A Smart Speaker Lamp for Assisting Bedtime Smartphone Non-Use: A Feasibility Study

Gyeyoung Jung[1], Seungsu Kim[2], Minju Song[3], Yuju Kang[4], Jaeyong Lee [5], Jaejeung Kim*
Department of Computer Science and Engineering, Chungnam National University
Daejeon, South Korea
Email: [1]gye0203@o.cnu.ac.kr, [2] holywater.kim025@gmail.com, [3] minjusssong@gmail.com,
[4] yuju@o.cnu.ac.kr, [5] 202350311@o.cnu.ac.kr, *jjkim@cnu.ac.kr

***Abstract*—Smartphone use before and during bedtime has been pointed out as one of the major contributing factor of sleep disorders. In this paper, we designed a smart speaker lamp to support smartphone non-use at bedtime. It uses two devices with three delivery channels (smartphone screen notification, smart speaker sound & light) for intervention delivery at three different time periods (pre-bedtime preparation, pre-bedtime, bedtime). In our feasibility study with 30 participants, we measured perceived behavioral adherence, awareness, and appropriateness of different intervention periods/methods. The result showed the perceived adherence and awareness from the intervention as around moderate, and the deliveries are above moderately suitable for behavioral change. The sound from the smart speaker lamp was indicated acceptable compared to the sound from the smartphone and assessed the light-encoded information as highly interpretable. Five participants were randomly selected and interviewed for further implications from the results and to suggest the system's future directions.**

***Index Terms*—smart speaker lamp, digital behavior change intervention, digital intrusiveness, behavioral adherence**

I. Introduction

The smartphone has become a part of our daily life essential [1], being used day and night for various purposes. Unfortunately, it also has become one of the contributing factor of sleep disorders, which affects total sleep time and sleep quality [2]–[4]. Particularly, the screen time during the very last 30 minutes before sleep has shown significantly negative effects on sleep quality [5]. From the physiological perspective, the influence of the blue light emitted from smartphones suppresses melatonin, resulting in promoting alertness, which negatively affects sleep quality [6]. Next, the poor sleep quality can arouse stress [7], insomnia [8], [9], depression [3], anxiety [8], and day work impairment [10], which worsens quality of life.

Previous research studying the effect of media use before sleep among university students has shown that digital media use before the last hour of sleep significantly affects sleep health and an increment of media use correlates with sleep latency increment [11]. Based on the prior work, we surveyed 134 young adults (age: M=23.69, SD=4.39, Women: 41.8%) about the use of smartphones before sleep. The questionnaire was composed of three 5-point Likert scale questions, rated 1 as 'strongly disagree' and 5 as 'strongly agree'. The survey results are as follows: "I often use a smartphone before sleep"(M=4.44, SD=0.81), "I sleep later than I thought due to smartphone use before sleep" (M=3.81, SD=1.23), and "I feel fatigued due to smartphone use before sleep" (M=3.55, SD=1.28). The result indicates that the young adults frequently use smartphones before sleep, and it is very likely that smartphones are affecting their sleep, which aligns with prior works.

To tackle this problem, we employ Digital Behavior Change Intervention(DBCI) into a smart speaker lamp device to assist bedtime smartphone non-use. The DBCI is defined as "... a product or service that uses computer technology to promote behaviour change" [12], which has the intention to induce behavioral change through the wearable device, computer program, smartphone, and website, and can encourage and promote a healthy lifestyle, supporting in maintaining a well-being status [13]. In this work, we designed the system architecture and defined its features to conduct a feasibility study with 30 participants. The system has two human interface devices (HIDs), a smartphone and a smart speaker lamp, to monitor the user's smartphone use before sleep and intervene user's behavior toward smartphone non-use. We evaluated perceived behavioral adherence, awareness, and appropriateness of different intervention periods/methods. Based on the evaluation, we provide implications toward effective assistance of smartphone non-use before bedtime considering the intervention delivery timing and its channel.

II. Related Works

A. Digital Behavior Change Intervention

1) Push Notification: Push notification is an alarm in the smartphone, which delivers messages, emails, and social events, and the user receives 65.3 notifications per day on average [14]. Modalities, which are sound, light, and vibration, are implemented into the alarm to increase user engagement [15]. The push notification has the property to significantly disrupt demanding tasks and continuously maintains the awareness of the alarm [16]. Prior research has proven its effectiveness in weight loss [17], and alcohol reduction [18]

2) Ambient Light: Ambient light delivers significant information with ambient display, minimizing the disruption and simultaneously delivering information while focusing on the primary task [19]. Information can be encoded to the light parameters, which are brightness, luminance, color, and frequency [20]. Through the encoded information, light can let users be aware of their behavior and induce psychological and physical changes [21]. The intervention has proven its effectiveness for stress management [22], and behavior encouragement [23].

3) Voice Assistant: The voice assistant can understand the human conversation and take action if requisite [24]. It is effectual in behavior and psychological changes through the interaction with the user [25]. It can intervene with users promptly based on personal preferences and the acceptance can vary on account of the assistant voice characteristics [26]. The intervention showed its efficacy superior to the intellectual text intervention in behavior changes [27] but does not recommend using it solely [26]. The voice assistant has proven its effectiveness in obesity treatment [28], and academic performance improvement [29].

B. Smart Lamp for Smartphone Non-Use

Lee *et al.* designed a lamp that changes the light color based on the screen time of the smartphone before bedtime [30]. The lamp was designed with the character emitting the light at the eye to imply the user expected eye health due to smartphone use. The system used 'gamification', an effective persuasive technique for behavior change [31], to induce the user to refrain from smartphone use. The system is designed to gain incentives from the refrained time and is able to buy the merchandise.

Choi *et al.* proposed two different lamp designs, which change the number of lights(i.e. level) based on smartphone use [32]. The first lamp design decreases the level as the time reaches the user's bedtime. The second lamp design is composed of two lamps in which one decreases the level with the mechanism as the first lamp design, and the other simultaneously increases the level, representing the arousal level.

Our system adopts the metaphorical design, as designing the lamp like a battery icon which acts as an indicator to imply the user status due to smartphone use before sleep. Referring to the prior lamp designs, which encodes the user status to the light change, the expected sleep quality is encoded into the light color change and the expected next-day condition is encoded into the light level change. The system uses DBCIs for the behavior change method, alternating the 'gamification'.

III. Proposed Method

A. System Architecture

The proposed system architecture is shown in Fig. 1. The system has two HIDs, a smartphone, and a smart speaker lamp, and is composed of four modules: (1) Input module, (2) Intervention module, (3) Server, and (4) Output module.

B. System Component

1) Input Module: The module has the device context and the environment context as an input type and is used for user monitoring.

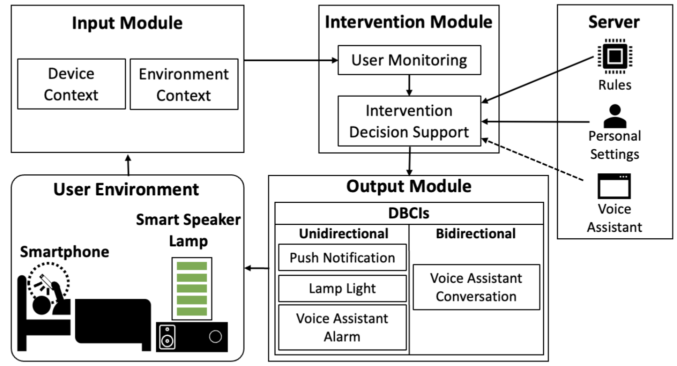

Fig. 1. Smart Speaker Lamp System Architecture

a) Device Context: The device context has the current use status and screen time, collected through the smartphone. The use status is based on the screen on/off log, to determine user sleep with ease [33]. Screen time is an accumulated smartphone screen-on time during the pre-bedtime and bedtime.

b) Environment Context: The environment context has the surrounding's light intensity measured through the light sensor. The context is applied for to determine rather the user environment is dark or not.

2) Intervention Module: The module has a user monitoring component and an intervention decision support component

a) User Monitoring: The component monitors the user's smartphone use based on the received input module information during the three different periods before sleep.

b) Intervention Decision Support: The component decides the intervention timing based on the user monitoring and defined rules, determining which DBCIs to apply to the user. The defined rules are based on the rules and personal settings in the server. The voice assistant in the server is used when a voice assistant alarm or conversation is applied to the user. The defined rules are described in *D. Intervention Method*

3) Server:

a) Rules: Rules are for determining which DBCIs to apply from the user status and the timing.

b) Personal Settings: The user's sleep time and wake-up time are the context of personal settings and are set through the user's smartphone. The intervention delivery timing is set based on personal settings.

c) Voice Assistant: The voice assistant has Speech-To-Text and Text-To-Speech for input/output and natural language processing techniques to intervene user unidirectionally or bidirectionally.

4) Output Module: The module applies DBCIs to users through the HIDs, determined from the intervention decision support.

a) DBCIs: The DBCIs are classified into unidirectional and bidirectional, based on the interactive level between the user and the system. The unidirectional intervention prompt without direct user interaction and the bidirectional intervention prompt with requiring active user interaction.

Push notification (PN) is a unidirectional DBCI, designed to intervene directly with the user through the smartphone and is applied with recommendation messages(e.g.“For your healthy sleep, would you stop using smartphone?”) to induce behavior change.

Lamp light (LL) is a unidirectional DBCI and is designed to inform user status through the light change, which has the characteristics of ambient light intervention. The lamp light operates based on the device context and environment context. The lamp light encoded information is described in *C. The Lamp Design*.

Voice assistant has alarm type (VAA) and conversation type (VAC). The alarm type is designed to prompt the user without requiring user actions (e.g. “You have used your smartphone over 30 minutes. Please stop the smartphone use for your good sleep”) and is classified as unidirectional DBCI. The conversation type, which is classified as bidirectional DBCI, is designed to require the user to participate and take action when intervened (e.g. “Soon is the time for pre-bedtime. Are you prepared for your sleep?”).

C. The Lamp Design

The design of the lamp metaphors the battery icon to induce the user easily understands the encoded information. The lamp light is designed to change the color and the number of lights (i.e. level). The changes are shown in Fig. 2. The lamp color implies the expected user sleep quality, representing green: fair / yellow: poor / orange: very poor / red: worst. Based on the smartphone screen time over 30 minutes before sleep affects sleep quality negatively, the screen time (t) is designed: (1) 0 min $\leq$ t $<$ 30 min: green, (2) 30 min $\leq$ t $<$ 40 min: yellow, (3) 40 min $\leq$ t $<$ 50 min: orange, (4) 50 min $\leq$ t: red. The lamp level implies the user expected next-day condition, designed to reduce 100% to 0% with 25% unit. The design has an objective to induce the user to simulate their expected status due to smartphone use before sleep.

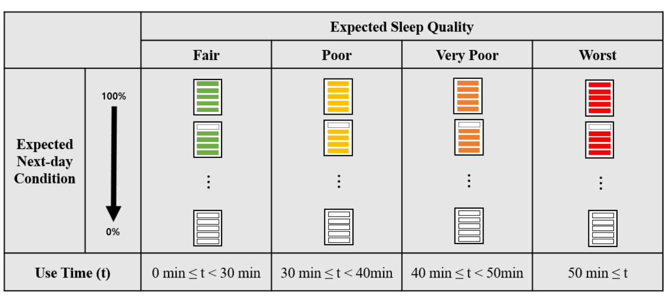

Fig. 2. The Changes of Lamp Light

D. Intervention Method

1) Intervention Delivery Timing: The National Sleep Foundation (NSF) recommends refraining from any electronic device 30 – 60 minutes before bedtime for good sleep quality [34]. Based on the NSF recommendation, we have defined three periods of the user going to sleep for intervention delivery timing based on personal settings: (1) pre-bed preparation, (2) Pre-bedtime, (3) Bedtime. The pre-bed preparation is defined as between 10 minutes before the pre-bedtime and the start of the pre-bedtime. The pre-bedtime is defined as between an hour before the user’s bedtime and the start of the bedtime. Bedtime is the time between the user’s sleep time and wake-up time. The intervention delivery is designed as maximum, medium, and minimum intrusive, reducing the intrusiveness as time flows to reduce the disturbance to entering sleep.

a) Pre-Bed Preparation: The period has maximum intrusive intervention delivery, containing one bidirectional intervention (i.e. VAC) and two unidirectional interventions (i.e. PN and LL). The intervention intervenes regardless of the device context and environment context.

The VAC is designed to intervene by notifying the start of each intervention period and asking if the user is prepared for sleep. The intervention period can be shifted by the user’s response through the conversation. The PN notifies the start of the period, and LL is designed to emit white color light constantly during the period.

b) Pre-Bedtime: The period has medium intrusive intervention delivery, containing three unidirectional interventions (i.e. VAA, PN, and LL) and intervenes based on the device context and environment context.

The VAA is designed to alarm when the screen time is over 30 minutes, beginning the alarm with a short melody and state vocal alarm to refrain from smartphone use. PN alarms the user whenever the lamp light changes, and is applied with a recommendation message to induce sleep. LL is designed to change the color as the screen time during this period affects sleep quality, but is ineffective to sleep duration. The LL is designed to turn off when the user environment is determined dark and the smartphone screen is off for 3 minutes.

c) Bedtime: The period has minimum intrusive intervention delivery, containing two unidirectional interventions (i.e. PN and LL), and is designed to intervene based on the device context and environment context.

PN has the exact mechanism as the delivery in the previous period. LL changes its color and level, as smartphone use during this period affects sleep quality and sleep duration. The LL turn on/off mechanism is same as in pre-bedtime. The voice assistant intervention is excluded, which may wake up the user from sleepiness.

IV. Feasibility Study

We have conducted a feasibility study with 30 students (Age: M=21.97, SD=2.22, Women: 33%) recruited from a university, who self-reported a frequent use of smartphone before sleep. We did not make a working prototype of the system. Instead, we provided the detailed descriptions of each system features with situational context, so that the participants could make an accurate assessments. Examples of voice assistant audio were demonstrated and showed the example of lamp light and push notifications through images for further understanding. The study assumed the situation of smartphone use before sleep as while lying on the bed. After the explanation, the participants filled in a survey composed of three categories: (1) intervention adherence, (2) intervention awareness, and (3) intervention appropriateness.

The intervention adherence category evaluates the user's perceived adherence to the four types of DBCIs (VAC, VAA, PN, LL) in three delivery periods. The intervention awareness evaluates the perceived level of awareness to the DBCIs in each defined time periods. The intervention appropriateness category evaluates the appropriateness of DBCIs design and the suitability of DBCIs delivery at each delivery period. In the appropriateness of DBCIs design evaluation, about the PN message, the question evaluates the expected adherence to two different message types, which are system status message (e.g. "Color: Red / Level: 50%") and recommendation message (e.g. "For your healthy sleep, would you stop using smartphone?"). The voice assistant design question evaluates the perceived acceptance of the sound source from the smartphone and from the smart speaker lamp. The LL design question evaluates the level of interpretation of the LL example image (e.g. lamp light with red color and 50% level). All the questions were evaluated with 5-point Likert scale, rating 1 as 'strongly disagree' and 5 as 'strongly agree'. After the survey, five random participants were selected for the interview to elaborate on the reasons behind each responded survey items.

V. Result

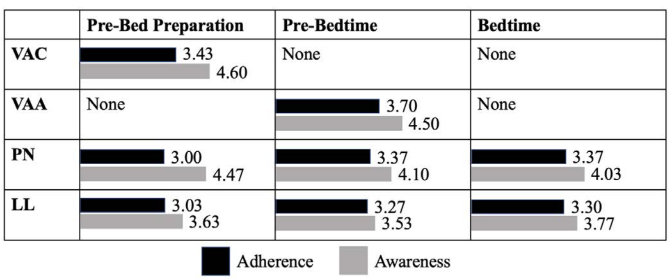

Fig. 3. Intervention Adherence and Awareness Result

A. Intervention Adherence

The evaluated result is shown in Fig. 3. In the pre-bed preparation, VAC was perceived moderate adherence (M=3.43, SD=1.07), evaluated as the most effective DBCI in the period. PN showed perceived moderate adherence (M=3.00, SD=1.17), and LL was perceived moderate adherence (M=3.03, SD=1.25). In the pre-bedtime, VAA was perceived slightly above moderate adherence (M=3.70, SD=1.02), evaluated as the most effective DBCI in the period. PN was perceived moderate adherence (M=3.37, SD=1.03), and LL was perceived moderate adherence(M=3.27, SD=1.14). In bedtime, PN was perceived moderate adherence (M=3.37, SD=1.19), evaluated as the most effective DBCI in the period. LL was perceived moderate adherence (M=3.30, SD=1.26).

B. Intervention Awareness

The evaluated result is shown in Fig. 3. In the pre-bed preparation, VAC was perceived as very highly aware (M=4.60, SD=0.50), evaluated as the highest level of awareness among other DBCIs in the period. PN was perceived as highly aware (M=4.47, SD=0.57), and LL was perceived as slightly above moderately aware (M=3.63, SD=1.22). In the pre-bedtime, VAA was perceived as very highly aware (M=4.50, SD=0.73), evaluated as the highest level of awareness among other DBCIs in the period. PN was perceived as highly aware (M=4.10, SD=0.96) and LL was perceived as slightly above moderately aware (M=3.53, SD=1.28). In bedtime, PN was perceived as highly aware (M=4.03, SD=1.07), evaluated as the highest level of awareness among other DBCIs in the period, and LL was perceived as slightly above moderately aware (M=3.77, SD=1.28).

C. Intervention Appropriateness

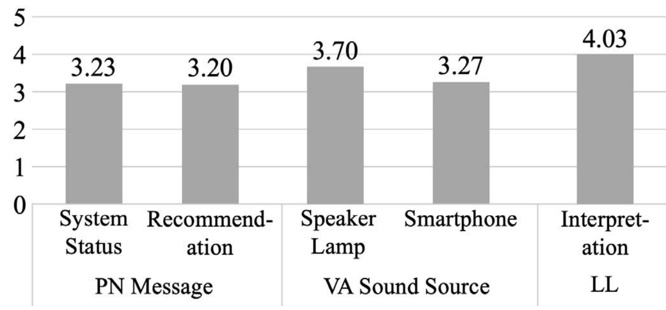

Fig. 4. DBCIs Design Evaluation Result

1) DBCIs Design: The evaluated result is shown in the Fig. 4. PN with system status message was perceived as moderate adherence (M=.23, SD=1.30), and recommendation message was perceived as moderate adherence (M-3.20, SD=1.37), showing no significant difference in the t-test (t=.115, p=.909). Voice assistant (VA) sound source from the smart speaker lamp showed perceived as slightly above moderate acceptance (M-3.70, SD=0.84), and from the smartphone showed perceived as moderate acceptance (M=3.27, SD=1.05), showing a significant difference in the t-test (t=3.261, $p<.05$). The interpretation of encoded information in LL example was easily interpretable (M=4.03, SD=1.10).

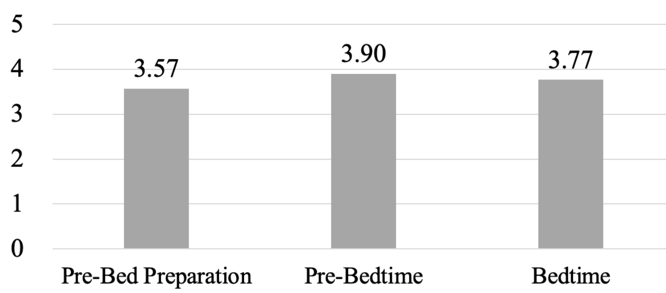

Fig. 5. Intervention Suitability Result

2) Intervention Delivery Suitability: The evaluated result is shown in Fig. 5. The maximum intrusive intervention delivery in pre-bed preparation was perceived as slightly above moderately suitable (M=3.57, SD=1.04). The medium intrusive intervention delivery in pre-bedtime was perceived as slightly above moderately suitable (M=3.90, SD=0.99), evaluated as the most suitable intervention delivery design among others. The minimum intrusive intervention delivery design in bedtime was perceived as slightly above moderately suitable (M=3.77, SD=0.94).

VI. Discussion

We have defined the three periods before sleep to deliver the interventions according to intrusiveness. Although the intervention deliveries in all periods were perceived as slightly above moderately suitable, the interview results show that it was not sufficient for inducing behavioral change. P2 and P5 stated that they did not empathize with the reasons for distinguishing the three time periods. All interviewees commonly mentioned the pre-bedtime was too long. The term ”preparation of sleeping” is perceived as an unfamiliar term that is not used on a daily basis, and the period does not match one's lifestyle, failing to empathize. Therefore, considering the fact average sleep latency for adults is 21.9 minutes [35], and the minimum NSF pre-bedtime recommendation is 30 minutes, it is necessary to adjust currently defined pre-bedtime from 1 hour to 30 minutes. Furthermore, changing personal settings to target sleep time and target sleep duration can expect to arouse motivation, applying persuasively empathized reasons to defined periods.

All of the DBCIs' perceived awareness in each period were evaluated as above moderate but showed perceived moderate adherence except for VAA. In the interview, P1, P2, and P3 mentioned the possibility of refraining from smartphone use when being aware of smartphone use status, and P2 and P4 mentioned that multiple DBCIs delivered as a combination would be more effective. Except for P1, who considered all DBCIs were not enough to make a behavioral change, rather required more compulsory and vigilant stimulus for intervention. Prior research revealed that tailored intervention, which can be perceived as personal and more enduring, showed improvements in behavior change [36]. As the LL intervention can continuously be perceived through the user's will, therefore, revising DBCIs with linguistic messages (i.e. push notification and voice assistant) to tailored messages and work in conjunction with LL can expect to raise awareness.

Regarding the design of PN in DBCIs design evaluation, there was no difference in perceived adherence between the system status message and the recommendation message. However, the system status message were revealed to be more preferred in the interview, as it simulates own expected status. Again, all interviewees except for P1 commonly implied insufficient to induce behavioral change, which was found to be a lack of raising awareness of smartphone use in the message. Applying the tailored message (e.g. comparing past and current smartphone use status) can be expected to increase awareness. Furthermore, activating continuously visible status monitoring window (e.g. android foreground service) is expected to increase adherence to the intervention.

VA intervention from a smart speaker lamp was found to be preferred over the smartphone speaker. The majority of interviewees agreed to intervene from the lamp as it gives freshness as if someone points out from a relatively long distance than the smartphone.

The interpretation of encoded information in LL was evaluated positively. However, all interviewees expressed skeptical opinions about the encoded information. P1, P4, and P5 mentioned the need for a direct and easily interpretable design, implying the encoded information is difficult to interpret without explanation. P4 and P5 mentioned the mismatch of light changes and their lifestyle, feeling less empathetic toward the design and P2 expressed doubts about the information the lamp presented, implying would be less likely to adhere depending on the accuracy of information. Prior research has shown that interpretation is reduced when more than one information is encoded in the light [37]. Therefore, providing more simplified, yet direct information through LL could be more effective.

There are several limitations in the study. The system was evaluated through a verbally and textually described system with low-fidelity examples, such as a voice assistant audio sample and images of the lamp light, to assist in the explanation of the assumed situation. Therefore, the evaluation may not be completely reliable as the full implemented system. Also, one's perception on the intensity of each intervention modality(e.g., light intensity) may differ. Some participants considered the light intensity of the lamp was bright enough to illuminate the whole room, while some did not. Furthermore, only assumed the situational context of the user lying on the bed using a smartphone before sleep. While in reality, there could be many other variations. In order to resolve these limitations, it is necessary to conduct a field experiment with a fully implemented system.

VII. Conclusion

We designed a smart speaker lamp system to assist the user to refrain from smartphone use before sleep. We conducted a feasibility study to identify the potential effectiveness and problems of our system features in the form of DCBIs in delivered in different periods. We expect the study results to be refine our future system implementation as well as guide potential researchers in this field toward building more effective systems for bedtime smartphone non-use interventions.

Acknowledgment

This work was partly supported by Institute of Information & communications Technology Planning & Evaluation (IITP) grant funded by the Korea government(MSIT) (No.RS-2022-00155857, Artificial Intelligence Convergence Innovation Human Resources Development (Chungnam National University)) and (No.2022-0-01200, Convergence security core talent training business(Chungnam National University))

REFERENCES

[1] D. Wang, Z. Xiang, and D. R. Fesenmaier, "Smartphone use in everyday life and travel," *Journal of travel research*, vol. 55, no. 1, pp. 52–63, 2016.

[2] M. A. Christensen, L. Bettencourt, L. Kaye, S. T. Moturu, K. T. Nguyen, J. E. Olgin, M. J. Pletcher, and G. M. Marcus, "Direct measurements of smartphone screen-time: relationships with demographics and sleep," *PloS one*, vol. 11, no. 11, p. e0165331, 2016.

[3] K. Demirci, M. Akgönül, and A. Akpinar, "Relationship of smartphone use severity with sleep quality, depression, and anxiety in university students," *Journal of behavioral addictions*, vol. 4, no. 2, pp. 85–92, 2015.

[4] K. J. Mehta, "Effect of sleep and mood on academic performance—at interface of physiology, psychology, and education," *Humanities and Social Sciences Communications*, vol. 9, no. 1, pp. 1–13, 2022.

[5] N. Rafique, L. I. Al-Asoom, A. A. Alsunni, F. N. Saudagar, L. Almulhim, and G. Alkaltham, "Effects of mobile use on subjective sleep quality," *Nature and science of sleep*, pp. 357–364, 2020.

[6] J. H. Oh, H. Yoo, H. K. Park, and Y. R. Do, "Analysis of circadian properties and healthy levels of blue light from smartphones at night," *Scientific reports*, vol. 5, no. 1, p. 11325, 2015.

[7] M. Bunyalug and N. Kanchanakhan, "Effect of using smartphone before bed on sleep quality among undergraduate students at chulalongkorn university, thailand," *Journal of Health Research*, vol. 31, no. Suppl. 2, pp. S225–231, 2017.

[8] N. Al Battashi, O. Al Omari, M. Sawalha, S. Al Maktoumi, A. Alsuleitini, and M. Al Qadire, "The relationship between smartphone use, insomnia, stress, and anxiety among university students: A cross-sectional study," *Clinical Nursing Research*, vol. 30, no. 6, pp. 734–740, 2021.

[9] J. Lee, H.-Y. Jung, S. I. Lee, H. Youn, and S.-G. Kim, "Smartphone addiction proneness is associated with subjective-objective sleep discrepancy in patients with insomnia disorder," *Psychiatry Investigation*, vol. 18, no. 11, p. 1035, 2021.

[10] B. LaRocque, C. Mu, and S. Lee, "Poor sleep health and next day work impairment: The mediating role of fatigue," *Innovation in Aging*, vol. 4, no. Suppl 1, p. 428, 2020.

[11] K. M. Orzech, M. A. Grandner, B. M. Roane, and M. A. Carskadon, "Digital media use in the 2 h before bedtime is associated with sleep variables in university students," *Computers in human behavior*, vol. 55, pp. 43–50, 2016.

[12] R. West and S. Michie, *A guide to development and evaluation of digital behaviour interventions in healthcare*. Silverback Publishing, 2016.

[13] Y. Chen, F. J. Perez-Cueto, A. Giboreau, I. Mavridis, and H. Hartwell, "The promotion of eating behaviour change through digital interventions," *International Journal of Environmental Research and Public Health*, vol. 17, no. 20, p. 7488, 2020.

[14] M. Pielot, K. Church, and R. De Oliveira, "An in-situ study of mobile phone notifications," in *Proceedings of the 16th international conference on Human-computer interaction with mobile devices & services*, 2014, pp. 233–242.

[15] A. Mashhadi, A. Mathur, and F. Kawsar, "The myth of subtle notifications," in *Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct Publication*, 2014, pp. 111–114.

[16] C. Stothart, A. Mitchum, and C. Yehnert, "The attentional cost of receiving a cell phone notification." *Journal of experimental psychology: human perception and performance*, vol. 41, no. 4, p. 893, 2015.

[17] A. Hernández-Reyes, F. Cámara-Martos, G. M. Recio, R. Molina-Luque, M. Romero-Saldaña, R. M. Rojas *et al.*, "Push notifications from a mobile app to improve the body composition of overweight or obese women: randomized controlled trial," *JMIR mHealth and uHealth*, vol. 8, no. 2, p. e13747, 2020.

[18] L. Bell, C. Garnett, T. Qian, O. Perski, E. Williamson, and H. W. Potts, "Engagement with a behavior change app for alcohol reduction: data visualization for longitudinal observational study," *Journal of medical Internet research*, vol. 22, no. 12, p. e23369, 2020.

[19] Z. Pousman and J. Stasko, "A taxonomy of ambient information systems: four patterns of design," in *Proceedings of the working conference on Advanced visual interfaces*, 2006, pp. 67–74.

[20] M. H. Kim, T. Weyrich, and J. Kautz, "Modeling human color perception under extended luminance levels," in *ACM SIGGRAPH 2009 papers*, 2009, pp. 1–9.

[21] C. Cajochen, "Alerting effects of light," *Sleep medicine reviews*, vol. 11, no. 6, pp. 453–464, 2007.

[22] B. Yu, J. Hu, M. Funk, and L. Feijs, "Delight: biofeedback through ambient light for stress intervention and relaxation assistance," *Personal and Ubiquitous Computing*, vol. 22, pp. 787–805, 2018.

[23] P. Burns, C. Lueg, and S. Berkovsky, "Activmon: encouraging physical activity through ambient social awareness," in *CHI'12 Extended Abstracts on Human Factors in Computing Systems*, 2012, pp. 2363–2368.

[24] A. Valera Román, D. Pato Martínez, Á. Lozano Murciego, D. M. Jiménez-Bravo, and J. F. de Paz, "Voice assistant application for avoiding sedentarism in elderly people based on iot technologies," *Electronics*, vol. 10, no. 8, p. 980, 2021.

[25] K. Seaborn, N. P. Miyake, P. Pennefather, and M. Otake-Matsuura, "Voice in human–agent interaction: A survey," *ACM Computing Surveys (CSUR)*, vol. 54, no. 4, pp. 1–43, 2021.

[26] E. Sezgin, L. K. Militello, Y. Huang, and S. Lin, "A scoping review of patient-facing, behavioral health interventions with voice assistant technology targeting self-management and healthy lifestyle behaviors," *Translational Behavioral Medicine*, vol. 10, no. 3, pp. 606–628, 2020.

[27] A. Hassoon, Y. Baig, D. Q. Naiman, D. D. Celentano, D. Lansey, V. Stearns, J. Coresh, J. Schrack, S. S. Martin, H.-C. Yeh *et al.*, "Randomized trial of two artificial intelligence coaching interventions to increase physical activity in cancer survivors," *npj Digital Medicine*, vol. 4, no. 1, p. 168, 2021.

[28] J. A. Wright, B. D. Phillips, B. Watson, P. Newby, G. Norman, and W. Adams, "Randomized trial of a family-based, automated, conversational obesity treatment program for underserved populations," *Obesity*, vol. 21, no. 9, pp. E369–E378, 2013.

[29] R. Winkler, M. Söllner, and J. M. Leimeister, "Enhancing problem-solving skills with smart personal assistant technology," *Computers & Education*, vol. 165, p. 104148, 2021.

[30] J. Lee, J. Y. Lee, S. W. Kim, and J. D. Cho, "D-tox: Inducing digital detox for nighttime via smart lamp applied gamification," in *Proceedings of the 2017 Conference on Interaction Design and Children*, 2017, pp. 497–502.

[31] I. Blohm and J. M. Leimeister, "Gamification: Design of it-based enhancing services for motivational support and behavioral change," *Business & information systems engineering*, vol. 5, pp. 275–278, 2013.

[32] H.-y. Choi, K.-R. Lee, Y.-W. Park, and C.-j. Kim, "Designing for improving sleep hygiene through the reflection of smartphone awareness with ambient lighting." Manchester Metropolitan University, 2019.

[33] A. Cuttone, P. Bækgaard, V. Sekara, H. Jonsson, J. E. Larsen, and S. Lehmann, "Sensiblesleep: A bayesian model for learning sleep patterns from smartphone events," *PloS one*, vol. 12, no. 1, p. e0169901, 2017.

[34] N. S. Foundation. (2023) Sleep hygiene. [Online]. Available: https://www.sleepfoundation.org/sleep-hygiene

[35] D. S. Lauderdale, K. L. Knutson, L. L. Yan, P. J. Rathouz, S. B. Hulley, S. Sidney, and K. Liu, "Objectively measured sleep characteristics among early-middle-aged adults: the cardia study," *American journal of epidemiology*, vol. 164, no. 1, pp. 5–16, 2006.

[36] P. Ryan and D. R. Lauver, "The efficacy of tailored interventions," *Journal of Nursing Scholarship*, vol. 34, no. 4, pp. 331–337, 2002.

[37] K. Davis, E. B. Owusu, L. Marcenaro, L. Feijs, C. Regazzoni, and J. Hu, "Effects of ambient lighting displays on peripheral activity awareness," *IEEE Access*, vol. 5, pp. 9318–9335, 2017.