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Research on the Sensory Compensation Paradox Effect of Digital Sleep Aid

Chunxi Tian

School of Drama, Film and Television/Acting, Nanjing Media College, Nanjing, China
jinrui@cucn.edu.cn

Abstract. Sleep disorders have become a global health issue, and a large number of insomniacs try to use digital media for sensory compensation to help them sleep. However, there may be risks inherent in such behaviors and a contradiction between their actual effects and their intended purpose. This study focuses on the use of digital media to help insomniacs sleep and aims to explore the 'sensory compensation paradox', i.e., the use of digital media aimed at compensating for sensory disturbances and facilitating sleep, but instead leads to risky alienation. The study adopts a mixed research method. Data on media use and sleep status of the insomnia groups were collected through questionnaires. At the same time, text mining and sentiment analysis were conducted on the massive user comments of sleep-help videos on social media platforms to gain an in-depth understanding of users' behavioral patterns and subjective experiences. The study found a significant paradoxical effect: the more frequently insomniacs used and relied on digital media to help them sleep, the worse their sensory health and sleep problems became. There is an interaction between insomnia symptoms and media dependence, with those who experience both being more likely to suffer from the side effects of media-induced sleep. Research reveals the potential risks of digitally mediated sleep aids, warning of the need to rationalize their effects and seek healthier ways to improve sleep.

Keywords: Sensory compensation, paradoxical effect, media dependence, sleep disorders, risk alienation

1. Introduction

This study looks at the context of the sharp contradiction between the global sleep crisis (WHO data: 27% of the population suffer from sleep disorders; more than 300 million insomniacs in China) and the prevalence of digitally-mediated sleep-aiding behaviours (60-80% of the population use electronic devices to help them sleep before going to bed). This study is of great theoretical and practical significance in revealing the hidden risks of technological sleep programmes, breaking the cognitive misconceptions of 'digital sleep aid', and reconstructing theories of healthy sleep interventions, especially in view of the fact that the existing research focuses on the elderly group or the harmful effects of a single medium (e.g., blue light), and lacks systematic empirical evidence of 'sensory compensation paradox effect' in a wide range of insomnia groups. It is of great theoretical and practical significance, especially in view of the fact that most of the existing studies focus on the

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elderly group or the harmful effects of a single medium (e.g. blue light), and there is a lack of systematic empirical evidence on the 'paradoxical effect of sensory compensation' in a wide range of insomnia groups. This study focuses on the core phenomenon of 'the paradoxical effect of sensory compensation', focuses on the insomnia group ′ s use of digital media to help them sleep, and explores in depth the internal logic and circular mechanism of the risk of alienation (increased sensory dependence and deterioration of sleep quality).he core themes include verifying the positive correlation between compensation frequency, dependence, sensory harm, and sleep suppression, analysing how the interaction between insomnia symptoms and media dependence exacerbates sleep disorders, and explaining the mechanism of the dissimilarity cycle (dissimilarity cycle hypothesis), in which 'the need for compensation leads to dependence on media, which leads to sensory harm, which further deteriorates sleep quality'. and explaining the mechanism of the cycle of dissociation (the dissociation cycle hypothesis), which states that 'the need for compensation leads to media dependence, which leads to sensory harm, which leads to further deterioration of sleep quality, and finally, sensory compensation is reinforced'. Literature analysis is used to systematically review the research on sensory compensation theory, digital media influence and sleep disorders. The advantage of this method is that it can accurately analyse the theoretical contributions and dimensional deficiencies of the existing results (e.g. neglecting the behavioural mechanisms of young and middle-aged people, and failing to pay attention to the cyclic alienation of compensatory behaviours), and provide theoretical anchors for the construction of an explanatory framework of the 'paradoxical effect'. The ultimate goal of the study is to confirm and systematically explain the 'sensory compensation paradox' and its core mechanisms (especially the alienation cycle and interaction) when insomniacs use digital media to help them sleep through mixed empirical methods (questionnaire surveys and big data analyses of social media texts).In order to achieve the goal, the study carefully designed a media use and sleep status questionnaire for the insomnia group, and deeply explored the emotional tendency of the user comments of the massive sleep-aid videos in the social media platforms (e.g. Jitterbug) in an attempt to capture the truth of this complex phenomenon from the dual perspectives of the behavioural data and the subjective experience.

2. Literature review

2.1. Literature review

The World Health Organisation (WHO) systematically studied the global sleep health situation in the Global Status Report on Sleep Health, revealing the grim reality that approximately 27% of the population suffers from sleep problems, providing authoritative corroboration of the severity of sleep problems for this study [1]. In the China Sleep Index Report, the China Sleep Research Association focuses on the local situation in China, pointing out that there are more than 300 million insomnia patients in China and the insomnia rate of young people is rapidly rising, which provides an important basis for this study to target the 'insomnia group' (especially young and middle-aged people) as the core research object [2]. However, these two studies focused primarily on describing the macro status and demographic characteristics of sleep disorders, with little coverage of specific behavioural intervention strategies (e.g., digitally-mediated sleep aids) and their underlying risk mechanisms that are commonly used by contemporary insomniacs. Zhang et al. investigated the relationship between specific digital forms of sleep aid (ASMR) and sleep fragmentation in ASMR Dependency and Sleep Fragmentation, contributing in revealing the negative effects of single-media ASMR dependency on sleep [3]. However, the scope of the study is limited to ASMR, a single type of media, and focuses more on the changes in sleep structure at the medical level, but fails to

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systematically analyse the mechanisms of 'behavioural alienation' and 'sensory dependence' triggered by the long-term use of multiple digital media (e.g., white noise, social media scrolling, and meditation apps, etc.) in real-life scenarios. In particular, there is a lack of theoretical explanation on how 'compensatory intentions lead to paradoxical outcomes'. In this paper, we will start from the insomnia group's behavioural pattern of using multi-digital media for sensory compensation, and combine the social theory of risk and the theory of behavioural reinforcement to explore the 'paradoxical effect of sensory compensation' and its internal cyclic mechanism (e.g., deepening of dependence, withdrawal reaction, and deterioration of sleep) in the long term, so as to supplement the empirical gap of existing research on the systematic risk and alienation process of the digital sleep aid behaviour. This will complement the existing research on the systemic risk of digital sleep aids and their alienation process.

2.2. Popularity and controversy of digital sleep aids

The Sleep Foundation's National Survey on Bedtime Technology Use empirically examined the prevalence of bedtime electronic device use behaviours through a large-scale survey, noting that 60-80% of adults engage in this habit, with a significant portion of them aiming to aid sleep [4]. This provides a solid behavioural basis for this study to focus on the prevalence and value of 'digitally mediated sleep-aiding behaviours'. In Sensory Compensation in Digital Environments, Smith et al. explored the theory of sensory compensation in digital environments, investigating compensation mechanisms such as white noise masking ambient noise, and made important theoretical contributions to this research in explaining why and how individuals use digital media for sensory compensation to cope with external distractions [5]. It is an important contribution to this study in explaining why and how individuals use digital media for sensory compensation to cope with external disturbances [5]. In Digital Detox and Insomnia Remission, Chen, on the other hand, examines the negative effects of digital media (especially its addictive nature) on sleep from a critical perspective and explores the effectiveness of 'digital detox' as a solution, contributing to shedding light on the risks of technology use (e.g., blue light suppresses melatonin) and providing ideas for reverse interventions [6]. Blue light suppresses melatonin and provides ideas for reverse interventions [6]. This paper will focus on the insomnia group's active use of digital media for sensory compensation through the lens of Ulrich Beck's risk society theory [7]. Empirically exploring the process of alienation from a predetermined 'solution' to a 'risk promoter', i.e., the 'paradoxical effect' [8]. In particular, the chain of positive correlations and their interactions were verified: 'the frequency of compensation affects the degree of sensory dependence, which in turn harms the senses and finally suppresses sleep'.

3. Research strategy

3.1. Research Hypothesis

Three hypotheses will be made for the study, Hypothesis 1: Compensatory Reinforcement Hypothesis, the theoretical basis of which is the Behavioural Reinforcement Theory [9]. When the frequency of digital media use is higher, the degree of sensory dependence is stronger. Hypothesis 2:Sleep inhibition hypothesis, the theoretical basis of which is the theory of attention restoration [10]. When the length of a single use of digital media is longer, the sleep latency is longer; Hypothesis 3:The Cycle of Alienation Hypothesis, theoretically based on the Risk Society Theory

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[7]. Sensory dependence leads to a higher number of device viewing behaviours at night, which leads to poorer sleep quality.

3.2. Research methodology

The target group of the study focused on people with insomnia symptoms in the last month (difficulty falling asleep, waking up easily during the night, early awakening), who use sleep-aid videos in digital media to fall asleep before bedtime (apps, videos, social media, etc.).Through the last 5 years of Chinese and English literature, no study has been conducted to analyse the long-term effects of multiple digital media (e.g. white noise, ASMR, social media, etc.) in real sleep scenarios. This is precisely the breakthrough point of this study - the study of "behavioural alienation" and "sensory dependence" through mixed methods.

A structured questionnaire was distributed on the Questionnaire Star platform with a total sample size of 152 questionnaires covering core variables such as insomnia severity index and media usage frequency. The questionnaire data were analysed for correlation and variance using SPSS tools to test the hypotheses. Data crawling on social media was performed to build a natural language database for 10,420 comments on five types of sleep-aid videos. The tools are used to subject the comment data to sentiment analysis to further explore users' emotional motivations. The design logic of quantifying behavioural patterns with questionnaires and tapping into affective motivation with comments was followed to form a methodological triangle of mutual evidence.

4. Findings

4.1. Descriptive analysis

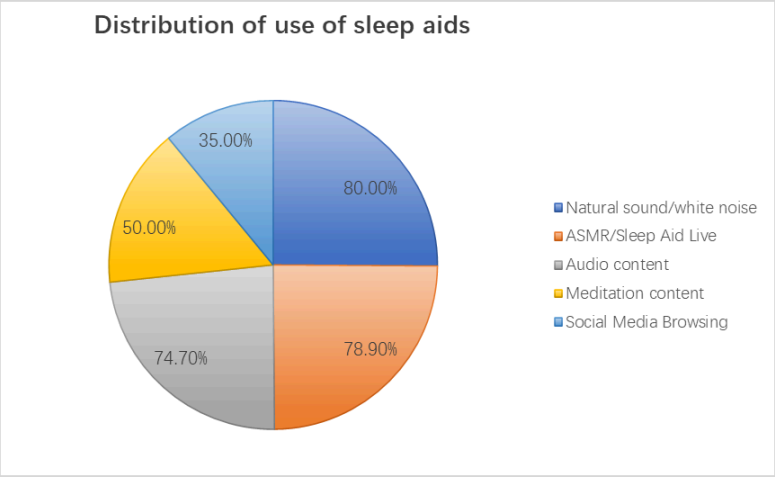

Figure 1. Distribution of the use of sleep aid media (photocredit: original)

According to the distribution of sleep aid media usage in Figure 1, the most popular medium among the sample population of the questionnaire was browsing videos with white noise and nature sounds, and on the contrary, the least popular medium among the sample population was browsing social media for sleep aid with infinite scrolling.

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4.2. Correlation analysis

Correlation analyses were conducted to test the correlations between the three dimensions of media dependence and sleep problems, the degree of media dependence and the degree of sensory harm, and the frequency of sensory compensation and the degree of sensory harm.

Firstly, media as a primary way of relieving anxiety was strongly and positively correlated with difficulty falling asleep (r=0.698), and waking up easily and early at night (r=0.621), suggesting that dependence on media may exacerbate insomnia symptoms. Second, irritability when reducing media use was highly correlated with media dependence (r=0.791) and sensory stimulation needs (r=0.82), suggesting that withdrawal reactions may exacerbate mood swings. Once again, those who relied on specific sensory stimuli (e.g., touch, sound) for relaxation were more likely to be irritable (r=0.82) as a result of reduced media use, suggesting that such behaviours may create a vicious cycle. Finally, easy nighttime awakening and early waking were significantly correlated with daytime fatigue (r=0.713), suggesting that sleep disruption can have a direct impact on daytime functioning and quality of life.

According to the results of the correlation analysis between the degree of media dependence and the degree of sensory harm, there is a significant positive correlation between the degree of media dependence and the degree of sensory harm ($r=0.863$, $p<0.01$), which indicates that as the degree of media dependence increases, the degree of sensory harm also increases accordingly. Over-reliance on media can have a negative impact on an individual's sensory health, increasing the risk of sensory hazards and even degradation of sensory functions.

According to the results of the correlation analysis between the frequency of sensory compensation and the degree of sensory harm, there was a significant positive correlation between the degree of media dependence and the degree of sensory harm ($r=0.863$, $p<0.01$), indicating that as the degree of media dependence increases, the degree of sensory harm increases accordingly. An increase in the frequency of sensory compensation using digital media can subsequently increase the level of harm to the senses, as well as negatively affecting the health of the senses and increasing the risk of sensory alienation.

4.3. Analysis of variance between groups

The sample population was divided into three groups by means of questionnaire data, the experimental group was the 'with insomnia and dependence' group, the control group 1 was the 'with insomnia and no dependence' group, and the control group 2 was the 'without insomnia and dependence' group. Control group 1 is the 'insomnia without dependence' group and control group 2 is the 'no insomnia with dependence' group. Compare the difference in effect between the group with insomnia with dependence and the control group.

Table 1. Comparative results of the control group fig

Subgroups	Perceived rate of paradoxical effect	Incidence of sleep side effects
With insomnia with dependence	100%	100%
With insomnia without dependence	21.4%	28.6%
Without insomnia with dependence	7.7%	0%

Comparison of the results of the control group in Table 1 shows that 100% of the people with insomnia and dependence had the side effects of delayed sleep onset and reduced deep sleep, while the incidence of this phenomenon was zero in the people with no insomnia and dependence.

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Moreover, insomnia interacted with media dependence, with the group with insomnia symptoms and media dependence being the most aware of the paradoxical relationship between media use and sleep.

4.4. Analysing social media comments

4.4.1. Sentiment analysis

The data shown through the comments on the sleep aid videos in the Shakeology app indicates that most people's emotions when using digital media to help them sleep are mostly negative emotions such as anxiety and worry about sleep. The data show that positive emotions only accounted for 28.2%, positive emotions are divided into three types, instant effect recognition type, 'listen to the second sleep, save insomniacs'; long-term dependence on the expression of the type, 'without this sound simply can not sleep'; emotional resonance type, 'it turns out that so many people insomnia'. 'So many people have insomnia, found the organisation'.Negative emotions are as high as 46.5%, reaching nearly half, divided into the effect of questioning type, 'the more you listen to the more sober, it's useless'; dependence anxiety type, 'now I can't sleep if I don't listen to it, what should I do?' ; content critical type, 'all psychological effect, cheat traffic'.Among them, the neutral sentiment is 25.3%, which is divided into the type of uncertain effect, 'a little bit useful but not much'; the type of technical discussion, 'it is recommended to lower the background volume'; the type of scenario-based demand expression, "can you come up with a special version for napping".

4.4.2. Analysis of high-frequency words

Data analysis of the high-frequency word cloud map in Figure 2 shows that the common high-frequency words are: can't sleep, insomnia, stay up late, tomorrow, latest, wee hours of the morning, hard to get to sleep, and so on. Behind the high-frequency words, the study found that users' pre-bedtime moods were not calm and soothing, but more in favour of anxiety, restlessness, etc., when they viewed sleep-aid videos. Not only is it impossible to fall asleep instantly, but a portion of users have become addicted to such videos as a result.

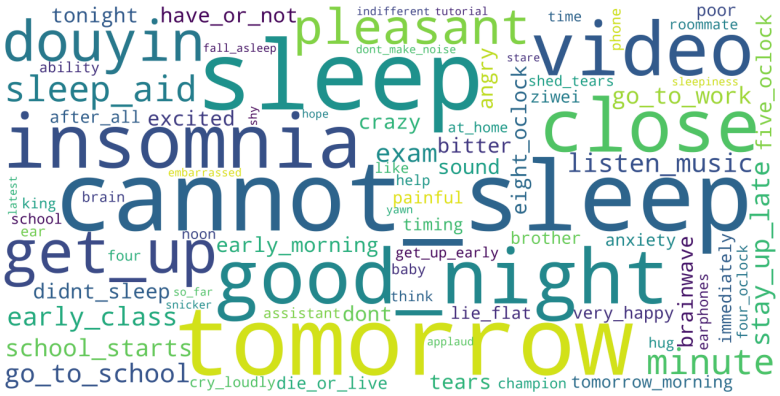

Figure 2. High frequency word cloud (photocredit: original)

5. Discussion

The research hypothesis that digitally mediated sleep-aiding behaviours provide short-term relief from anxiety through sensory compensation mechanisms, but that long-term use triggers a cycle of

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dependence, was confirmed. The higher the frequency, the more severe the sensory harm when insomnia groups compensate sensually through digital media. Media dependence can lead to difficulty falling asleep and waking up easily during the night. When the dependent person reduces the use, he or she will experience irritability and anxiety, forming a vicious circle of 'compensation needs lead to dependence on the medium, which in turn leads to harm to the senses, which further deteriorates the quality of sleep, and finally, the sensory compensation is reinforced again'.

Side effects (e.g. prolonged sleep latency, reduced deep sleep) were seen in 100% of the group with insomnia and dependence, but not in the control group (no insomnia and no dependence).The need to be vigilant against 'health technology' turning into 'health risks'; sentiment analysis showed that 46.5% of the negative emotions (questioning the effect, dependency anxiety, content criticism) and only 28.2% of the positive feedback ('slept in a second'), and most of them contained expressions of long term dependency ('I can't sleep without this sound').High-frequency words such as 'insomnia', 'staying up late', "uncomfortable" and 'early eights' testify to sleep anxiety.

Firstly, try to develop non-screen-dependent sleep aids, such as sound-optical synergy devices (e.g. bedside lamps combined with directional speakers) that induce sleepiness through low-frequency pulsed light in conjunction with binaural beat audio. Secondly, establish a safe duration standard for digital sleep aids (≤30 minutes) and enforce a colour temperature lock of 1800k (≥85% red-orange light) for sleep aid videos.

6. Conclusion

This study confirmed a significant sensory compensation paradox effect in digitally mediated sleep-assisting behaviours by analysing 152 clinical insomnia sample questionnaires with 10,420 social media comments. The findings of this study are, firstly, the higher the frequency of sensory compensation to digital media (white noise, ASMR, social media) in the insomnia group, the stronger the direct sensory harm (r=0.898), and conversely, the poorer the quality of sleep. (Difficulty falling asleep r=0.698, easy waking at night r=0.621); Secondly, the use of digitally mediated sleep aids creates a vicious cycle of 'withdrawal leads to mood swings, which deepen dependence' (r=0.791 for withdrawal irritability and dependence); and thirdly, 100% of the 'insomniacs with dependence' group suffered from deterioration in sleep (e.g., reduced deep sleep, prolonged latency), whereas controls without this trait were almost unaffected. Again, 100% of the 'insomnia-dependent' group experienced sleep deterioration (e.g., reduced deep sleep, prolonged latency), while the non-dependent control group was virtually unaffected; Finally, the study found that 46.5% of the users expressed the emotion of dependency anxiety when using the programme, such as 'can't sleep without listening', 'awake after switching off', etc. Meanwhile, the data showed that the high-frequency words were 'can't find sleep, insomnia, stay up late, early eight', etc., revealing the reciprocal relationship between stress and sleep. At the same time, the data shows that the most frequent words are 'can't find sleep, insomnia, stay up late, 8 am', etc., which reveals the reciprocal relationship between stress and sleep.

The core conclusion of the study is that the digital media has been alienated from a pre-designed 'sleep aid' to a 'sleep risk promoter', resulting in a cycle of alienation in which 'the need for compensation leads to dependence on the media, which in turn leads to sensory harm, which further deteriorates the quality of sleep,' and ultimately deviates from the original purpose of the sleep aid. The need for compensation leads to dependence on the media, which in turn leads to harm to the senses, further deterioration of sleep quality, and finally the reinforcement of sensory compensation", thus deviating from the original purpose of sleep aid. This study provides many valuable implications for future research in this direction, providing a triple contribution to the study

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of health communication and digital behaviour. Firstly, at the theoretical level, it provides an empirical anchor in the field of digital sleep, revealing the inner mechanism of 'self-subversion of technological solution paths'. Second, at the practical level, the idea of 'harmless sleep aids' is dispelled, and the public is warned of the addiction thresholds for media dependence (e.g., single use ≥30 minutes exacerbates sleep suppression). Finally, at the level of health communication values, we promote the establishment of platform-wide safety standards for digital sleep aids (e.g., mandatory blue-light filtering, length-of-use alerts); and guide the public in identifying the potential risks of 'reliance on expressive positive feedback' (e.g., 'can't sleep without sound').

Based on the limitations and findings of the present study, future studies should focus more on cross-group comparisons, such as comparing the differences in media dependence sensitivity between adolescents (high sleep plasticity) and patients with chronic insomnia (solidified compensatory behaviours); At the same time, the expansion of technical ethics can be strengthened, such as the short video platform 'sleep-aiding content' push mechanism how to intensify the dependence and other research directions for in-depth investigation.

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