Wake up and talk with me! In-the-field study of an autonomous interactive wake up robot***

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Abstract. In this paper, we present a robot that is designed to smoothly wake up a user in the morning. We created an autonomous interactive wake up robot that implements a wake up behavior that was selected through preliminary experiments. We conducted a user study to test the interactive robot and compared it to a baseline robot that behaves like a conventional alarm clock. We recruited 22 participants that agreed to bring the robot to their home and test it for two consecutive nights. The participants felt significantly less sleepy after waking up with the interactive robot, and reported significantly more intention to use the interactive robot.

Keywords: In-The-Field · User Study · Autonomous Robot.

1 INTRODUCTION

In the scientific literature, the temporary period of reduced alertness and impaired cognition that immediately follows the wake up is known as "sleep inertia" [11, 16]. As Trotti says in [17]: "The intensity and duration of sleep inertia vary based on situational factors, but its effects may last minutes to several hours". Since, sleep inertia affects how we perform after wake up [14, 10], it is desirable to have few impairment from sleep inertia to move on to carry our daily activities.

We often rely on a device to sound an alarm at the desired time so that we timely wake up. But, there are still some occasions when this is not enough and we oversleep. Consequently, for very important events, we often ask a relative, a friend or a staff member to make sure that we are awake at a specific time. In particular, we trust that waking up with the help of another person will prevent us to fall asleep again and help us be more alert. The main drawback is that this person also has to wake up and we are asking a favor or using a service. There is either an affective cost, we should make it up to that relative or friend that helped us, or a financial cost, we should pay for the service.

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* *This research was supported by JST CREST Grant Number JPMJCR17A2, Japan.

** The final authenticated version is available online at https://doi.org/10.1007/978-3-030-62056-1_6

Fig. 1. Wake up robot installed in a "real-world bedroom". The positional relationship between the robot and the bed is important.

The fact that people routinely rely on someone else to wake them up for important occasions is a very interesting observation from a Human robot interaction (HRI) researcher perspective. What if a robot could wake someone up effectively? Using a robot would not come with the same affective cost and the financial cost could be spread as it is something we do daily. The problem is that, to the knowledge of the authors, we do not know what a robot should do or could do to effectively wake people up. In particular, we have to investigate what is the added value over conventional wake up means like alarm clocks and smartphones. Some people may argue that we could use some virtual agent but we believe that the physical presence of the robot is important [3].

In the US, a nationwide survey of 1014 hiring and human resource managers and 809 workers across industries was conducted online by The Harris Poll in 2017 for careerBuilder [1]. Among the 25% of the people that admitted to be late a work at least once a month 31% told the reason was oversleeping. Oversleeping is second only to traffic 51%. Concerning younger generations, 42% of the surveyed adolescents in Portugal reported that they have difficulty to wake up every day [2]. Consequently, we think that there is a need for a better device to wake up.

This paper presents how we designed the wake up behavior for our robot, implemented that behavior and tested it in the field. In particular, we would like to stress that the user study was conducted in real-world conditions as illustrated in Fig.1.

2 RELATED WORKS

Sleep inertia has been extensively studied and several researchers investigated the effect of light [15], sound [19] or temperature [12] among others for improving the condition after wake up. These experiments are most of the time conducted in controlled environments in laboratories and aim at understanding the underlying causes of sleep inertia. But, the aim of our approach is to find a technological solution to alleviate the problem and not study the causes. In particular, our proposed system is designed to be operated out of the laboratory.

There are several researchers that proposed technological solutions to replace the conventional alarm clock. Many of these solutions are labelled as smart alarm clocks. For example in [13], the authors proposed a smart alarm clock that wakes up the user by gradually increasing the light intensity while playing music. That smart alarm clock also displays reminders of the events scheduled on that day.

Another popular approach is to force the user to move. Some commercial products implement this strategy. For example, an alarm clock that sends a propeller in a random location in the room when the alarm sounds. Then the user has to wake up, find the propeller and put it back on the alarm clock to stop the alarm.

Robots have also been used to wake up people. For example, in [5], the authors proposed a robot that runs and hides while the alarm sounds. The user has to find the robot to stop the alarm. This is an advanced robot alarm as it uses sensors to understand the environment and move accordingly. They conducted an experiment with 12 participants to compare their robot to a conventional alarm clock. The proposed robot prevented people from oversleeping or snoozing.

As we can see, there are several technological replacements to the alarm clock that involve a robot. However, the focus is usually on building a product and there is relatively few or no analysis of the effect of the robot on the user. Moreover, to the knowledge of the authors, no one considered this issue with a Human Robot Interaction (HRI) perspective [7]. In particular, it is known that robots have the ability to change human behaviors, emotions and attitudes through interactions [6, 4]. Then, we should ask ourselves how we could design the behavior of a wake up robot in order to be efficient and pleasant.

In [18], as an illustrative example, the authors tell that *being woken up by a family member is a complex affective transaction* and suggest that a robot alarm clock should not reproduce perfectly that behavior but *it is rather about creating a waking up experience in between the alarm clock and the mother yanking up the blinds and shouting "good morning, my dear!"*. In a sense, our research aims at finding this right balance.

3 BEHAVIOR DESIGN PROCESS

First, we conducted an informal interview survey to understand how people feel about being woke up by someone. We found three participants who were regularly waken up by their relatives. All of them reported that when asked to wake up several time with a loud voice, they feel that they must wake up or their relative will get angry. One of them pointed out how unpleasant it is to wake up in such conditions and how he wished to have a gentler wake up.

To understand what strategies people use to wake someone up, we conducted a preliminary experiment. In this experiment, the four participants had to wake up an experimenter that pretended to sleep deeply. The participants were primed that the sleeper was unlikely to wake up easily. We observed how these participants acted and noticed these following characteristics:

Being loud: The four participants started by being loud until the sleeper showed some response. A participant simply repeated "Get up!" with a loud voice while clapping hands. Another participant was loudly calling the name of the sleeper. One participant even played loud music from his mobile phone.

Adjusting the behavior: The participants were adjusting their waking up behavior to the response of the sleeper. As soon as the sleeper answered to the loud sound, the participants stopped being loud and listened to the sleeper.

Caring: Some of the participants were trying to motivate the sleeper to wake up by showing that they cared for him. For example, one participant was saying "You will catch a cold if you sleep in this place".

Threatening: In contrast with the "caring" words, some participants used some threats to motivate the sleeper to wake up. For example, "You will not have any breakfast if you don't wake up now".

Taking into account the information gathered from the informal interviews and our observations, we devised three possible methods for waking up people with the robot:

1. Keep making loud sound until the person gets up,
2. Make loud sound but stop every time there is a reaction,
3. Use caring words for wake up.

To select the most promising method for an implementation on a robot, we conducted another preliminary experiment to investigate what method the person being woken up prefers.

In this experiment, the experimenter is in charge of applying the three wake up methods on the three participants. First the participants are instructed to sleep, or to pretend to sleep if not possible to fall asleep, then the experimenter applies one of the methods to wake the participant up. Each of the participants experienced the three methods. Then, to gather their opinions, the participants were interviewed by the experimenter.

The participants judged that method 1 may be the most effective for waking up but it is very aggressive and unpleasant. With method 2, the participants felt that they would easily fall back asleep when the loud sound stops. Concerning method 3, the participants did not understand what the experimenter was saying when asleep. However, some participants felt it was less aggressive than the other two methods. Moreover, with method 3, the participants felt that they would be unlikely to sleep again because of the verbal interaction after they woke up.

Participants expressed the feeling that method 3 would be better with a louder sound at the start. They also pointed out that further interactions after being somehow awake could help them to further wake up.

From the preliminary experiments and our observations, we understood that a loud sound is necessary to start the wake up procedure and then that interaction is important for an effective wake up. Consequently, we decided to create an interactive wake up behavior that has two steps. First, the robot keeps on

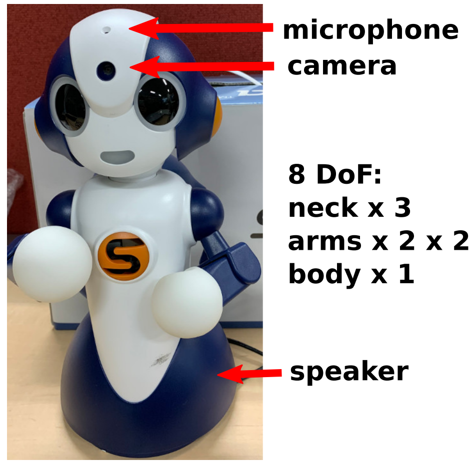

Fig. 2. Table top robot Sota from Vstone

saying with a loud voice ”Get up, show me your face.” until the person to wake up shows her/his face to the robot. Then, the robot engages in a conversation and interacts a while with the person to wake up.

4 INTERACTIVE SYSTEM

To have a portable system, we decided to use a small table top robot called Sota. Sota is a small humanoid robot built by the company Vstone, see Fig. 2. This robot has 8 degrees of freedom (DoF). It can rotate on its base, move its arms and its neck. It is also equipped with a camera, a microphone and a loud speaker all connected to an on-board computer.

The proposed wake up system is composed of four modules. The conversation control module implements the proposed wake up behavior whereas the other modules just implement the necessary basic functionalities.

First, the robot starts by asking the user to wake up and show their face. The robot uses a loud voice and repeats the call regularly until the robot detects the face of the user. At this point, the user should be facing the robot and the robot engages the conversation by asking the first question. If speech recognition results show that the user talked, the robot moves to the next question. The question answer cycle is iterated until all the six prepared questions are answered. Then, the robot stops the interaction by using a closing remark. For any questions, if the user does not give an answer to the robot the flow loops back at the first step.

We selected questions that require the user to think and are related to time. Moreover, the answers are likely to change every day. We asked several people to use the system and received feedback to determine the details of the questions.

Finally, the questions and the order we selected for the final system is the following:

1. "What is today's schedule?"
2. "At what time does the schedule start?"
3. "What did you do yesterday?"
4. "Was it fun?"
5. "How was the weather yesterday?"
6. "What time is it now?"

To end the conversation, the robot uses the closing remark "Please do your best today".

One of our requirements is that, with minimal training, a novice user should be able to set up the wake up robot by herself/himself while at home. The robot should be placed close to the bed in a location where the user can easily face it. For example, in Fig. 1, the robot is close to the head side of the bed. The robot is connected to a notebook computer (not visible in the figure) and the user just has to enter the wake up time on the computer using a simple interface we designed.

5 USER STUDY

5.1 Hypothesis and predictions

Our hypothesis is that interaction is the main factor that contributes to an effective wake up and prevents the user to fall asleep again. We also believe that interaction contributes to a better experience and the user is more likely to use the system. Consequently we make the following predictions:

- **Prediction 1 (sleepiness):** Compared to a non interactive wake up means, the proposed interactive wake up robot is better at reducing sleepiness after wake up.
- **Prediction 2 (intention to use):** Compared to a non interactive wake up means, the proposed interactive wake up robot increases the "intention to use" in the future.

5.2 Method

To verify our predictions, we designed an experiment to asses the sleepiness of the user after waking up and their intention to use the system in the future.

We recruited 22 university students using an online recruitment agency. The students were all from Kyoto city but attended different universities. There was 11 males and 11 females all aged between 20 and 24 years old. The participants were asked to take the robot to their home and install it at an adequate location close to their bed, set the alarm and go to sleep as usual. The participants were paid to take part in the study.

We used a within-participant design with counter-balanced order. Each of the participants experienced the two following conditions:

- **The baseline condition:** waking up using a non interactive wake up robot.
- **The proposed condition:** waking up using the proposed interactive wake up robot.

For the baseline condition, rather than letting the participants wake up with their alarm clock or smartphone, we decided to have them use a non interactive version of the wake up robot. Then, both conditions are the same across all participants and we factor out the novelty associated with using a robot.

The behavior of the non interactive wake up robot consists only of a modified version of the first step of the proposed behavior. The robot repeatedly says "wake up" with a loud voice until the participant pushes a button to stop it. This behavior closely resembles that of a conventional alarm clock.

First, the participant came to the laboratory to learn how to setup the robot and program the alarm. After the training was completed, the participant went home with the robot, the notebook computer and blank questionnaires. At their home, for two consecutive nights, the participant had to enter their desired wake up time before sleeping and go to sleep as usual. In the morning, the participant woke up using the robot and then immediately answered the questionnaire. Finally, the participant brought back the robot and computer to the laboratory and an interview was conducted. The experimental protocol was approved by the IRB of our institution.

In this study, we measured three things: the "sleepiness" after wake up, the "intention to use",and the amount of sleep that night.

To measure the sleepiness after wake up, we used the Stanford Sleepiness Scale [9]. This scale has a single item. The participant has to select one of the following seven statements that best represents her/his level of perceived sleepiness:

1. Feeling active, vital, alert, or wide awake
2. Functioning at high levels, but not at peak; able to concentrate
3. Awake, but relaxed; responsive but not fully alert
4. Somewhat foggy, let down
5. Foggy; losing interest in remaining awake; slowed down
6. Sleepy, woozy, fighting sleep; prefer to lie down
7. No longer fighting sleep, sleep onset soon; having dream-like thoughts

It is a 7-point likert-type scale ranging from "Feeling active, vital, alert, or wide awake" (score 1) to "No longer fighting sleep, sleep onset soon; having dream-like thoughts" (score 7).

To measure the "intention to use" of the participants, we use the scale introduced in [8] and asked the participants the following three questions:

- If I have the opportunity, I will use this robot again soon.
- If I have the opportunity, I will definitely use this robot again in the next few days.
- If I have the opportunity, I would plan to use this robot in the near future.

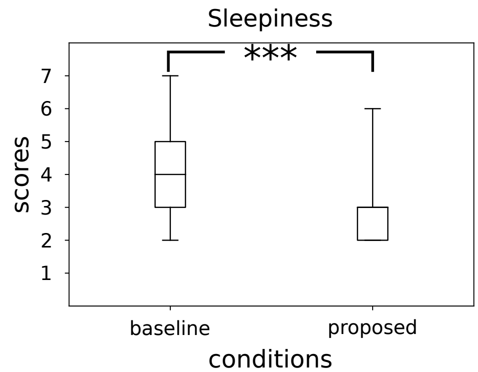

Fig. 3. Questionnaire results for "sleepiness" (lower is better)

For each of the items, the participant had to answer on a 7-point Likert scale (1-strongly disagree to 7-strongly agree). We averaged the score for these three questions to obtain our measure of "intention of use".

Finally, in order to verify that the participant had the same amount of sleep for both conditions, she/he also had to indicate how long she/he slept that particular night.

The post experiment interviews were semi-structured. First, the participant was asked to comment on her/his experience with the robot. Then, the structured part of the interview consisted of several questions.

6 RESULTS

6.1 Verification of predictions

Prediction 1 ("sleepiness"): The first item of our questionnaire indicates that the participants felt less sleepy after interacting with the robot using the proposed model (M = 2.91 SD = 1.00) than when using the baseline model (M = 4.18 SD = 1.19), see Fig.3. This difference is significant (paired t-test t = 4.96 p < .001), and the effect size was large (Cohen's d = 1.13). This result supports our prediction that: **The proposed wake up robot is more effective at waking up people.**

Prediction 2 ("intention to use"): The second item of our questionnaire indicates that the participants were more inclined to use the robot implementing the proposed model in the future ($M = 4.06$ $SD = 1.37$) than a robot using the baseline model (M = 3.48 SD = 1.25), see Fig.4. This difference is significant (paired t-test t = -2.25 p = .035) and the effect size was medium (Cohen's $d = 0.43$). This result supports our prediction that: **The user are more likely to use the proposed wake up robot in the future.**

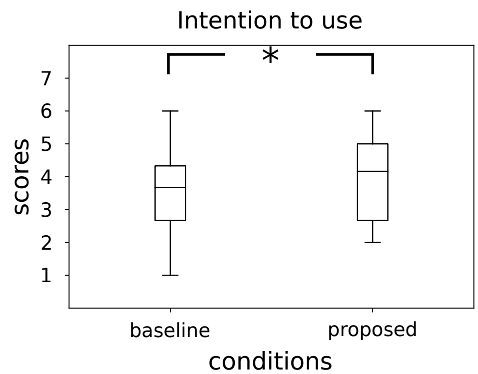

Fig. 4. Questionnaire results for "intention to use" (higher is better)

6.2 Amount of sleep

The reported sleeping duration for the two conditions was not significantly different (paired t-test $t = 1.38$ $p = .18$). **The participants had an equivalent amount of sleep before wake up for both conditions.** The overall average sleeping duration was 6.49 hours ($SD = 1.09$).

6.3 Interview results

Many participants told that they had to think to answer the robot's questions and that it contributed to their awakening. In particular, many thought that questions about the day's schedule and what they did the previous day were effective. Many participants also told that talking immediately after waking up contributed to a better awakening. Several participants felt it was easier to proceed to the next action after waking up with the proposed interactive wake up robot.

Several participants pointed out that they expected the robot to elaborate on their answers and have the conversation unfold. A few participants reported that the conversation was not smooth. Some of them told it was due to poor speech recognition performance. A small number of participants felt that the interaction was too long.

Many of the participants that showed the highest intention to use the robot in the future told that they enjoyed the conversation with the humanoid robot. On the other hand, many of the participants who scored low on this item were generally dissatisfied with the inconvenience of setting the alarm using the computer and the low accuracy of face detection or voice recognition.

A few participants experienced difficulties to have the robot detect their face. In spite of the training in the laboratory, some participants told it was troublesome to set the alarm using the computer.

All the participants told they usually use their smartphone for waking up. When asked about how smoothly they usually wake up, nearly everyone told the process was not that smooth.

7 DISCUSSION

7.1 Effect on post wake up sleepiness

The results of the questionnaires show that the participants felt the proposed wake up robot is significantly more effective at waking them up. In the interviews, the participants explained that putting effort in a conversation forced them to stay awake and prepared them better to move on. Some participants singled out a few questions they felt had a greater effect on their wake up. Thus, we can think that the content of the interaction is important.

The length of the interaction was also evoked by several participants. A few participants felt that it was frustrating to have to go through all the questions if they already feel awake after a few of them. However, other participants hinted to the fact that they need a long conversation to fully wake up. Then, to improve the system, it may helpful to adapt the length of the interaction depending of the user's state.

All the participants reported that they usually use the basic alarm function of their smartphone to wake up. Consequently, the actions required during their regular wake up is close to the ones required in our baseline condition. Then, we believe that the proposed wake up robot should also be more effective than a conventional smartphone alarm.

A difference in the amount of sleep could influence sleep inertia [16]. The reported duration of sleep was similar for both conditions and should not have influenced the results.

At the time of the experiment, the sun rose before 5:45 and the participants did not mention about turning on the light to perform face recognition. However, in other locations, it may be important to control for light as turning on the light may influence the result in favor of the robot using face recognition.

7.2 Intention to use in the future

The participants already reported significantly more intention to use the proposed interactive robot in its current form. Many participants wished they could have a smoother and richer conversation with the robot. If this point is improved and the conversations become more interesting, the intention to use the robot in the future is likely to increase.

7.3 Long term effect

In this study, the participants just tested the proposed wake up robot for one morning. Our rudimentary conversation module was enough to test our hypothesis that interaction is important. However, we can easily imagine that on the long run it is necessary to have more variety for the questions. In addition, it would be useful to incorporate user's preferences. For example, a busy person may not want to wake up talking about the day's schedule.

7.4 Limitations

Recruiting participants that are eager to bring and setup the robot in their home and, then, conduct the experiment for two consecutive days was not easy. Thus, our recruiting advertisements targeted the specific demographic of university students. The reasons given by the participants during the interviews did not seem specific to this particular demographic. Then, we can expect the effect to exist for other demographic groups. But, further research is necessary to confirm this hypothesis.

The participants felt that it is the conversation and the associated cognitive effort that helped them to wake up. One might think that a smart speaker could be used to talk with the user. We believe that talking with the humanoid robot, that has a physical presence reminiscent of a human, helps to engage in the conversation and contributes to the "wake up effect". To have a definitive answer, a further study comparing the proposed behavior by a robot or by a smart speaker would be necessary.

8 CONCLUSION

In this paper, we first investigated what behavior a robot could use to effectively wake up people in the morning. From preliminary experiments and observations we proposed to use a two-step behavior that combines a loud wake up step followed by a short conversation between the robot and the user. In particular, it was the interaction between the robot and the user that was expected to cause a smooth wake up. To confirm this hypothesis, we implemented that behavior in a small robot and conducted a user study. A particularity of this user study is that we conducted it in real conditions. The participants used a robot with and without interaction for waking up on two consecutive days at their home. The results showed that the robot using interaction was significantly reducing the sleepiness of the participants after wake up. Moreover, the participants were significantly more eager to use that interactive robot in the future. The post experiment interviews showed that the participants attributed the effectiveness of the system to the interaction. However, further research is needed to understand in more details why the participants preferred the interactive robot.

ACKNOWLEDGMENT

We would like to thank Yoko Kubota and Hiromi Kobayashi for their help in organizing the user study. We would also like to thank Kyohei Hosoda, Kota Maehama and Koki Makita for their involvement in the preliminary experiments.

References

1. This Year's Most Bizarre Excuses for Being Late to Work, According to New CareerBuilder Survey (accessed March 1, 2020), http://press.careerbuilder.com/2018-03-22-This-Years-Most-Bizarre-Excuses-for-Being-Late-to-Work-According-to-New-CareerBuilder-Survey
2. Amaral, O., Garrido, A., Pereira, C., Veiga, N., Serpa, C., Sakellarides, C.: Sleep patterns and insomnia among portuguese adolescents: a cross-sectional study. Atencion primaria / Sociedad Espanola de Medicina de Familia y Comunitaria **46**(5), 191–194 (2014)
3. Bainbridge, W.A., Hart, J., Kim, E.S., Scassellati, B.: The effect of presence on human-robot interaction. In: RO-MAN 2008-The 17th IEEE International Symposium on Robot and Human Interactive Communication. pp. 701–706. IEEE (2008)
4. Dautenhahn, K.: Socially intelligent robots: dimensions of human–robot interaction. Philosophical transactions of the royal society B: Biological sciences **362**(1480), 679–704 (2007)
5. Ee, L., Zamin, N., Aziz, I., Haron, N., Mehat, M., Ismail, N.: Bedrunn3r: An intelligent running alarm clock. ARPN Journal of Engineering and Applied Sciences **10**(23), 17890–17898 (2015)
6. Fong, T., Nourbakhsh, I., Dautenhahn, K.: A survey of socially interactive robots. Robotics and Autonomous Systems **42**(3), 143 – 166 (2003). https://doi.org/https://doi.org/10.1016/S0921-8890(02)00372-X, socially Interactive Robots
7. Goodrich, M.A., Schultz, A.C., et al.: Human–robot interaction: a survey. Foundations and Trends® in Human–Computer Interaction **1**(3), 203–275 (2008)
8. Heerink, M., Kröse, B., Wielinga, B., Evers, V.: Enjoyment, intention to use and actual use of a conversational robot by elderly people. In: Proceedings of the ACM/IEEE Int. Conf. on Human-Robot Interaction (HRI2008). pp. 113–119 (2008)
9. Hoddes, E., Zarcone, V., Smythe, H., Phillips, R., Dement, W.C.: Quantification of sleepiness: a new approach. Psychophysiology **10**(4), 431–436 (1973)
10. Horne, J., Moseley, R.: Sudden early-morning awakening impairs immediate tactical planning in a changing 'emergency' scenario. J Sleep Res **20**(2), 275–278 (2011)
11. Jeanneret, P., Webb, W.: Strength of grip on arousal from full nights sleep. Percept Mot Skills **17**, 759–761 (1963)
12. Kräuchi, K., Cajochen, C., Wirz-Justice, A.: Waking up properly: is there a role of thermoregulation in sleep inertia? J Sleep Res **13**(2), 121–127 (2004)
13. Kumar, S., Dhiraj, D., Cibi, C., Sowmya, S., Sabitha, S.: Smart alarm clock. In: 2018 3rd International Conference on Communication and Electronics Systems (ICCES). pp. 999–1001 (2018)
14. Muzet, A., Nicolas, A., Tassi, P., Dewasmes, G., Bonneau, A.: Implementation of napping in industry and the problem of sleep inertia. J Sleep Res **4**(52), 67–69 (1995)
15. Santhi, N., Groeger, J., Archer, S., Gimènez, M., Schlangen, L., Dijk, D.: Morning sleep inertia in alertness and performance: effect of cognitive domain and white light conditions. PloS One **8**(11), e79688 (2013)
16. Tassi, P., Muzet, A.: Sleep inertia. Sleep Med Rev **4**, 341–353 (2000)
17. Trotti, L.: Waking up is the hardest thing i do all day: Sleep inertia and sleep drunkenness. Sleep Med Rev **35**, 76–84 (2017)

18. Welge, J., Hassenzahl, M.: Better than human: About the psychological superpowers of robots. In: Agah, A., Cabibihan, J.J., Howard, A.M., Salichs, M.A., He, H. (eds.) Social Robotics. pp. 993–1002. Springer International Publishing (2016)
19. Wilkinson, R.: Interaction of noise with knowledge of results and sleep deprivation. J Exp Psychol **66**(4), 332–337 (1963)