports Chronobiology: It's About Time.
- [11] BBC, "Body clock: What makes you tick?." <http://www.bbc.co.uk/news/health-27161671>, 2014. Online; Accessed: 2016-02-18.
- [12] B. iWonder, "Are you getting enough sleep?." <http://www.bbc.co.uk/guides/zwpycw>, 2017. Online; Accessed: 2016-02-18.
- [13] R. Simeit, R. Deck, and B. Conta-Marx, "Sleep management training for cancer patients with insomnia," *Supportive Care in Cancer*, vol. 12, no. 3, pp. 176–183, 2004.
- [14] S. Koch, E. Haesler, A. Tiziani, and J. Wilson, "Effectiveness of sleep management strategies for residents of aged care facilities: findings of a systematic review," *Journal of Clinical Nursing*, vol. 15, no. 10, pp. 1267–1275, 2006.
- [15] P. King and J. Tester, "The landscape of persuasive technologies," *Commun. ACM*, vol. 42, pp. 31–38, May 1999.
- [16] E. S and M. E, "Lack of perceived sleep improvement after 4-month structured exercise programs," *Menopause*, vol. 14, no. 3, pp. 535–540, 2007.
- [17] H. Gross and P. E. Bee, "Perceptions of effective advice in pregnancy the case of activity," *Clinical Effectiveness in Nursing*, vol. 8, no. 34, pp. 161 – 169, 2004. Womens Mental Health.