A study of the impacts of message framing and narrative visualization on sleep behavior intervention

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Abstract—**This research investigated the effect of narrative visualization and message framing on health behavior change by combining the theory of planned behavior (TPB) and the protection motivation theory (PMT). Relevant hypotheses were examined to test the effect of message framing and narrative visualization in enhancing perceived threat and facilitating behavior change decisions. The effect of sleep information intervention was examined based on the interaction of message framing and narrative visualization. Using a survey of 467 college students, the study shows that negative framing information enhances the perception of response resistance better than positive framing information. On the other hand, positive framing information can enhance the perception of behavioral attitude better than negative framing information. The results provide a basis for the following information presentation in health behavior change.**

Keywords—Narrative visualization, message framing, health risk perception, sleep behavior

I. INTRODUCTION

Since the increase and rise of data journalism, it has sparked interest among researchers and designers in narrative visualization to better support public health practice [1]. By combining the presentation form of visualization and narrative mechanism, narrative visualization leverages the ability to describe stories as exciting and memorable data health news, enabling information to be communicated more effectively to the public through storytelling and advocating the use of storytelling techniques in information visualization. Existing health behavior interventions have been communicated to the public through narrative visualization methods of communication.

Prior research has shown that narrative intervention messages may be effective in promoting and eliciting positive behavior change on a variety of health topics, as they can elicit individual attitudes consistent with the story and increase behavioral intentions, including promoting physical activity [2], breast cancer detection [3], healthy eating [4], and sexual health [5].

Sleep is important for the promotion of physical and mental health. Sleep disorders may greatly threaten people's cognitive ability, mood, immunity, quality of life, well-being, learning, socialization, and psychological, physical, and social

functioning [6, 7]. It was noted that the prevalence of sleep disorders among college students in China ranged from 12.92% to 52.84% [8]. In a study of college students, 50.2% of the total subjects reported less than 7 hours of sleep [9]. Moreover, less than 7 hours of sleep were likelier to have poorer sleep self-reported ratings. However, little attention has been paid to how narrative visualization can be used to provide specific populations, for instance, college students, with more valuable guidance on sleep health intervention.

Moreover, the understanding of health risk information can vary significantly due to differences in the cognitive speeds of information processing [10]. To this end, we need to understand better the factors driving the expected public sleep behavior change and how to understand better the impact of narrative visualization on the intention to change the behavior of engaging in sleep health promotion.

A. Message framing

The concept of message framing mentioned in this paper is derived from the framing effect [11, 12], which refers to information with the same logical meaning. If the description is different, it will also lead to cognitive biases in the receiver, resulting in different decision-making tendencies. Generally, in the field of health behavior intervention, it is more to emphasize the specific consequences of certain behavior by information transmission. More specifically, information that describes the possible benefits (positive effects) of taking a certain action, or the possible losses (negative effects) of not taking it. Although both kinds of information can improve the people's behavior awareness, the effect of the intervention and related behavioral decisions of the individual is different.

B. Health behavior related theories

This research investigated the information intervention of narrative visualization and message framing on health behavior change by combining the theory of planned behavior (TPB) and the protection motivation theory (PMT), this is the first study that focuses on two related theories of what factors can affect intended participation of sleep behavior.

The Theory of Planned Behavior (TPB), which is one of the most important and valuable frameworks for explaining and predicting health behaviors, has demonstrated its effectiveness in many studies. In the TPB, the behavioral intention represents

the most significant behavioral predictor, which is explained by people's attitude toward performing the behavior (i.e., an evaluation of how good or bad the outcome of the behavior is), subjective norms (i.e., perceived social pressure to engage in conduct), and perceived behavioral control (i.e., the perceived ability to perform a particular behavior) [13]. TPB has been used as a possible theory to explain sleep hygiene behaviors in a sample of college students, and it was found that perceived behavioral control and subjective norms predict intention [14]. We chose TPB to develop a deep understanding of the important elements driving purposeful engagement in healthy sleep behaviors.

The Protection Motivation Theory (PMT) states that individuals will evaluate behavior changes to protect themselves from harm in the process of advocating risk-reducing behavior. The theory is divided into four critical cognitions or perceptions parts, regarding the severity and vulnerability to the threats, the self-efficacy, and the response efficacy of following the advocated behavior [15, 16]. A study of the meta-analysis showed that interventions explored by PMT regarding perceived severity, perceived vulnerability, response efficacy, and self-efficacy were effective in promoting health behavior change [17]. However, the associations between sleep behavior intervention and PMT factors have not been examined.

The transtheoretical model of behavior change (TTM) [18]. The model regards the change of individual health behavior as a complex, gradual and dynamic process, which is generally divided into five stages: precontemplation (not seriously considering a change), contemplation (seriously considering a change), preparation (making small changes), action (making changes to an appropriate level), maintenance (sustaining the change over time). Moreover, in TTM, the change in the individual stage and the transformation of cognition are always affected by the individual's decision-making behavior and self-efficacy. It represents the decision-making process for individuals to correct bad behaviors or adopt healthy behaviors.

The current study was designed with two dimensions: narrative visualization and message framing. As a novel method of data representation, the impact of narrative visualizations on sleep health behavioral intervention is unknown. To increase the understanding of sleep health messages, we use narrative visualization to present the information [19]. It has been shown that the format of narrative information can affect comprehension and memorability because the process of decision-making tends to be more empirical and emotional than rational [20, 21]. Few studies about health behavior intervention based on narrative visualization that has been conducted, but it remains challenging to determine if narrative visualization has an impact on and how it relates to behavioral intentions.

By measuring the impact of "narrative visualization" and "message framing" on people's intended engagement, this paper aims to examine how to provide more effective forms of sleep health messaging that allow the public to understand and change their health behaviors.

In summary, our study considered these two questions:

(1) What factors strongly correlated with the intention of participation in sleep health behavior? The factors studied here were combined from the TPB and PMT.

(2) Does the message form and framing affect the factors of the intention related to sleep health behavior change? We expect that receiving positive information framing will at least increase sensitivity to perceived threats compared to negative information framing. Also, it was expected that the narrative visualization would increase the positive behavior intention about healthy sleep, or lead to increased severity perception about the consequence of sleep disorder.

II. MATERIALS AND METHODS

A. Respondents

In June 2022, the potential participants were recruited in China through a company that provides academic research sampling (18-25 years). We chose this respondent group because this is the period during which sleep habits are most likely to be affected. Data from 467 college students during the pre-and post-intervention period were surveyed using an online questionnaire. Each respondent received 5 RMB as a reward.

B. Research process

The research process is shown in Fig. 1. The participants need to read the information of the survey first, which includes the purpose and form. Then the respondents need to complete the pre-questionnaire T0 and post-questionnaire T1. Before T1, they received an introduction about the knowledge of sleep, which was manipulated into four groups, message framing (including the positive or negative description of the behavior risk) and narrative visualization (including or excluding narrative visualization images). Both T0 and T1 were conducted individually.
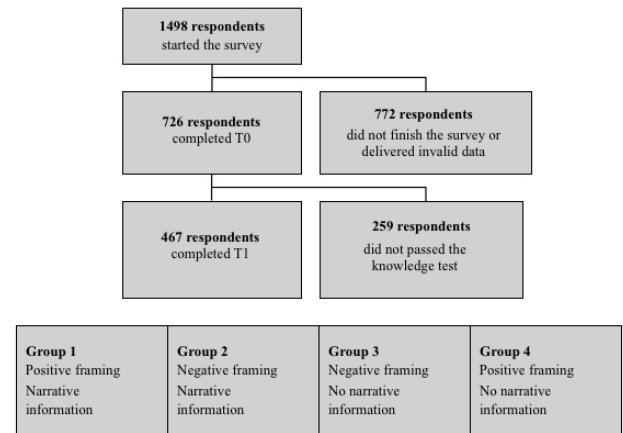

Fig. 1. Folw chart of the research process.

We used T0 and T1 data to measure the effects of narrative visualization and message framing on behavioral intention. Because the intervention information was delivered together, the impact of the interaction between narrative visualization and message framing was also measured.

To better measure the effectiveness of the intervention information, respondents must fully understand the message. Otherwise, it was unclear whether the effect of the manipulation was due to a lack of understanding or the way the message was presented. Therefore, only respondents who passed the material knowledge test were included in the experimental data to exclude those who did not adequately read the intervention information. Eligible respondents were randomly assigned to one of four groups.

C. Manipulations

a) Message framing. Two versions of promotional materials make the same logical sense but have different types of message framing. In the negative framing, the information about sleep is delivered in a way that emphasizes the dangers of sleep deprivation and the diseases that can result. In the positive framing, the emphasis is on the benefits of getting enough sleep and the physical benefits that it can bring us.

b) Narrative visualization. Half of the participants received intervention information in the form of narrative visualizations. The other half of the participants received the intervention message in text form.

c) The stages of behavior change. Division of behavior change stages: "I have no intention to start trying to get enough sleep every night within 6 months" (precontemplation stage), "I plan to start trying to get enough sleep every night within 6 months" (contemplation stage), "I am going to start trying to get enough sleep every night in 30 days" (preparation stage), "I have only started getting enough sleep every night in the last 6 months" (action stage) and "I am getting enough sleep every night, and has been more than 6 months" (maintenance stage).

D. Measurement instruments

Decision Balance Survey. The questionnaire consists of 30 items, and these scales were adapted to the sleep topic based on the TPB and PMT frameworks and previous research on health behavior change. The questionnaire was pre-experimentally tested and analyzed for reliability before the actual test.

The pre-test validity analysis showed that the KMO value was 0.834 and Bartlett's spherical test chi-square value was 1540. 0.01 level of significance was reached, and the post-axis component matrix was analyzed and came out with six factors:

1) The "Perceived behavioral control" in TPB was combined with "Self-efficacy" (SE) in PMT;

2) The "Perceived severity" was combined with "Perceived vulnerability" in PMT and renamed "Perceived Threat" (PT);

3) The "Intrinsic rewards", "Extrinsic rewards," and "Response costs" in PMT were integrated and renamed "Response resistance" (RR);

4) The name and meaning of the remaining dimensions were kept unchanged, as "Response efficacy" (RE) in HMT; "Behavioral attitude" (BA) and "Subjective norms" (SN) in TPB;

E. Statistical analysis

To understand our first research question, the factors in the natural state without the message framing intervention (T0) were analyzed by univariate linear regression analysis ($p < 0.05$), to demonstrate if there was a significant correlation with their initial behavior stages.

TABLE I. GROUPS OUTCOME OF VARIABLES DATA.

Types	Level 1	Level 2	Level 3	Level 4	Level 5	Total
Group 1[a]	19	18	38	16	17	108
Group 2[b]	19	25	52	13	17	126
Group 3[c]	13	36	39	8	19	115
Group 4[d]	19	26	43	11	19	118
Total	70	105	172	48	72	467

(Level 1=pre-contemplation; Level 2=contemplation; Level 3=preparation; Level 4=action; Level 5=maintenance).

(a=positive and narrative; b=negative and narrative; c=negative and no narrative; d=positive and no narrative).

For the second research question, the pre-questionnaire scores (T0) data from 467 respondents were analyzed. Sample distribution data at different behavioral stages were examined. To determine whether there was a significant behavior change in four groups, the difference between the average score of the same item in the pre-questionnaires (T0) and post-questionnaires (T1) was analyzed with paired t-tests to analyze the differences in the degree of change in the decision-making propensity of individuals at different stages after receiving different information. Statistical significance ($p < 0.05$) of the differences between the manipulations was examined. All statistical analyses were performed using IBM SPSS Statistics 26.

III. RESULTS

RQ1: What factors strongly correlated with the intention of participation in sleep health behavior?

The factors significantly associated with behavior intention to participate were: behavioral attitude, subjective norm, perceived threat, self-efficacy, response efficiency, response resistance (see Table 2). Subjective norm and self-efficacy were the most influential factors (standardized betas of 0.31 and 0.55, respectively).

TABLE II. UNIVARIATE LINEAR REGRESSION ANALYSIS.

Variables	b (confidence intervals)	SE b	β[a]	p
BA	0.49 (0.35, 0.63)	0.07	0.30	<0.001*
SN	0.50 (0.36, 0.64)	0.07	0.31	<0.001*
PT	0.22 (0.02, 0.42)	0.10	0.10	0.032*
SE	0.61 (0.53, 0.70)	0.04	0.55	<0.001*
RE	0.42 (0.21, 0.62)	0.10	0.18	<0.001*
RR	-0.41 (-0.52, -0.30)	0.06	-0.32	<0.001*
Gender	-0.09 (-0.32, 0.14)	0.12	-0.04	0.440

(BA=Behavioral attitude; SN=Subjective norm; PT= Perceived Threat; SE=Self-efficacy; RE=Response efficacy; RR=Response resistance; *=p<0.05; ᵃstandardized regression coefficient).

TABLE III.   RESULTS OF EXPERIMENTAL DATA.

Variables	Group 1[a] Mean(SD)	t	p	Group 2[b] Mean(SD)	t	p
BA	-0.13 (0.60)	-2.16	0.033*	-0.14(0.81)	-1.92	0.058
SN	-0.11(0.46)	-2.43	0.017*	-0.19(0.54)	-3.99	<0.001*
PT	-0.09(0.35)	-2.52	0.013*	-0.10(0.43)	-2.67	0.009*
SE	-0.22(0.62)	-3.70	<0.001*	-0.20(0.62)	-3.54	0.001*
RE	0.02(0.49)	0.39	0.697	-0.05(0.39)	-1.33	0.187
RR	-0.01(0.43)	-0.32	0.749	0.13(0.69)	2.07	0.040*
Variables	**Group 3[c] Mean(SD)**	**t**	**p**	**Group 4[d] Mean(SD)**	**t**	**p**
BA	-0.02(0.57)	-0.41	0.684	-0.20(0.72)	-2.99	0.003*
SN	-0.10(0.46)	-2.36	0.020*	-0.13(0.62)	-2.24	0.027*
PT	-0.09(0.45)	-2.24	0.027*	-0.02(0.34)	-0.51	0.611
SE	-0.25(0.51)	-5.29	<0.001*	-0.25(0.60)	-4.51	<0.001*
RE	0.03(0.42)	0.67	0.502	-0.01(0.52)	-0.27	0.790
RR	0.10(0.48)	2.24	0.027*	0.06(0.58)	1.10	0.272

(a=positive and narrative; b=negative and narrative; c=negative and no narrative; d=positive and no narrative; *=P<0.05).

(BA=Behavioral attitude; SN=Subjective norm; PT= Perceived Threat; SE=Self-efficacy; RE=Response efficacy; RR=Response resistance).

RQ2: Does the message form and framing affect the factors of the intention related to sleep health behavior change?

The distribution of respondents in the study is shown in Table 1. Most participants were in the preparation stage, as shown in Table 1. The results of paired samples t-test are shown in Table 3. The inclusion of negative framing (emphasizing the harms of sleep deprivation) had a more significant effect on the factors of response resistance compared to the positive framing (emphasizing the benefits of adequate sleep). However, the positive framing information was more significant than the negative framing information group on behavioral attitude.

In addition, the inclusion of narrative visualization information had a significant effect on the perceived threat of sleep deprivation compared to the non-narrative visualization information. The t-statistic of subjective norms and self-efficacy reached a significant level in all four groups.

IV. Discussion

This is the first study by integrating two health behavior-relevant theories i.e. PMT and TPB and clarifies which factors are most related to information intervention form of sleep behavior. From the above results, it can be seen that the two hypotheses proposed were verified, that is, narrative visualization and message framing have significant effects on people's behavioral intention in the process of behavior change.

As shown by the above results negative framing information enhances the perception of response resistance better than positive framing information. On the other hand, positive framing information can enhance the perception of behavioral attitude better than negative framing information. Moreover, the form of narrative visualization had a more significant effect on the perceived threat. In the e-health communication public program, adding narrative visualization information, such as the consequences of unhealthy sleep behaviors, could possibly increase awareness of the consequences of sleep deprivation. Most importantly, the form of narrative visualization for health behavior change has great potential to become a more acceptable form of intervention for the public to adopt and make changes.

There is a limitation of this study. The selected population in this paper is homogeneous, as respondents were recruited through an existing group in sampling. It is difficult to determine whether the current result is representative of a broader population sample. Moreover, detailed information on specific health behavior is needed in the future, and this paper was only able to select a specific intervention subject for a health behavior change that is prevalent in real life. It cannot avoid the impact of the uniqueness of a specific behavior on the study results. Therefore, to further extend the findings of this paper to a broader application, more extensive subjects are needed to be included.

In conclusion, this study innovatively explores the relationship between intervention information in the form of narrative visualizations and sleep behavior change. To some extent, narrative form and message framing can influence people's behavioral intentions. As subjective norms and self-efficacy are the significant change factors in all experiment groups, it needs to be further examined the effect of these two factors.

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