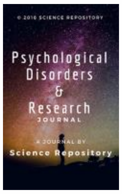

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Research Article

The Relationship of Electronic Equipment Use Before Bedtime and Sleep Problems: Evidence from Young Adults of Southern China

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ABSTRACT

It was demonstrated that there are lots of impact of the usage of electronic equipment before bedtime to individual health. However previous studies focused on the acute short-term effects rather than long-term accumulating effect. To investigate this issue, 2330 participants were invited to answer the questionnaire about their usage of electronic equipment before bedtime and their sleep quality. Results indicated that: (1) Higher level of using electronic equipment before bedtime, longer sleep onset latency and shorter valid sleep time among individuals; (2) Higher level of using electronic equipment before bedtime, higher sleepiness level and lower self-satisfactions of academic, health, and sleep among individuals; (3) and as mediator, sleep efficiency plays an important role between usage of electronic equipment and daily sleepiness, as well between usage of electronic equipment and self-satisfactions. These results are useful to reveal the long-term accumulating effect of the usage of electronic equipment before bedtime and enrich the understanding of the effect to young adults' sleep and daily performance.

Introduction

The popularity of electronic equipment

With the development of technology and science, lap top, tablet, and smart phone made a dramatic change to our life. A survey among 1508 Americans showed that 90% individuals would use an electronic equipment before bedtime [1]. In 2015, the contact rate of reading by cell phone reached 60% among Chinese adults, 89.6% of them aging from 18-29 years old. Although it brought great convenience in our daily life, many researchers have noticed the negative effect of usage of the electronic equipment.

Impact of the usage of electronic equipment before bedtime to health

Plenty previous researches suggest that it is harmful for our health that using an electronic equipment with shortwave light before bedtime. It would impact sleep quality, disturb sleep structure and alertness, lead to insomnia, etc. [2-5]. The negative impact of the usage of electronic equipment before bedtime was verified by many investigations. Levenson and his colleagues (2017) clearly indicated that it would disturb sleep independently [6]. And previous research showed that after using electronic equipment with shortwave light before bedtime, the secretory quantity of endogenous melatonin would be suppressed and the secretory time would be delayed by the interfered, which lead to a longer sleep onset latency time and shorter rapid eye movement time; and after cognitive arousal by a task, sleep onset latency time would be

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extended too; individuals with longer electronic equipment using before bedtime would predict a shorter total sleep time, while individuals with more active types would predict a longer total sleep time [5, 7, 8]. In addition, some investigations found that the slow wave activity of frontal EEG, which was usually considered as the main active wave during non-rapid eye movement sleep, would be reduced during sleep, and the time of rapid eye movement would also be shorten by this action [9-11]. Those means our sleep structures could be disturbed by this action. There is certain influence of the usage of electronic equipment before bedtime to alertness. Studies showed it would rise the alertness, reduce the sleepiness, and predict more high frequency EEG activity [5, 8]. It's harder to fall asleep with higher alertness. For example, the alertness of individuals who use electronic equipment for watching fierce fighting video would be higher than who use electronic equipment just for checking the weather before bedtime. Previous study found that individuals who played exciting computer game before bedtime would have lower sleepiness, lower EEG activity level, and longer sleep onset latency time [11]. Also, related study showed the usage of electronic equipment before bedtime would impact individuals' sleepiness not only before falling asleep but also after getting up [7].

Daytime sleepiness level and self-evaluation were other factors affected by the usage of electronic equipment before bedtime. School children with higher daytime sleepiness level reported that they would have more video watching [12]. And individuals who watching TV, playing computer game or using internet before bedtime reported higher tiredness in daytime [13]. In addition, researches showed that people's self-evaluation of health and sleep quality would be reduced when they use the electronic equipment before bedtime [14, 15]. On the one hand, although there were lots of discussion about the impact to individuals' physical and mental health, most previous studies focus on the acute short-term effects of the usage of electronic equipment before bedtime. That is, participants exposed to light-emitting electronic equipment before bedtime in a short-term (usually 2-5 days), then their health would be observed these days. Even some studies investigated the long-term effects, rare study could access or quantify this variable entirely to get relatively accurate data [16]. On the other hand, numerous people keep this behavior several weeks, months, even years rather than just a few days in the real life. Additionally, there are also differences between individuals about the using duration of each day. Thus, it obviously sacrificed part of ecological validity. According to above considerations, there are some problems remained here: with this behavior becoming a habit, what the impact to people is; furthermore, will this impact be stable or gradually deepened over time?

Influential mechanism of the usage of electronic equipment before bedtime

At the same time, there are a large amount of studies trying to reveal the process of the effect from the usage of electronic equipment before bedtime to individuals' sleep and daytime performance. Exelmans and Van den Bulck（2016）sorted out and generalized predecessors' researches. There are three major reasons that individuals could be affected: (1) individuals exposed in the short-wave light circumstance emitted by electronic equipment, which could interfere with the secretion of melatonin and activity of EEG. Thereby, the rhythm would be disturbed [7, 17-23]. (2) Individuals with different active content would have different cognitive workload, which affect subjective fatigue and sleepiness [24]. And sleep homeostasis could be disturbed then [5, 8, 11]. (3) As the lack of sense to time, sleep displacement could be appearing easily [2]. Therefore, individuals' sleep-wake pattern would be influenced [25, 26].

So, the usage of electronic equipment before bedtime could affect our sleep quality (such as extending sleep onset latency time, shortening time of slow-wave sleep, etc.) and daytime performance (such as reducing daytime alertness and raising daytime sleepiness level etc.) by above three ways. However just to know the casual is not enough. To figure out the influential mechanism is more important. So according to previous studies, we can infer that there is a relationship among the usage of electronic equipment before bedtime, sleep quality, and daytime performance. And this study suggests that the variable of individuals' night sleep quality will play an important mediating role. Specifically, the effects of the usage of electronic equipment before bedtime to daytime performance will be appeared by the mediating effect of sleep quality, not directly.

Purposes and hypotheses of this study

Although predecessors have done a lot of work in this field, problems mentioned above should arouse our attention. Thus, the current study will combine the characteristics of previous studies, focus on the investigation of long-term accumulation effect. And we will explore the effect of the usage of electronic equipment before bedtime on sleep quality, daytime sleepiness level, self-evaluation as well as the influential mechanism. We will adopt the large sample survey to suit the realistic situation and balance the active contends of the usage of electronic equipment before bedtime. We hypothesized that using electronic equipment before bedtime will disturb the sleep quality (extending sleep onset latency, shortening valid sleep time), and have certain negative influence on daytime performance and self-evaluation. At the same time, the influences of the usage of electronic equipment before bedtime on daytime performance and self-evaluation are manifested by the mediating effect of variables related to sleep quality. In addition, since most previous studies focus on the discussion of 2 hours before bedtime, this study followed this time setting too [7, 8, 10].

Method

I Participants

This survey was conducted among the students from six universities, including South China University of Technology, South China Normal University, South China Agricultural University, Jinan University, Guangdong University of Technology, and Guangdong University of traditional Chinese Medicine. The total number of the questionnaires in this survey was 4000. 3639 of them completed the questionnaire and their answers were totally valid. 2330 of them were selected (33.4% males; mean age ± SD: 19.6±1.6) who reported that they: (1) had no travel across more than one time -zone and shift work in the prior two months, (2) had no sleep disorder, (3) were not on any long-term medications, (4) had no history of mental or psychological disorders, (5) had no history of smoking, alcohol abuse, coffee addiction or taking sleeping pills.

II Measurement

II. I Light-emitting electronic equipment using before bedtime

The light-emitting electronic equipment (LE-EQ) includes smartphone, light-emitting tablets and laptop. The participants reported the usage of LE-EQ before bedtime: (1) the frequency of using LE-EQ during the two hours before bedtime each week; (2) the duration of using LE-EQ each night before bedtime; (3) the length of time for using LE-EQ. For the first question, there were four options: not use, occasionally use (1 to 2 days each week), regularly use (three to five days each week), daily use; for the second question, participants reported not use or the length they used (minute); for the third question, there were five options: within three months, within half a year, within a year, one to three years, and more than three years.

II. II Daytime sleepiness level

The previous study (Johns, 1991) indicated that Epworth Sleepiness Scale (ESS) scores were correlated with many sleep disorders and can measure sleep propensity in adult validly [27]. This scale was used in this survey to measure daytime sleepiness level. Participants were asked to rate the probability of falling asleep in eight different situations, including “Sitting and reading”, “Watching TV”, “Sitting, inactive in a public place”, “As a passenger in a car for an hour without a break”, “Lying down to rest in the afternoon when circumstances permit”, “Sitting and talking to someone”, “Sitting quietly after a lunch without alcohol”, and “In a car, while stopped for a few minutes in the traffic”. Participants responded on a four- point scale: “0 = would never doze; 1 = slight chance of dozing; 2 = moderate chance of dozing; 3 = high chance of dozing.” The score for each item is added together to obtain the total ESS scores. The higher total ESS scores indicate the higher daytime sleepiness level.

II. III Sleep quality and daytime performance

Participants were asked to report some questions related to their sleep and daily performance. We assessed total sleep time (TST), sleep onset latency (SOL, the time between close your eyes to sleep), valid sleep time (VST, the duration of sleep). For the TST assessment, participants reported the time lying in bed. For SOL assessment, participants chose one of four conditions: (1) fell asleep as soon as touching the pillow, (2) fell asleep in 10~20 minutes, (3) fell asleep more than 30 minutes, (4) fell asleep in 1 hours or more. To facilitate data analysis, we defined these 4 chooses as 0 minute, 15 minutes, 30 minutes, and 60 minutes respectively. Sleep efficiency was calculated using following formula:

$$\underline{\text{Valid Sleep time} = TST - SOL}$$

II. IV Self evaluation

Self-satisfaction was assessed by three items. Participants reported the extent to the condition of their healthy, study, and sleep respectively (e.g. “How satisfied are you with your health?”). Responses ranged from 1 (totally dissatisfied) to 5 (totally satisfied).

III Analysis

All the data were analyzed by using SPSS version 16.0.

Due to three variables (frequency and duration of using LE-EQ during two hours before bedtime, and the length of time of above states) contributed to the usage of LE-EQ mentioned above, it was difficult to get a normal distribution of data. First, we applied Principal Component Analysis (PCA) to the data of usage of LE-EQ, which combined three variables mentioned above into one variable. After PCA, we got one variable which was named total usage of LE-EQ (TU-LE). It was defined as the quantity of using LE-EQ during two hours before bedtime. In addition, according to the total quantity of using LE-EQ, participants were divided into three groups. The top 27%, the mid 46%, and the last 27% of them were labeled High group (N = 663), Mid group (N = 1129), and low group (N = 663). And we also investigated mediating effects by causal steps approach throughout the mediating testing process (Baron & Kenny, 1986) [28]. Three equations, as shown below, were tested to examine mediating effects.

$$Y = cX + e_1 \quad (1)$$
$$M = aX + e_2 \quad (2)$$
$$Y = c'X + bM + e_3 \quad (3)$$

Results

I Principal components analysis

First of all, frequency, duration, and length were normalized respectively. And then, we applied PCA by a varimax rotation. Then one main factor was extracted from three variables contributing 43.502% variance. And it was named “TU-LE” which contained three variables: frequency (factor loading: 0.757), duration (factor loading: 0.663), and length (factor loading: 0.540). Results indicated that “TU-LE” could reflect the information in three dimensions. The variable TU-LE was used in the following analysis.

II ANOVA

Take group (Low, Mid, and High) as an independent variable and use TST, SOL, VST, and daytime sleepiness level as the dependent variable for ANOVA (descriptive statistics of variables was shown in table 1). The results showed that there was no significant difference among three groups on TST, F (2, 2327) = 0.893， p = 0.409. As for VST, there was no significant difference among three groups too, F (2, 2327) = 1.721， p = 0.179.

However, there were significant differences among groups on SOL F (2, 2327) = 3.522， p = 0.030. Then, we conducted post hoc analysis (LSD) which indicated that the time of SOL of High group ($Mean_H$ = 0.283 h, SD = 0.219) was significantly longer than Low group ($Mean_L$ = 0.253 h, SD = 0.189, p = 0.009), and no significant differences between High group and Mid group ($Mean_M$ = 0.272 h, SD = 0.194).

When the dependent variable was daytime sleepiness level, ANOVA analysis indicated that there were significant differences among groups, F (2, 2327) = 10.175， p < 0.001. LSD showed that the daytime sleepiness level of High group ($Mean_H$ = 7.784, SD = 3.240) was significantly higher than Mid group ($Mean_M$ = 7.380, SD = 3.016, p = 0.010), and the Mid group was significantly higher than Low group ($Mean_L$ = 6.991, SD = 3.168, p < 0.001).

Table 1: Descriptive statistics of variables

Variables	Groups	Mean	SD	N
TST/h	all	7.07	0.81	2330
	low	7.11	0.79	629
	mid	7.05	0.78	1072
	high	7.07	0.88	629
SOL/h	all	0.27	0.2	2330
	low	0.25	0.19	629
	mid	0.27	0.19	1072
	high	0.28	0.22	629
VST/h	all	6.8	0.82	2330
	low	6.85	0.8	629
	mid	6.78	0.79	1072
	high	6.79	0.89	629
Daytime sleepiness level	all	7.38	3.13	2330
	low	6.99	3.17	629
	mid	7.37	3.02	1072
	high	7.78	3.24	629

III Correlation analysis

Then, we conducted the correlation analysis of TU-LE, TST, SOL, VST, daytime sleepiness level, health self-satisfaction, sleep self-satisfaction, and study self-satisfaction. The correlation matrix was shown in (Table 2). It indicated that TU-LE was significantly negatively correlated with TST and VST and positively correlated with SOL. TU-LE was significantly negatively correlated with health, study, sleep self-satisfaction. And there was significant positive correlation between TU-LE and daytime sleepiness level. From the above results, TU-LE correlated with lots of variables of our health. With the increasing of TU-LE, various indices we assessed have poorer performance. Subsequently, for the exploration of its deep influential mechanism, we conducted the test of mediating effect.

IV Testing of mediating effect

In testing of the mediation effect, we examined three equations by causal steps approach (presented in Method 2.3). First, we tested the mediation effect of VST of the relationship between TU-LE and daytime sleepiness level. Results were shown in (Figure 1A). Regression analysis indicated that TU-LE had a significant predictive effect on daytime sleepiness level (β = 0.277, p < 0.001). And TU-LE could negatively predict valid sleep time significantly (β = - 0.051, p = 0.003). When TU-LE and VST predict daytime sleepiness level, results showed that VST could negatively predict daytime sleepiness level (β = -0.267, p = 0.001), and TU-LE could positively predict daytime sleepiness level significantly (β = 0.263, p < 0.001).

Furthermore, we examined the mediation effect of VST of the relationship between TU-LE, health self-satisfaction, study self-satisfaction, and sleep self-satisfaction, shown in fig.1B, 1C, and 1D. As for health self-satisfaction, regression analysis indicated that TU-LE could significantly predict health self-satisfaction negatively (β = -0.095, p < 0.001). And TU-LE could negatively predict VST (β = -0.051, p = 0.003). When TU-LE and VST predict health self-satisfaction, results showed that VST could positively predict health self-satisfaction (β = 0.164, p < 0.001), and TU-LE could negatively predict health self-satisfaction significantly (β = -0.087, p < 0.001).

As for study self-satisfaction, regression analysis indicated that TU-LE could significantly predict study self-satisfaction negatively (β = -0.106, p < 0.001). And TU-LE could negatively predict VST (β = -0.051, p = 0.003). When TU-LE and VST predict study self-satisfaction, results showed that VST could positively predict study self-satisfaction (β = 0.134, p < 0.001), and TU-LE could negatively predict study self-satisfaction significantly (β = -0.099, p < 0.001).

As for sleep self-satisfaction, regression analysis indicated that TU-LE could significantly predict sleep self-satisfaction negatively (β = -0.104, p < 0.001). And TU-LE could negatively predict VST (β = -0.051, p = 0.003). When TU-LE and VST predict sleep self-satisfaction, results showed that VST could positively predict sleep self-satisfaction (β = 0.280, p < 0.001), and TU-LE could negatively predict sleep self-satisfaction significantly (β = -0.090, p < 0.001).

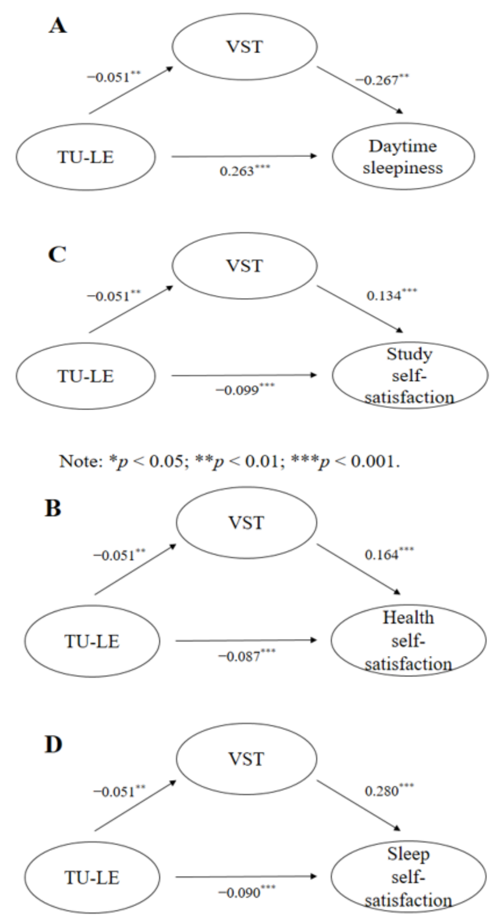

Figure 1: The mediation effect of valid sleep time

Table 2: Correlations for TU-LE, TST, SOL, VST, health self-satisfaction, study self-satisfaction, sleep self-satisfaction, and daytime sleepiness level.

variables	1.TU-LE	2.TST	3.SOL	4.VST	5. health self-satisfaction	6. study self-satisfaction	7. sleep self-satisfaction	8. daytime sleepiness level
1.TU-LE	1.000							
2.TST	-0.044^{*}	1.000						
3.SOL	0.076^{***}	0.063^{**}	1.000					
4.VST	-0.061^{**}	0.970^{***}	-0.180^{***}	1.000				
5. health self-satisfaction	-0.126^{***}	0.151^{***}	-0.153^{***}	0.186^{***}	1.000			
6. study self-satisfaction	-0.136^{***}	0.134^{***}	-0.071^{***}	0.149^{***}	0.505^{***}	1.000		
7. sleep self-satisfaction	-0.118^{***}	0.206^{***}	-0.271^{***}	0.269^{***}	0.556^{***}	0.420^{***}	1.000	
8. daytime sleepiness level	0.088^{***}	-0.083^{***}	-0.028	-0.075^{***}	-0.126^{***}	-0.152^{***}	-0.111^{***}	1.000

NOTE：$*p < 0.05$; $**p < 0.01$; $***p < 0.001$.

Discussion

The development of electronic science and technology brought great convenience to our life. Meanwhile, to some extent it has also brought us a negative impact. Based on previous studies, the current study investigated effects of the usage of electronic equipment before bedtime on sleep quality, daytime sleepiness level, and self-satisfaction etc. and we also analyzed the influential mechanism. With the gradual increase of TU-LE, we found increased sleep onset latency, reduced valid sleep time, and increased daytime sleepiness level. At the same time, individuals' self-evaluation of satisfaction about health, study, and sleep were reduced significantly. Moreover, we found the variable of valid sleep time, as a mediator variable, played an important role between the usage of TU-LE and young adults' daily performance and subjective evaluation.

According to the results, there were significant correlations between TU-LE and sleep quality, TU-LE and daytime sleepiness level etc. and the variable of valid sleep time, as a mediator variable, played an important role though the process. Chang and colleagues (2015) indicated that individuals who use electronic equipment before bedtime would have longer sleep onset latency and shorter valid sleep time. Defer from previous studies which focus on the acute short-term effects, the current study emphasizes the long-term effects of the usage of electronic equipment before bedtime. The results showed that there was a gradual deterioration of sleep quality, and the sleep onset latency of individuals gradually extended, and the valid sleep time also decreased. This indicated that the negative effects of TU-LE on-sleep quality is a gradual process of accumulation. Moreover, the current study also found the change in daytime sleepiness level was consistent with this process. With the increase of TU-LE, the higher daytime sleepiness level will be predicted. This means that it is a dynamic process, rather than a stable one. Like sleep debt, with the increasing of sleep restricted days, individuals' daytime sleepiness level gradually accumulated and raised [29]. Similarly, the current study showed the cumulative effect of the total quality of the usage of electronic equipment before bedtime. Thus, with the increase of TU-LE, individuals' health and performance may get worse gradually.

In addition, the results indicated the significant mediation effect of valid sleep time between TU-LE and daily performance, as well as self-evaluation of sleep, study and health from the young adults. With the increase of TU-LE, valid sleep time is shortening gradually. And daytime sleepiness level gets higher and by the impacts of both of them. The results link the relationship between TU-LE, sleep quality, and daytime performance, and it revealed the internal influential mechanism of the relationship.

On the other hand, we also found the negative effects of TU-LE on self-evaluation. Consistent with previous study, results showed that TU-LE would predict lower health and sleep self-satisfactions [14]. In addition, as this study was conducted among college students whose main task is to learn. So, differ from previous, the current study investigated their academic performance self-satisfaction too. And we found that with the increase of TU-LE, their academic performance self-satisfaction would gradually get lower too. Self-reported results indicated that individuals could perceive their change in health, sleep, and study in this process. It means that individuals could feel the pressure along with this behavior. So, this behavior is reducing our self-evaluation. And without intervention, it could weaken our confidence for a long time. Furthermore, the results of mediating effect testing showed the valid sleep time also plays a significant mediating role in the process. Thus, there are not only physiological but also psychological effects of TU-LE.

In data analysis, TST, SOL, and VST were related sleep structure and our sleep quality closely, but why we interested in VST? First, the variable of TST contains two processes SOL and VST and can be directly replaced by them. Thus, we just need to investigate these two variables. Second, as for SOL and VST, SOL is relatively difficult to be controlled in real life. On the contrary, we can intervene in VST easier. Therefore, we consider that only VST is appropriate as an intermediary variable.

From the current study, we know that the harm will increase along with the increase of TU-LE gradually. So, what can we do to relive this impact? Here are some suggestions for those who plagued by this problem. Today, many mobile phone manufacturers add eye protection function to their products, like night shift in IOS system. It can adjust the screen to be warm-toned to reduce the harm of light. You just need to turn it on when it is close to bedtime. So, it's very convenient. At the same time, wearing the blue blocker glasses is another way to relieve this impact [30]. Also, to make sure there is a lower alertness, you should avoid reading or watching the intense content. In addition, this study showed that people's daytime sleepiness level will be getting higher with the increase of TU-LE. However, exercise can improve our sleep quality and is very helpful to sleep [31]. So, proper exercise during the day, especially after getting up, would be better for the whole day's work.

This study had some limitations too. First, about the measurement of TU-LE, there must be deviation between report and reality. Although it was divided into three dimensions, it's hard for participants to estimate the precise time. Second, among the valid questionnaires, the number of females were larger than males. Due to the difference of lifestyle, the content of TU-LE maybe different which could affect the sleep structure too [8]. Third, as an ecological study, we did not control the light during electronic equipment usage. As an important environment factor, light disturbed our sleep by regulating melatonin release which was related to our alertness. However, to some extent, this study balanced the impact of inconsistent content by the large sample survey. Then, this study lacks the monitor of sleep processes, which was an important issue for the chronic electronic equipment usage. As the basic of neural plasticity theory, under the long-term effects, our physiologic sleep structure might be changed stably. Therefore, it's necessary for further studies to monitor the sleep process by PSG or by the measurement of melatonin. Finally, this study did not investigate the cognition and behavior effects which also valued a lot. As for the daytime performance, there were many mental functions remain to be discussed. For instance, as the self-satisfaction was reduced, it was reasonable that the mood or emotion was impaired too, which worth to be investigated deeply. Thus, further research might pay attention to the cognition and behavior investigations

Conclusion

The sleep structure would be disturbed by the total quantity of the usage of electronic equipment before bedtime. Sleep onset latency would be extended, and valid sleep time would be reduced. At the same time, people's daytime sleepiness level would be decreased. Their health, sleep, and study self-satisfaction evaluation would be worse. As a mediator, valid sleep time played a role in the effects of total quantity of the usage of electronic equipment before bedtime to daily performance and self-satisfaction evaluation.

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