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Effect of Positive Mental Imagery Stimuli on Anhedonic Depressive Symptoms

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This study aimed to investigate the effect of the intervention of positive mental imagery on anhedonia and the underlying reward mechanism in depression, and to explore the sustainability of the impact of the intervention following stress induction. Participants reporting anhedonic depressive symptoms ($N = 54$) were randomly assigned to either a positive mental imagery condition or a verbalization condition, the former utilizing positive imagery stimuli only, and the latter utilizing language-based on meaning. Participants in both the conditions completed a computerized picture-word task for imagery generation and mental arithmetic stress task for stress induction. The results showed that both intervention conditions significantly reduced anhedonia and negative affect and that the mental imagery intervention was not superior to verbalization intervention. After stress induction, there was no significant difference between the two conditions in terms of the sustainability of the impact of the intervention on mood, reward subcomponents, and anhedonia. These findings provide preliminary evidence of the effectiveness of positive mental imagery in improving anhedonia. Furthermore, this study emphasizes the importance of repetitive imagery intervention due to the unsustainable impact of brief interventions after stress induction.

Keywords: positive mental imagery, anhedonic depressive symptoms, stress induction

Anhedonia, a reduced capacity to experience or pursue pleasure, is one of the core symptoms of major depressive disorder (American Psychiatric Association, 2013). Traditionally, anhedonia is considered as a phenomenon related to "loss of pleasure", operationalized as blunted positive affect (PA). However, since previous studies have posited that the level of PA alone may not predict anhedonic symptoms (Bryant, Winer, Salem, & Nardoff, 2017), recent neuropsychological studies have reconceptualized the concept of anhedonia by emphasizing not only mood states but also a multifaceted stage related to reward processing (Rizvi, Pizzagalli, Sproule, & Kennedy, 2016). Several studies have revealed that deficits in subcomponents of reward processing, such as anticipatory pleasure (Da Silva et al., 2017; Treadway & Zald, 2011), pleasure derived from predicted future rewards (Geaney, Treadway, & Smillie, 2015) or motivation (Bryant et al., 2017; Sherdell, Waugh, & Gotlib, 2012) may serve as potential precursors of anhedonic depression (Thomsen, 2015).

Difficulties in reward processing in anhedonic depression are likely caused by dysfunctional interactions between the stress and brain reward systems. According to Pizzagalli (2014), stress reduces activation in the reward-related brain regions, known for their association with reinforcement learning, through the inhibition of the mesocorticolimbic dopaminergic pathways. Consequently, anhedonia may occur as a consequence of blunted reward encoding caused by the negative effects of stressors on the dopamine pathway in depression. Since several studies have upheld the abnormal processing of reward-related stimulus in anhedonic depression (Atchley et al., 2012; Winer & Salem, 2016), identifying the means that facilitate reward processing may hold important therapeutic value in treating anhedonic depressive symptoms.

Given the mechanism of anhedonia, mental imagery may be a

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promising tool for psychological interventions. Mental imagery refers to the experience of accompanying representation of sensory information without a direct external stimulus (Pearson, Naselaris, Holmes, & Kosslyn, 2015). Research evidence suggests that mental imagery can elicit powerful affective responses by helping effective reward encoding. Unlike verbal processing, imagery-based processing may exert a stronger effect on emotion by constructing images that use relevant sensory autobiographical memories (Holmes, Mathews, Mackintosh, & Dalgleish, 2008). Because mental imagery and visual perception rely on similar neural mechanisms (Dijkstra, Bosch, & Van Gerven, 2019), mental imagery may aid the representation of relevant personal memories with their associated emotional tone (Conway, 2001; Holmes, Lang, & Shah, 2009). As a result, it induces "as-if real" emotional responses (Ji, Heyse, MacLeod, & Holmes, 2016).

Based on prior studies, it is plausible that mental imagery contributes to the improvement of the anhedonic depressive symptoms by affecting reward-encoding. This has been confirmed in several studies that reported that the generation of positive mental imagery induces changes in depressed mood states (Blackwell et al., 2015; Heyes et al., 2017). However, only a limited number of studies have investigated the effect of positive mental imagery on anhedonic depressive symptoms focusing specifically on reward processing. While several studies have reported the effect of mental imagery on improving anhedonic symptoms (Blackwell et al., 2015; Min, Kwon, & Lee, 2019), few studies have investigated the relationship between mental imagery and reward processing in anhedonic depression. Moreover, it is important to investigate whether the potentially positive effects of mental imagery are sustained after stress induction. Given the mechanism of anhedonia which may be specifically induced through its interaction with stress (Pizzagalli, 2014), investigating the change in the mental imagery effect after stress induction may be useful for examining the clear effect of mental imagery on anhedonic symptom. However, few studies have investigated the changes of the impact of mental imagery after stress induction. While some prior studies have reported that the effects of mental imagery are maintained in two-week follow-up (Lang, Blackwell, Harmer, Davison, & Holmes, 2012; Torkan et al, 2014), studies that have directly investigated the interaction between the impact of mental imagery and stress are scarce.

Thus, the purpose of the present study was to explore the effect of positive mental imagery intervention on anhedonia and the underlying reward mechanism in depression and to investigate the durability of the impact of the intervention following laboratory stress induction. For this purpose, participants reporting anhedonic depressive symptoms were randomly allocated to one of two conditions: mental imagery or verbalization, which is another mode of representing information according to the dual-coding theory (Paivio, 1991). The present study hypothesized that 1) compared to individuals assigned to the verbalization condition, individuals in the mental imagery condition show higher self-rated mood states, reward subcomponents (anticipated pleasure, consummatory pleasure, and motivation), and less significant anhedonic symptoms after the intervention and that 2) individuals in the mental imagery condition show lower levels of changes in self-ratings of their mood, reward subcomponents, and anhedonic symptoms after a stress induction task.

Method

Participants

Individuals between aged between 19 and 29 years were recruited through online advertisements posted on internet communities. They were screened for anhedonic depressive symptoms using the Anhedonic Depression subscale of the Mood and Anxiety Symptoms Questionnaire (MASQ-AD) (Clark & Watson, 1991). Specifically, individuals who exceeded the cutoff score of 23 on the MASQ-AD scale were selected and rewarded with 10,000 Korean won to participate for taking part in the study. Individuals taking prescribed antipsychotic medications or receiving psychological treatment were excluded from the study. Finally, a total of 54 adults comprising of 36 females and 18 males, with a mean age of 23.02 ($SD = 3.06$), were selected. The present study was approved by the institutional review board of the university and informed consent was obtained from all the participants.

Questionnaire Measures

The Anhedonic Depression Scale from the Mood and Anxiety Symptoms Questionnaire (MASQ–AD; Clark & Watson, 1991)

The MASQ-AD (Clark & Watson, 1991) is a 22-item scale that as-

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sesses anhedonic depressive symptoms using a 5-point Likert scale ranging from 1 (not at all true) to 5 (very true), with a higher score indicating more severe symptoms. In the present study, the 8-item subscale from the K-MASQ-AD, translated and validated by H. Lee and Kim (2014), was used to screen participants who scored 23 and higher. The 8-item subscale of the MASQ-AD has been identified as outperforming the total scale in predicting current major depressive episode related to anhedonia (Bredemeier et al., 2010). Internal consistency measured by Cronbach's α was .94 in H. Lee and Kim (2014) and was .72 in this study.

Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988)

The PANAS is a 20-item self-report measure of PA and negative affect (NA) using a 5-point Likert scale ranging from 1 (not at all true) to 5 (very true). It included 10 items measuring PA and 10 items measuring NA. The Korean version of the PANAS (H. H. Lee, Kim & Lee, 2003), was used in the present study. Internal consistency was .84 in H. H. Lee et al. (2003) and Cronbach's α was .86 in the present study.

Dimensional Anhedonia Rating Scale (DARS; Rizvi et al., 2015)

The DARS is a self-report scale measuring the different types of reward deficits across four domains (hobbies, food/drinks, social activities, and sensory experience) using a 5-point Likert scale ranging from 1 (not at all true) to 5 (very true), which is specifically developed for the assessment of anhedonic symptoms in depression. In this study, the modified DARS scale, translated by Park (2018) and revised and validated by E. J. Kim (2018), was used to measure consummatory pleasure, anticipatory pleasure, and motivation. Internal consistency was .95 for total items, .82 for consummatory pleasure, .88 for anticipatory pleasure and .95 for motivation. In this study, the internal consistency was .95 for the total items, .74 for consummatory pleasure, .89 for anticipatory pleasure, and .89 for motivation.

Center for Epidemiological Studies–Depression Scale (CES–D; Radloff, 1977)

The CES-D is a 20-item scale that measures depressive symptoms experienced by the participants in the past week using a 4-point Likert scale ranging from 0 (rarely or none of the time) to 3 (most or all of the time). The K-CES-D, translated and validated by Chon, Choi, and Yang (2001), was used in this study. Internal consistency was .92 in the original validation study (Chon et al., 2001), and was .72 in this study.

Questionnaire upon Mental Imagery (QMI; Sheehan, 1967)

The QMI is a 35-item scale assessing vividness of imagery in seven sensory modalities (e.g., audition) using a 7-point Likert scale ranging from 1 (no imagery) to 7 (imagery as vivid as real). In the current study, the Korean version of the QMI, translated and validated by J. H. Kim (1995), was used to exclude the confounding effects of the imagery ability. Cronbach's α was .92 in Min et al.'s (2019) study and was .95 in this study.

Picture Word Task

The participants of the present study took part in a computerized Picture Word (PW) task adapted from a previous study (Holmes et al., 2008), which was programmed using Psychopy3 version 3.0. and was administered using an Intel Core i3-6100U CPU laptop. In the PW task, the participants were repeatedly instructed to generate images or a single sentence by combining ambiguous pictures and positive verbal captions. Specifically, the participants in the mental imagery condition were instructed "Imagine the situation vividly combining the word and the picture" for 1,500 ms, while participants in the verbalization condition were given the direction "Make a single concrete sentence combining the word and the picture". Then, as Table 1 indicates, all the participants were presented with ambiguous/neutral pictures with positive word captions for 3,500 ms. Ambiguous/neutral pictures were downloaded from the Internet (non-copyrighted). Each picture was an ambiguous photo of daily objects and scenes, as in previous studies (Blackwell et al.,

Table 1. *Example of Picture-word Stimuli used in the Intervention*

Picture	Accompanying caption
Smartphone	"Fun"
Alarm clock	"Relaxation"
Night	"Peace"
Blackboard	"Achievement"
Box	"Gift"
Tree	"Refreshing"

2015; Holmes et al., 2008; Pictet, Coughtrey, Mathews, & Holmes, 2011). Positive words were selected from the Korean Affective Words List (Hong, Nam, & Lee, 2016), with positive valences ranging from 6 to 8 ($M = 7.36$, $SD = .52$), together with a variety of arousal levels ($M = 4.57$, $SD = 1.35$). Subsequently, a beep sounded, and the participants were asked to respond about the vividness of their imagination or concreteness of sentence construction using a 5-point Likert scale ranging from 1 (very hard to imagine/make a sentence) to 5 (very easy to imagine/make a sentence). After the rating, the participants were guided to continue the remaining trials. The task consisted of one training block which contained 4 trials, followed by 4 test blocks, each containing 16 trials.

Mental Arithmetic Stress Task

Mental Arithmetic Stress Task (MAST) is a computer-based mental calculation task designed to induce stress (Sawai et al., 2019). Because of its strong stress component, many previous studies, including depressive disorder studies, have used the MAST to elicit stress (Jonassaint et al., 2009; A. Y. Kim et al., 2019). In this study, all participants were instructed to perform serial subtraction of 17 from 8,500 mentally (e.g., 8,500-17, 8,483-17). After 5 min, a beep sounded and the participants were asked to rate the stress load using a 5-point Likert scale ranging from 1 (not at all) to 5 (completely).

Manipulation Checks

Manipulation check measures were used at the end of the experiment to identify task compliance. The participants were asked to rate the degree of the use of each strategy (mental imagery vs. verbalization) using a 10-point Likert scale ranging from 1 (never) to 10 (always) and check the predominant strategy they used during the PW task. The questionnaire items were obtained from Lim (2018).

Procedure

The participants provided written informed consent after being briefed on the study. They were randomly allocated to one of the two conditions (mental imagery or verbalization). The experimental session began with self-reported measurements of anhedonic depressive symptoms, current mood, and reward deficits, as pre-intervention measures. After the baseline assessment, the PW task was completed, which included either trial-by-trial ratings of the vividness of picture-word combinations in the mental imagery condition or a rating of verbalization concreteness of the association in the verbalization condition. Following the PW task, the participants completed a self-report questionnaire using the same scale used in the previous measurement. MAST was then implemented to induce stress in the participants. The participants assessed their mood, reward-related symptom, and anhedonia again. Additionally, all the participants were guided to rate the predominant strategy they used while engaging in the PW task at the end of the experiment. Finally, the participants were debriefed and compensated for their participation.

Data Analysis

SPSS 25.0 was used for all statistical data analysis. A chi-square test of homogeneity was conducted to determine whether the participants complied with the experimental instruction, and to rule out the possibility of heterogeneity between the two groups. To investigate between-group differences in the variables of interest, an independent sample *t*-test was used. A two-way mixed-model ANOVA was then applied to examine the efficacy of mental imagery on mood, reward subcomponents, and anhedonic symptoms, as well as the sustainability of the impact of the intervention. Finally, a paired samples *t*-test was used to further investigate the pre- and post-intervention differences in both the conditions.

Results

Baseline Measures

Table 2 shows the outcomes of the baseline measures. Neither condition (mental imagery condition vs. verbalization condition) showed significant differences in the current anhedonic depression score, baseline PANAS mood magnitude, anticipatory pleasure, consummatory pleasure, and motivation.

Manipulation Checks

To examine instructional compliance, the chi-square and independent *t*-tests were used. Regarding the prevalent usage of strategy, the two groups showed significant differences in the use of

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Table 2. *Baseline Measures*

	Mental Imagery (n = 31)		Verbalization (n = 23)		*t*	*p*
	M	*SD*	*M*	*SD*		
MASQ-AD	73.35	8.89	73.04	10.29	.12	.906
CES-D	27.35	7.47	25.35	8.47	.92	.361
QMI	186.58	33.59	192.48	21.26	-.74	.464
PANAS						
Positive Affect	19.16	5.02	20.74	5.66	-1.08	.284
Negative Affect	17.94	5.77	19.96	7.74	-1.05	.276
DARS						
Consummatory Pleasure	4.31	.57	4.22	.52	.59	.561
Anticipatory Pleasure	4.22	.74	4.22	.63	.00	.999
Motivation	3.88	.90	3.84	.74	.18	.860

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire-Anhedonic Depression; CES-D = Center for Epidemiological Studies-Depression Scale; QMI = Questionnaire upon Mental Imagery; PANAS = Positive and Negative Affect Schedule; DARS = Dimensional Anhedonia Rating Scale.

prevalent strategy during the PW task ($\chi^2(1) = 6.400$, $p = .011$), indicating that a substantial proportion of the participants followed instructions corresponding to the allocated condition. Regarding the degree of the usage of each strategy, there was a significant difference in the degree of verbalization ($t(52) = -2.64$, $p = .011$), whereas there was no significant difference in the degree of mental imagery usage between the two groups ($t(52) = .99$, $p = .328$). These results indicate that the participants in both the conditions used similar levels of mental imagery and that, while the mental imagery group depended more on imagery processing, the verbalization group relied more on verbal processing.

PW Task Outcome

To examine the efficacy of mental imagery, a two-way mixed-model ANOVA was used with the group (mental imagery condition vs. verbalization condition) as the between-subjects factor and time (pre- vs. post-intervention) as the within-subjects factor (Table 3). As indicated in Table 3, time had a statistically significant main effect on anhedonic depression ($F(1, 52) = 25.69$, $p < .001$). However, there was no significant interaction effect between the group and time on anhedonia, indicating that both the conditions showed a reduction in anhedonic symptoms; however, the difference between the two groups was not significant ($F(1, 52) = .37$, $p = .543$). In addition, there was also a significant main effect of time on NA ($F(1, 52) = 38.33$, $p < .001$), despite the lack of evidence supporting a statistically significant interaction between the group and time ($F(1, 52) = 2.41$, $p = .127$). Contrary to our research hypothesis, neither a significant main effect nor an interaction effect on PA was found. In addition, no statistically significant main effect or interaction effect on consummatory pleasure, anticipatory pleasure, or motivation was found.

MAST Outcome

Regarding the rating of the stress load, moderate stress levels were observed in all the participants ($M = 3.15$, $SD = .91$). As indicated in Table 4, time had a significant main effect on anhedonic depression ($F(1, 52) = 5.54$, $p = .022$), NA ($F(1, 52) = 36.90$, $p = .000$), consummatory pleasure ($F(1, 52) = 4.57$, $p = .037$), and anticipatory pleasure ($F(1, 52) = 8.42$, $p = .005$) after inducing stress. However, the interaction effect between the group and time was not statistically significant. Hence, a paired-samples *t*-test and Cohen's *d* coefficient were used to further assess the effect size of each intervention after stress induction. As indicated in Table 5, in the mental imagery condition, there were significant differences between pre- and post-MAST in anhedonia ($t(30) = -2.36$, $p = .025$) and NA ($t(30) = -5.09$, $p = .001$), indicating that anhedonic symptoms and NA increased significantly after stress was induced in mental imagery condition. However, there were no significant differences in PA, anticipatory pleasure, consummatory pleasure, or motivation. In the verbalization condition, significant differences were observed in NA ($t(22) = -3.67$, $p = .001$), consummatory pleasure ($t(22) = 2.07$, $p = .050$), and anticipatory pleasure ($t(30) = 2.16$, $p = .042$), indicating that there was a significant increase in NA and decrease in consummatory and anticipatory pleasure in the verbalization condi-

Table 3. *Pre- and Post-intervention Outcome*

	Groups	Pre-		Post-		Time	Time*Group
		M	*SD*	*M*	*SD*		
MASQ-AD	Imagery	28.13	3.19	23.81	6.08	25.69**	.37
	Verbal	28.26	3.65	24.87	4.65		
PANAS							
Positive Affect	Imagery	19.16	5.02	19.84	6.15	.52	2.69
	Verbal	20.74	5.66	19.00	6.84		
Negative Affect	Imagery	17.94	5.77	15.10	5.19	38.33**	2.41
	Verbal	19.96	7.74	15.22	5.66		
DARS							
Consummatory Pleasure	Imagery	4.31	.74	4.24	.64	.04	1.69
	Verbal	4.22	.52	4.30	.62		
Anticipatory Pleasure	Imagery	4.22	.66	4.25	.68	.74	.07
	Verbal	4.22	.63	4.28	.64		
Motivation	Imagery	3.88	.90	3.92	.81	3.16	.33
	Verbal	3.84	.74	4.04	.74		

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire-Anhedonic Depression; PANAS = Positive and Negative Affect Schedule; DARS = Dimensional Anhedonia Rating Scale.
**$p < .01$.

Table 4. *MAST Outcome*

	Groups	Pre-		Post-		Time	Time*Group
		M	*SD*	*M*	*SD*		
MASQ-AD	Imagery	23.81	6.08	25.97	5.49	5.54*	.43
	Verbal	24.87	4.65	26.09	6.01		
PANAS							
Positive Affect	Imagery	19.84	6.15	19.77	6.65	.99	.84
	Verbal	19.00	6.84	17.48	6.50		
Negative Affect	Imagery	15.10	5.19	19.48	5.57	36.90**	.30
	Verbal	15.22	5.66	20.48	8.46		
DARS							
Consummatory Pleasure	Imagery	4.24	.64	4.17	.64	4.57*	.47
	Verbal	4.30	.62	4.16	.62		
Anticipatory Pleasure	Imagery	4.25	.68	4.13	.76	8.42**	.21
	Verbal	4.28	.64	4.10	.68		
Motivation	Imagery	3.92	.81	3.88	.87	3.16	.33
	Verbal	4.04	.74	3.92	.73		

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire-Anhedonic Depression; PANAS = Positive and Negative Affect Schedule; DARS = Dimensional Anhedonia Rating Scale.
*$p < .05$, **$p < .01$.

tion after completing the stress-induction task. However, no significant differences were found in anhedonia, PA, or motivation.

Discussion

This study aimed to investigate the efficacy of the intervention of positive mental imagery on anhedonic depressive symptoms and to examine the sustainability of the impact of the intervention following the stress induction. Several major findings were obtained in this study. First, contrary to our hypothesis, the expected superiority of mental imagery over the verbalization was not found to improve anhedonic symptoms, mood, anticipatory pleasure, con-

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Table 5. *Effect Size of the Intervention after MAST*

	Groups	Pre-		Post-		*t*	*p*	Cohen's *d*
		M	*SD*	*M*	*SD*			
MASQ-AD	Imagery	23.81	6.08	25.97	5.49	-2.36	.025**	.36
	Verbal	24.87	4.65	26.09	6.01	-1.09	.289	.23
PANAS								
Positive Affect	Imagery	19.84	6.15	19.77	6.65	.07	.948	.01
	Verbal	19.00	6.84	17.48	6.50	1.19	.248	.23
Negative Affect	Imagery	15.10	5.19	19.48	5.57	-5.09	.000**	.81
	Verbal	15.22	5.66	20.48	8.46	-3.67	.001**	.73
DARS								
Consummatory Pleasure	Imagery	4.24	.64	4.17	.64	1.04	.306	.11
	Verbal	4.30	.62	4.16	.62	2.07	.050*	.23
Anticipatory Pleasure	Imagery	4.25	.68	4.13	.76	1.89	.068	.17
	Verbal	4.28	.64	4.10	.68	2.16	.042*	.27
Motivation	Imagery	3.92	.81	3.88	.87	.46	.648	.05
	Verbal	4.04	.74	3.92	.73	1.22	.235	.16

Note. MASQ-AD = Mood and Anxiety Symptom Questionnaire-Anhedonic Depression; PANAS = Positive and Negative Affect Schedule; DARS = Dimensional Anhedonia Rating Scale.
*$p < .05$, **$p < .01$.

summatory pleasure, and motivation. However, there was a significant main effect of time on anhedonia and NA, with a larger effect size in the mental imagery condition.

While no significant difference was found between the two conditions in reducing anhedonia, the result could be interpreted as an effect of mental imagery comparable to that of verbalization on anhedonia. Previous investigations have shown that cognitive therapy, which is mainly tuned to treating verbal forms of cognition (Saulsman, Ji, & McEvoy, 2019), has a beneficial effect in treating depression (Dobson, 1989; Rupke, Blecke, & Renfrow, 2006) as well as severe anhedonia (Khazanov et al., 2020). Based on the prior studies, the impact of mental imagery comparable to that of verbalization seems notable in that it reduces anhedonia, which is known for poor treatment responses (Craske, Meuret, Ritz, Treanor, & Dour, 2016), with only one session. Thus, the marginal difference between the two conditions may indicate the potential role of mental imagery in the treatment of anhedonic symptoms.

Moreover, there was neither a significant main effect nor an interaction effect of the intervention on the PA and reward subcomponents, including consummatory pleasure, anticipatory pleasure, and motivation. Considering prior studies that have reported the effect of mental imagery on PA and reward subcomponents (Renner, Murphy, Ji, Manly, & Holmes, 2019), such unexpected findings from the present study need further explanation. One possible explanation may be related to the arousal levels of the stimuli used in the PW task. In the PW task, the mean arousal level of the positive word stimuli were 4.57 ($M = 4.57$, $SD = 1.35$), indicating a medium level of arousal. However, reward subcomponents such as anticipatory pleasure, are likely to have a stronger relationship with high-aroused pleasant states (Geaney et al., 2015). Moreover, PA induced by medium-arousal stimuli could not be properly evaluated because of the limitation of the PANAS, which is suitable only for capturing high-arousal PA states (McManus, Siegel, & Nakamura, 2019). Therefore, it is likely that the impact of mental imagery on PA or reward subcomponents was not actually reflected.

Second, there was no significant difference between the two groups in terms of the durability of the impact of the intervention on mood, reward subcomponents, and anhedonia. However, the degree of the change varies depending on the condition. After performing the MAST, anhedonia and NA increased in the mental imagery condition while in the verbalization condition, NA increased and consummatory and anticipatory pleasure decreased. Regarding anhedonia, the impact of the intervention was not sustained only in the mental imagery condition perhaps due to the increased sensitivity to emotional state after performing mental imagery (Mitchell & Cusack, 2016). Consequently, it is likely that

the participants reported lower levels of anhedonia after the intervention, causing larger changes in anhedonic symptoms following the stress induction task. Thus, a significant change in anhedonia score was found only in the mental imagery condition even though anhedonia symptoms were higher in the verbalization condition than in the mental imagery condition.

Moreover, as for anticipatory pleasure, we may explain the results by considering the characteristics of the reward subcomponents and the mechanism of mental imagery. Anticipatory pleasure, a prospect-based emotion, seems to be drawn from positive past experiences that induce a stronger sense of pleasure (Painter & Kring, 2016). Thus, mental imagery may have an impact on anticipatory pleasure by representing an image related to sensory personal memories (Holmes et al., 2009). However, the stress induced in this study was related to cognitive load rather than personal real-life stressors. As a result, it may be possible that the impact of mental imagery on anticipatory pleasure after stress induction was preserved in the mental imagery condition because of the discrepancy between the reward subcomponent-related stress and MAST-induced stress. In contrast, it seems that the impact of stress was stronger in the verbalization condition because they relied more on semantic processing.

This study contributes to our understanding of anhedonic depression by revealing the effects of mental imagery on anhedonic symptoms. While the results did not show a clear superiority of imagery intervention on anhedonic symptoms, mental imagery intervention was found to improve anhedonia. This implies that positive mental imagery can be used as an add-on therapy to an existing treatment considering that extant treatments are relatively ineffective for anhedonia. Another strength is that unlike previous studies that only identified the direct effects of imagery intervention, the current study investigated whether the impact of mental imagery on anhedonia is sustainable following stress induction. Although a more elaborate stress induction task is called for in future research, it is noteworthy that this study emphasizes the necessity of repetitive imagery intervention because of the unsustainability of the impact of a brief intervention after stress induction. However, the present findings must be considered in light of the following limitations. First, the sample size was not large enough to detect any differences between the two conditions. Second, even though there were insignificant changes in reward subcomponents after the imagery intervention, we could not confirm the efficacy due to usage of stimuli with a medium arousal range. In future studies, stimuli eliciting a higher arousal level are required considering the relevance between arousal level and reward subcomponents. Third, minute differences between the two conditions in the usage of mental imagery may render the comparison between the two interventions difficult. To make a clear comparison, more frequent monitoring of manipulation is required in future studies. Finally, given the mechanism of mental imagery, the stress induction task used in the present study may not induce stress relevant to reward subcomponents. We encourage future research to adopt stress-induction task related to daily life stress to identify the impact of stress more precisely on reward subcomponents after the intervention.

Author contributions statement

MJP, a graduate student at Yonsei University, collected and analyzed the data, and prepared the manuscript. SHP, an associate professor at Yonsei University, served as the principal investigator of the research grant and supervised the research process. All the authors provided critical feedback, participated in revision of the manuscript, and approved the final submission.

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