Journal of Affective Disorders 329 (2023) 460–469

Contents lists available at ScienceDirect

Journal of Affective Disorders

journal homepage: www.elsevier.com/locate/jad

Research paper

Reimagining rumination? The unique role of mental imagery in adolescents' affective and physiological response to rumination and distraction

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ARTICLE INFO

Keywords:
Rumination
Distraction
Mental imagery
Verbal thought
Adolescents
Physiology

ABSTRACT

Rumination is associated with increased risk for depression whereas distraction helps draw attention away from negative experiences, lowering risk. Many individuals who ruminate do so in the form of mental imagery and imagery-based rumination is more highly associated with depressive symptom severity than ruminating in the form of verbal thoughts. We do not yet understand why imagery-based rumination may be especially problematic nor how to intervene to reduce imagery-based rumination, however. Adolescents (N = 145) underwent a negative mood induction followed by experimental induction of rumination or distraction in the form of mental imagery or verbal thought while affective, high-frequency heart rate variability, and skin conductance response data were collected. Rumination was associated with similar affective, high-frequency heart rate variability, and skin conductance response regardless of whether adolescents were induced to ruminate in the form of mental imagery or verbal thought. Distraction led to greater affective improvement and greater increases in high-frequency heart rate variability, but similar skin conductance responses when adolescents were inducted to distract themselves in the form of mental imagery compared with verbal thought. Findings emphasize the importance of considering mental imagery in clinical contexts when assessing rumination and when intervening using distraction.

Rumination, or dwelling on negative cognitions, emerges in earnest during the adolescent years (Jose and Brown, 2008) and may, in part, account for the substantial increase in risk for depression observed during this developmental period. In adolescent samples, rumination is associated with increased depressive symptoms concurrently and prospectively (Abela et al., 2002; Broderick and Korteland, 2004; Burwell and Shirk, 2007; Hankin, 2008; Muris et al., 2004; Rood et al., 2009; Schwartz and Koenig, 1996), higher risk for first onset of major depressive disorder (Abela and Hankin, 2011), and longer duration of depressive episodes (Abela and Hankin, 2011; Gibb et al., 2012). As such, improved understanding of adolescent rumination and, in particular, how to effectively intervene to reduce rumination, has potential to lower depression risk in this age group.

Distraction, or drawing attention away from negative experiences or negative affect, has been posited as one way to promote disengagement from rumination. Distraction is frequently used to contrast rumination during experimental inductions and in clinical contexts as a short-term strategy to reduce distress (e.g., Wise Mind ACCEPTS skill in dialectical behavior therapy). Studies with adolescents consistently find distraction to result in a more adaptive response relative to rumination (Broderick, 2005; Park et al., 2004; Roelofs et al., 2009) and to be just as effective as established interventions (e.g., mindfulness) in helping adolescents to extricate themselves from ruminative cycles (Hilt and Pollak, 2013). Thus, distraction may provide one means to reduce the likelihood of, or aid in disengagement from rumination.

Although extant literature has established links between rumination and depression in adolescents (e.g., Rood et al., 2009) and posited distraction as a potentially helpful alternative to rumination in this age group (e.g., Hilt and Pollak, 2013), the vast majority of research has conceptualized these processes as occurring in the form of verbal thoughts (i.e., verbal mental sentences). Rumination commonly occurs in the form of mental imagery (i.e., imagery-based rumination;

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https://doi.org/10.1016/j.jad.2023.02.066
Received 14 July 2022; Received in revised form 4 February 2023; Accepted 15 February 2023
Available online 21 February 2023
0165-0327/

Lawrence and Schwartz-Mette, 2019; McLaughlin et al., 2007; Newby and Moulds, 2012; Speckens et al., 2007), with individuals dwelling on negative experiences like replaying a picture or movie in mind. Initial research suggests that imagery-based rumination may be even more problematic than typically studied verbally-based rumination. In two studies with college students (Lawrence et al., 2018) and adolescents high in trait rumination (Lawrence et al., 2022), trait rumination was more highly associated with depressive symptom severity when individuals reported that they ruminate in the form of mental imagery compared with verbal thoughts.

Relative to research on imagery-based rumination there exists more work evaluating distraction in the form of mental imagery. In fact, one of the mostly commonly used inductions of rumination and distraction (Nolen-hoeksema and Morrow, 1993) induces imagery-based distraction (Lawrence and Schwartz-Mette, 2019). There also is some evidence to suggest that imagery-based distraction alleviates distress more effectively than verbally-based distraction. Lawrence and Schwartz-Mette (2019) for instance found that among college students with elevated depressive symptoms, greater mental imagery during distraction was associated with greater decreases in negative affect. Verbal thought during distraction on the other hand was not related to affect change. These initial findings are bolstered by additional studies showing that other intervention techniques are more effective when they employ mental imagery versus verbal thought. For example, in all three studies comparing imagery- and verbally-based cognitive bias modification paradigms (i.e., computerized training to modify interpretation biases common in depression), positively imagining ambiguous situations improved anhedonia and reduced depressive symptoms to a greater extent than positively interpreting the same ambiguous situations using verbal thinking (Blackwell et al., 2015; Renner et al., 2017; Torkan et al., 2014).

Unfortunately, we do not yet fully understand why imagery-based rumination may be more problematic than ruminating in the form of verbal thoughts or why imagery-based distraction could be particularly helpful. Filling this gap in the literature would better enable clinicians to provide accurate psychoeducation to patients about why getting stuck in imagery-based ruminative cycles exacerbates depressive symptoms and how imagery-based distraction could help extricate oneself from these cycles. In addition, research comparing response to imagery- and verbally-based rumination and distraction has potential to inform appropriate markers of change during treatment. If for example, imagery-based rumination increases negative affect relative to verbally-based rumination and imagery-based distraction promotes greater positive affect relative to verbally-based rumination it may be especially important to assess for changes in affect across treatment as clinicians work with clients to catch themselves ruminating, and to use distraction instead.

Basic science research points to differences in affective and physiological response to mental imagery and verbal thoughts that may extend to differences in response to imagery- and verbally-based rumination and distraction. In terms of affect, mental imagery may amplify subjective indices of both negative and positive affect relative to verbal thought (Holmes et al., 2008; Holmes and Mathews, 2005). Compared with verbally thinking about the same content, mentally imagining negative stimuli resulted in greater “unpleasantness” (Mathews et al., 2013), anxiety (Holmes and Mathews, 2005), and “higher emotionality” (Holmes et al., 2008). These findings might suggest that imagery-based rumination may be more closely tied with depressive symptom severity than verbally-based rumination due to the tendency for imagery-based rumination to increase negative affect. Only two studies to date have partially evaluated this hypothesis, however, and findings are mixed. Slofstra et al. (2018) did find partial support for this hypothesis as adults assigned to process an aversive autobiographical memory in the form of mental imagery experienced greater negative affect than adults assigned to verbally ruminate about an autobiographical memory, though this finding held only for adults low in depressive symptoms. Lawrence and Schwartz-Mette (2019) on the other hand found experimentally induced rumination to similarly maintain negative affect regardless of the degree to which young adults reported mental imagery or verbal thought during rumination. Thus, it remains unclear how affective response to imagery- and verbally-based rumination may differ, particularly among adolescents given that no research has evaluated this question in non-adult samples.

Regarding distraction, mental imagery does not just amplify negative affect relative to verbal thought but may also increase positive affect as well. Individuals induced to mentally imagine positive stimuli experience greater reductions in anxiety and increases in positive affect (Holmes et al., 2006, 2009) compared with when individuals are induced to verbally think about the same stimuli. It would therefore follow that imagery-based distraction may be more effective than verbally-based distraction because imagery-based distraction promotes greater increases in positive affect. Lawrence and Schwartz-Mette (2019) tested this possibility, finding that among depressed young adults, greater mental imagery reported during induced distraction was in fact associated with greater relief from negative affect whereas verbal thought was unrelated. Again however, research is needed comparing response to imagery- and verbally-based distraction in adolescents to determine whether distraction in the form of mental imagery may also be an effective strategy in younger age groups.

Measuring physiological responses to imagery- and verbally-based rumination and distraction in addition to subjective affect provides an objective marker with more nuanced information regarding indices of parasympathetic and sympathetic response that could differentiate rumination and distraction in mental imagery and verbal form. As examples of the types of insight that come from including psychophysiology in similar investigations, Vrana et al. (1989) found young adults to experience higher heart rate when mentally imagining fear-inducing stimuli relative to verbally thinking about it and Reyher and Smeltzer (1968) reported greater skin conductance response (SCR) reactivity when male young adults mentally imagined word pairs about sex, hostility, or family relationships compared to verbally thinking about the same word pairs. Counter to these results, Baker and Jessup (1980) documented higher SCR in response to verbally thinking about depressing, neutral, or pleasant scenarios relative to mentally imagining the scenarios.

There exists some research to suggest that ruminating in the form of mental imagery is more impairing relative to ruminating in the form of verbal thought and that distraction in the form of mental imagery may be more helpful than distraction in the form of verbal thought. Significant gaps remain, however. It is not yet clear *why* imagery-based rumination is especially maladaptive and imagery-based distraction especially effective. Response to imagery- and verbally-based rumination and distraction also have yet to be compared in adolescents. It is especially important to clarify the role of mental imagery in rumination and distraction in this age group given that imagery abilities peak during adolescents (Kosslyn et al., 1990), and intervening early to reduce rumination and in turn depressive symptoms could have cascading positive effects on development. In addition, physiological response to imagery- and verbally-based rumination and distraction has not yet been captured. Evaluating SCR and HF-HRV response to imagery- and verbally-based rumination and distraction provides objective information as to why imagery-based rumination may be problematic and imagery-based distraction helpful. Peripheral psychophysiological assessment also allows for examination of continuous response during imagery- and verbally-based rumination and distraction rather than relying on affect ratings or self-report measures administered before and after. The current study fills these gaps, informing how to assess and intervene upon rumination in adolescents.

1. Current study

The current study compared adolescents' change in affect, HF-HRV, and SCR during induced rumination or distraction in the form of mental imagery or verbal thought. Following a negative mood induction,

Table 1
Demographic characteristics.

	Overall Sample $N = 145$		Imagery-based rumination group $n = 37$		Verbally-based rumination group $n = 37$		Imagery-based distraction group $n = 36$		Verbally-based distraction group $n = 35$	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
Gender identity										
Male	45	31.03	14	37.84	10	27.03	12	33.33	9	25.71
Female	90	62.07	21	56.76	23	62.16	23	63.89	23	65.71
Transgender	6	4.14	2	5.41	3	8.11	0	0	1	2.86
Other	4	2.76	0	0	1	2.70	1	2.78	2	5.71
Age										
13	11	7.59	3	8.11	2	5.41	2	5.56	4	11.43
14	25	17.24	6	16.22	8	21.62	6	16.67	5	14.29
15	31	21.38	11	29.73	5	13.51	9	25.00	6	17.14
16	45	31.03	8	21.62	13	35.14	11	30.56	13	37.14
17	33	22.76	9	24.32	9	24.32	8	22.22	7	20.00
Ethnicity										
Hispanic or Latino	3	2.07	2	5.41	0	0	1	2.78	0	0
Not Hispanic or Latino	141	97.24	35	94.59	37	100	35	97.22	34	100
Race										
American Indian or Alaska Native	2	1.38	1	2.78	0	0	0	0	1	3.03
Asian	3	2.07	2	5.56	1	2.94	0	0	0	0
Native Hawaiian or Other Pacific Islander	1	0.69	0	0	0	0	0	0	1	3.03
Black or African American	5	3.45	1	2.78		2.94	1	2.78	2	6.06
White	127	87.59	32	88.89		94.12	34	97.14	29	87.88

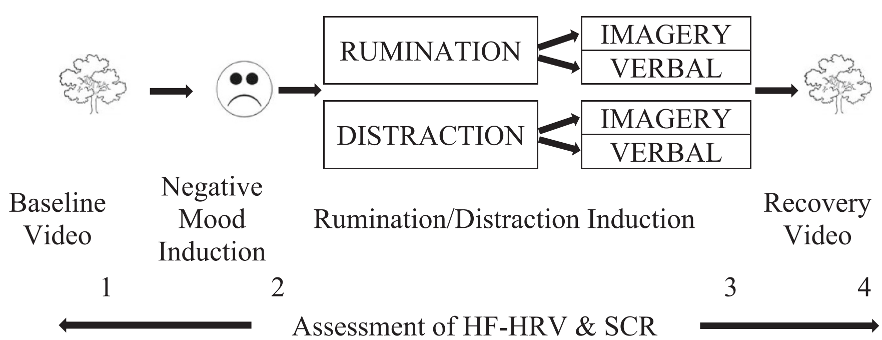

Fig. 1. Study procedure. 1, 2, 3, and 4 mark affect ratings.

adolescents were randomly assigned to ruminate or distract themselves using mental imagery or verbal thought while affect ratings and SCR and HF-HRV data were collected. To capture aspects of autonomic nervous system response, both HF-HRV and SCR data were captured. HF-HRV is a marker of parasympathetic response (Levy, 1990; Malik, 1996), which has, in some circumstances, been associated with regulatory control (e.g., of emotional responses; Williams et al., 2015). SCR is mediated by the sympathetic nervous system (Boucsein, 2012) and represents, in some cases, general arousal (van Dooren et al., 2012). We hypothesized that imagery-based rumination would result in lower affect ratings, lower HF-HRV, and higher SCR relative to verbally-based rumination and that imagery-based distraction would result in higher affect ratings, higher HF-HRV, and lower SCR relative to verbally-based distraction.

2. Method

2.1. Participants

Participants were adolescents ($N = 145$; age range: 13–17 years; $M_{age} = 15.44$ years, $SD = 1.23$) recruited from the community surrounding a mid-sized public university in New England. Exclusion criteria included cardiovascular or neurological conditions with potential to impact physiological functioning. Adolescents' parent(s)/guardian(s) provided informed consent prior to participation and adolescents provided assent before beginning the study. See Table 1 for demographic characteristics of the sample.

2.2. Procedure

See Fig. 1 for depiction of the study procedure. First, participants completed a resting baseline assessment of affect, HF-HRV, and SCR followed by a negative mood induction. Then, they were randomly assigned to induction condition in a 2 (rumination, distraction) X 2 (mental imagery, verbal thought) between-subjects design.[1] Finally, they completed a recovery period, ideally to allow them to return to baseline affect, HF-HRV, and SCR. All aspects of the study were presented on the computer using *E*-Prime 2.0 software. Adolescents were compensated $30 for participation in the study.

[1] A within-subjects design was also considered in which adolescents would ruminate (mental imagery, verbal thought) and then distract themselves (mental imagery, verbal thought. This design would have required some adolescents switch from only mental imagery (during rumination) to only verbal thought (during distraction) and vis versa, which we thought would be challenging. As such, we retained the between-subjects design.

2.2.1. Questionnaire assessments

2.2.1.1. Demographics and background information. Participants provided demographic information including date of birth, age, gender identity, and racial and ethnic identities. Participants were screened for relevant cardiovascular conditions and use of medications that may impact cardiovascular function.

2.2.1.2. Depressive symptoms. Participants completed the Center for Epidemiologic Studies Depression Scale (CES—D; Radloff, 1977) to assess past week depressive symptoms. The CES-D consists of 20-items reflecting various depressive symptoms (e.g., *I felt lonely*), which are rated on a scale reflecting how often participants experience each symptom ranging from 0 (*Rarely or none of the time*) to 3 (*Most or all of the time*). Internal reliability of the CES-D was excellent in the current study ($\alpha = 0.92$). Overall, participants reported moderate depressive symptoms ($M = 14.66$, $SD = 11.38$) and 38.62 % of the sample experienced clinically elevated depressive symptoms (i.e., CES-D scores ≥16; Lewinsohn et al., 1997).

2.2.2. Physiological data acquisition

Then, participants were outfitted with non-invasive sensors to measure electrical activity of the heart (i.e., electrocardiogram; ECG) and skin conductance (i.e., SCR). Physiological data were acquired with a MindWare Mobile Acquisition Unit (MindWare Technologies LTD, Gahanna, Ohio) and Biolab 3.3.1 software.

2.2.2.1. HF-HRV. Participants applied a 3-lead ECG with instruction from the experimenter. Continuous ECG data were collected at a sampling rate of 500 Hz. MATLAB code written by the second author was used to clean, ensemble, and calculate parameters including automated R peak detection. As we have done in the past (Rabellino et al., 2017), HF-HRV was calculated based on inter-beat-intervals (IBIs) extracted from the ECG data, and log transformed to yield an estimate of Respiratory Sinus Arrhythmia (RSA) which reflects the amplitude of heart rate fluctuations associated with breathing frequencies (Butler et al., 2006; Cacioppo et al., 1994). Briefly, R-wave peaks were identified in the smoothed data and IBIs were extracted. If IBIs were estimated to occur >1.6 s apart, a beat was assumed to have been missed, and a derivative-based estimation procedure was used to estimate the local max nearest to the mean IBI. If beats were detected <0.5 s apart, it was assumed that a spurious beat was detected, and it was removed. Following publications suggesting that the time-course of RSA can be understood via time-frequency decomposition (Mager et al., 2004), IBI data from the entire task were subjected to a single continuous Morlet wavelet transform (Torrence & Compo, 1998), which yielded continuously changing point-estimates of power throughout the frequency spectrum over the time-course of the task. Data in the 0.18–0.40 Hz range (consistent with the frequency band in which parasympathetic activity has maximal influence over IBIs) were averaged for each sample to yield a running estimate of HF-HRV using the MATLAB HRVAS toolkit (Ramshur, 2010), which we have independently verified to provide similar HF-HRV estimates to other canonical software packages. RSA was calculated as log (HF-HRV). Condition-related averages were computed from these estimates. Each second of HF-HRV data that fell +/− 1.5 SD away from surrounding data points was rescaled to the mean value of those surrounding data points. See Supplement 1, Table S1 for additional information on ECG acquisition and HF-HRV calculation.

2.2.2.2. SCR. To measure SCR the experimenter applied two electrodes to the thenar and hypothenar eminence on the participant's non-dominant hand. MATLAB code written by the second author was also used to clean and smooth SCR data. Initial preprocessing involved smoothing with a 1 s kernel and eliminating trials (i.e., 2-min blocks of prompts and rest) > 6 *SD* from the mean of all trials and where SCR changed >9 microsiemens within 3 s or > 15 microsimens within 30 s. A second preprocessing step linearly interpolated through outliers 1.5 times the interquartile range below the 25th percentile or above the 75th percentile of the timeseries. For group samplewise visual waveform analyses, data were further subjected to between-subjects outlier Windsorization and smoothing with a 20-s kernel. See Supplement 1, Table S2 for additional information on SCR acquisition and calculation.

2.2.3. Baseline

To establish resting baseline affect, HF-HRV, and SCR, and to allow participants to acclimate to wearing the sensors, participants watched a 7 min neutral film about United States National Parks. There was no sound or narration to avoid unintentionally inducing verbal thoughts. Similar films have been used previously to establish physiological baseline (e.g., (Woody et al., 2015).

2.2.3.1. Negative mood induction. Participants then played Cyberball (Williams et al., 2000) to induce negative affect due to perceptions of peer rejection. Cyberball is a virtual ball-throwing game in which participants believe they are playing catch on the computer with two same-aged peers, who are actually pre-programmed computer players. After several rounds of play in which all players throw the ball equally to one another, the computer players throw the ball only to one another, excluding the participant. Previous research has shown Cyberball to induce negative affect and subsequent rumination in adolescents (Wesselmann et al., 2013).

2.2.4. Rumination/distraction induction

Following Cyberball participants were randomly assigned to ruminate or distract themselves in the form of verbal thought or mental imagery in a 2 (rumination, distraction) X 2 (mental imagery, verbal thought) between-subjects design.

2.2.4.1. Rumination conditions. Participants in the rumination conditions were presented with 24 prompts shown to reliably induce rumination in adolescents (e.g., "[*think about/imagine] the kind of person you think you should be*" (Hilt and Pollak, 2012; Park et al., 2004) and to be equally likely to elicit mental imagery or verbal thought (Lawrence and Schwartz-Mette, 2019[2]). Participants were instructed to focus their attention on each of the ideas presented on the screen. Each prompt was presented for 15 s. After each set of four prompts participants saw a fixation cross for one minute as a rest period between prompts.

2.2.4.2. Distraction conditions. The distraction conditions were identical to the rumination conditions except that prompts distracted the participant from negative affect (e.g., "[*think about/imagine] the items on your grocery list*").

2.2.4.3. Mental imagery conditions

2.2.4.3.1. Mental imagery practice. To induce mental imagery during rumination/distraction participants first practiced forming mental imagery using instructions adapted from Holmes and colleagues (Holmes et al., 2006, 2008). Participants imagined a lemon, "what a lemon looks like when you shine a bright light on it", cutting a lemon with a knife, smelling the lemon zest/juice, and holding a lemon slice close to their eye and squeezing it. For each practice item, participants rated their imagery's vividness from 1 (*not at all*) to 9 (*extremely clear as in vision*) to reinforce instructions to make their mental imagery as vivid as possible. Previous research has established that this practice exercise is effective in leading participants to use mental imagery on subsequent tasks (Holmes et al., 2006, 2008).

[2] For a full list of rumination and distraction prompts used see Lawrence and Schwartz-Mette, 2019.

2.2.4.3.2. Mental imagery instructions. Before the start of the rumination/distraction induction participants were instructed to *"use your imagination to focus your mind on each of the ideas."* During the rumination/distraction induction participants were instructed to "*make mental images*" before each set of four rumination/distraction prompts, and each prompt began with "*Imagine*."

2.2.4.4. Verbal thought conditions

2.2.4.4.1. Verbal thought practice. To induce verbal thought during rumination/distraction participants practiced forming verbal thoughts, again using instructions adapted from Holmes and colleagues (Holmes et al., 2006, 2008). Participants practiced forming grammatically correct sentences in their mind combining a picture of a lemon with the word "yellow," a picture of a lemon with the word "refreshing," and a picture of a lemon slice with the word "squeeze." After each practice item, participants rated how easy it was to make the sentence in their mind from 1 (*extremely difficult*) to 9 (*extremely easy*) as an analog to participant rating the vividness of the mental imagery in the mental imagery conditions. Previous research has found these verbalize instructions to reliably induce verbal thoughts when completing subsequent tasks (Holmes et al., 2006, 2008).

2.2.4.4.2. Verbal thought instructions. Before the start of the rumination/distraction induction participants were instructed to *"use your concentration to focus your mind on each of the ideas."* During the rumination/distraction induction participants were instructed to "*make sentences*" before each set of four rumination/distraction prompts, and each prompt began with "*Think about*."

2.2.4.5. Manipulation check. Following the rumination/distraction induction participants rated how much they found themselves thinking in mental images and how much they found themselves thinking in words or sentences on separate scales ranging from 1 (*not at all*) to 9 (*totally*).

2.2.5. Recovery

To recover following the rumination/distraction induction participants viewed a second 7 min neutral video about United States National Parks. As with the baseline video there was no sound or narration.

2.2.6. Affect ratings

At four time points (see Fig. 1) participants rated their current effect on a VAS ranging from sad (1) to happy (100).

2.3. Transparency and openness

We report all measures and procedures in the study, detail how we manipulated all data (including physiological data), and describe all data exclusions (if any). All data, analysis code, and research materials are available by emailing the corresponding author. Data were analyzed using SPSS (version 28.0.1.1). This study was not pre-registered.

3. Analysis approach

Two (rumination, distraction) X 2 (mental imagery, verbal thought) between subjects ANOVAs were tested to compare affective, HF-HRV, and SCR response across conditions. In separate models mean affective, HF-HRV, and SCR change during the induction were evaluated as dependent variables.[3] Change in affect was computed by subtracting the pre-induction VAS rating from the post-induction VAS rating. Change in HF-HRV and SCR were calculated by subtracting the first second of HF-HRV/SCR from all subsequent seconds of HF-HRV/SCR during the induction and then taking the mean of all values. Follow-up pairwise comparisons evaluated differences between imagery- and verbally-based rumination and between imagery- and verbally-based distraction; Bonferroni corrections were applied to adjust for multiple comparisons within each ANVOA model.[4] Regarding outliers, the file was split by condition, and scores that fell more than ±3 standard deviations from the mean of each condition were treated as outliers. No outliers were identified for affect, HF-HRV, or SCR within any condition. A priori power analyses conducted using G*Power (Faul et al., 2009) indicated that a sample size of 142 was sufficient to detect moderate sized effects (0.35) comparing imagery- and verbally-based rumination and distraction conditions using ANOVA ($\alpha = 0.05$, following type I error control, power = 0.80). Data were missing[5] completely at random (MCAR), X^2 (79, N = 145) = 78.96, p = .48. Missing data were imputed using expectation-maximization procedures.

4. Results

4.1. Random allocation to conditions

See Table 2 for characteristics of the sample by condition. Two (rumination, distraction) X 2 (imagery, verbal thought) between subjects ANOVAs revealed no differences among conditions in depressive symptoms [$F(1,141) = 1.21$, $p = .27$, $\eta p^2 < 0.01$], baseline affect [$F(1,141) = 0.05$, $p = .82$, $\eta p^2 < 0.01$], HF-HRV [$F(1,141) = 0.57$, $p = .45$, $\eta p^2 < 0.01$], or SCR [$F(1,141) = 2.10$, $p = .15$, $\eta p^2 = 0.02$]. Thus, participants appeared to be randomly allocated to conditions.

4.2. Manipulation checks

4.2.1. Cyberball

Cyberball was effective in inducing negative affect as evidenced by a significant decrease in reported affect from baseline ($M = 76.75$, $SD = 17.17$) to post-Cyberball ($M = 62.33$, $SD = 21.55$), $t(144) = 8.35$, $p < .001$, $d = 0.69$. Decreases in affect were reported 52.5% of the sample, which is typical for mood inductions (Martin, 1990).

4.2.2. Induction of mental imagery and verbal thought

Adolescents assigned to the mental imagery conditions reported significantly greater mental imagery during the induction ($M = 6.70$, $SD = 1.84$) than adolescents assigned to the verbal thought conditions ($M = 5.40$, $SD = 2.16$), $t(138) = 3.83$, $p < .001$, $d = 0.65$. Adolescents assigned to the verbal thought conditions reported non-significantly greater verbal thought during the induction ($M = 7.14$, $SD = 2.00$) than adolescents assigned to the mental imagery conditions ($M = 6.54$, $SD = 2.21$), $t(138) = -1.69$, $p = .09$, $d = 0.28$.

4.2.3. Physiological responses

Supplement 2, Figs. S1 and S2 show clear condition-related HF-HRV and SCR responses to prompts versus rest.

4.3. Response to imagery- and verbally-based rumination and distraction

4.3.1. Affect

First, we compared change in affect across conditions. The 2 (rumination, distraction) X 2 (imagery, verbal thought) interaction among conditions was not significant, $F(1,141) = 0.99$, $p = .32$, $\eta p^2 = 0.007$ (see Fig. 2). Simple main effects analyses revealed a significant difference between adolescents in the imagery- and verbally-based distraction conditions, $F(1,141) = 4.70$, $p = .03$, $\eta p^2 = 0.03$, such that affect

[3] Given strong ties between rumination and depressive symptoms in adolescents (e.g., Rood et al., 2009) sensitivity analyses also were conducted controlling for severity of depressive symptoms (see Supplement 3).

[4] All presented p values have been adjusted where appropriate.

[5] Missing data were distributed as follows: depressive symptoms ($N = 0$), baseline affect ($n = 8$), baseline SCR ($n = 16$), baseline HF-HRV ($n = 19$), pre-induction affect ($n = 7$), post-induction affect ($n = 7$), SCR change during induction ($n = 21$), HF-HRV change during induction ($n = 12$).

Table 2
Baseline characteristics of the sample by condition.

	Total sample (N = 145)	Imagery-based rumination (n = 37)	Verbally-based rumination (n = 37)	Imagery-based distraction (n = 36)	Verbally-based distraction (n = 35)
Baseline characteristics	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*	*M (SD)*
Depressive symptoms	14.66 (11.38)	14.03 (11.71)	13.46 (9.58)	13.83 (10.55)	17.43 (13.44)
Affect	76.75 (17.17)	75.83 (16.39)	76.42 (18.52)	76.45 (15.85)	78.37 (18.40)
HF-HRV	3.87 (0.95)	3.76 (1.04)	3.82 (1.05)	3.80 (0.91)	4.10 (0.75)
SCR	7.56 (5.34)	9.19 (6.03)	6.44 (3.49)	7.38 (5.95)	7.19 (5.35)

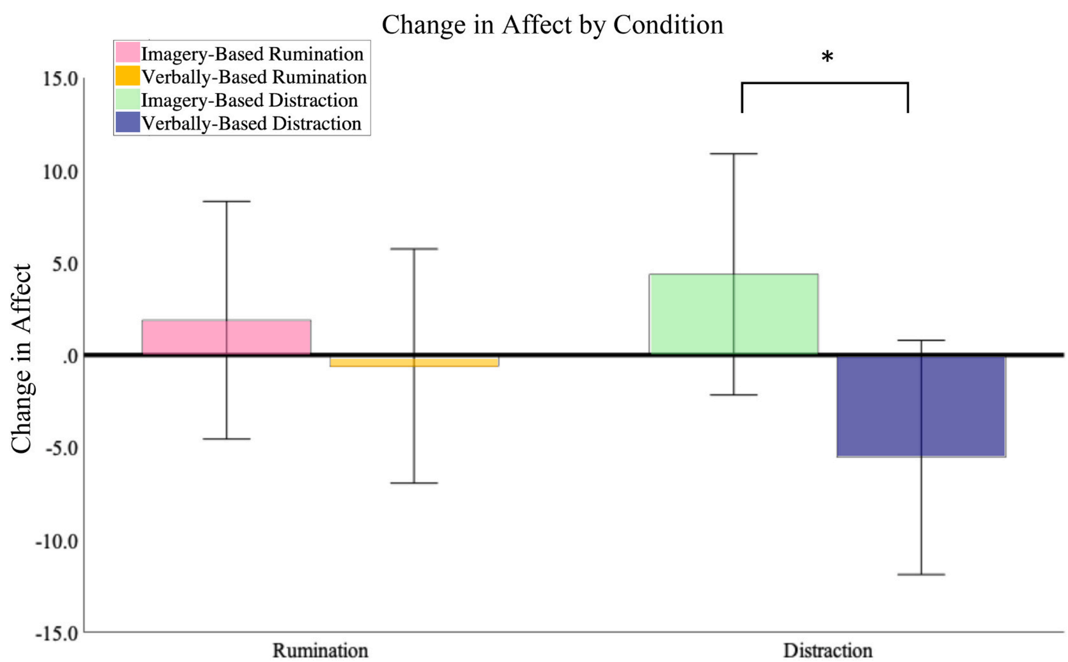

Fig. 2. Affect change from pre- to post-induction by condition. Positive values reflect improvements in affect relative to Cyberball. Negative values indicate decrements in affect relative to Cyberball. Error bars represent 95 % CI. Color figures availiable in web version of this article.

improved significantly more for adolescents induced to distract themselves in the form of mental imagery relative to verbal thought. The pairwise comparison between the imagery- and verbally-based rumination conditions was not significant, $F(1,141) = 0.62$, $p = .43$, $\eta p^2 = 0.004$; affective response following Cyberball was similar for adolescents in both rumination conditions.

4.3.2. HF-HRV

The 2 (rumination, distraction) X 2 (imagery, verbal thought) interaction among conditions significantly predicted HF-HRV change during the induction, $F(1,141) = 4.85$, $p = .03$, $\eta p^2 = 0.03$ (see Fig. 3). HF-HRV change during the induction did not differ between adolescents in the imagery- and verbally-based rumination conditions, $F(1,141) = 0.37$, $p = .54$, $\eta p^2 = 0.003$, but adolescents in the imagery-based distraction condition experienced significantly greater increases in HF-HRV than adolescents in the verbally-based distraction condition, $F(1,141) = 6.17$, $p = .01$, $\eta p^2 = 0.04$.

4.3.3. SCR

The 2 (rumination, distraction) X 2 (imagery, verbal thought) interaction was not a significant predictor of SCR change, $F(1,141) = 2.61$, $p = .11$, $\eta p^2 = 0.02$ (see Fig. 4). SCR change during the induction did not differ between adolescents in the imagery- and verbally-based rumination conditions, $F(1,141) = 0.40$, $p = .53$, $\eta p^2 = 0.003$. Adolescents in the imagery-based distraction condition experienced non-significantly greater decreases in SCR relative to adolescents in the verbally-based distraction condition, $F(1,141) = 2.71$, $p = .10$, $\eta p^2 = 0.02$.

4.3.4. Sensitivity analyses

Supplement 3 reports analyses controlling for depressive symptom severity. Two (rumination, distraction) X 2 (imagery, verbal thought) interactions predicting HF-HRV remained significant; 2 (rumination, distraction) X 2 (imagery, verbal thought) interactions predicting subjective affect and SCR remained non-significant. Supplement 4 reports analyses controlling for mental imagery and verbal thought experienced during the induction. Again, patterns of results remained unchanged.

5. Discussion

The present study tested adolescents' affective, HF-HRV, and SCR response to experimentally induced rumination and distraction in the form of mental imagery or verbal thought. Adolescents' response to imagery-based rumination largely did not differ from their response to verbally-based rumination. Specifically, affect, HF-HRV, and SCR change did not differ between adolescents in the imagery- and verbally-based rumination conditions. Although in line with prior research that also found similar affective response to rumination regardless of the degree of mental imagery or verbal thought experienced (Lawrence and Schwartz-Mette, 2019), this finding was surprising given prior work evidencing a stronger link between rumination and depressive symptom severity for

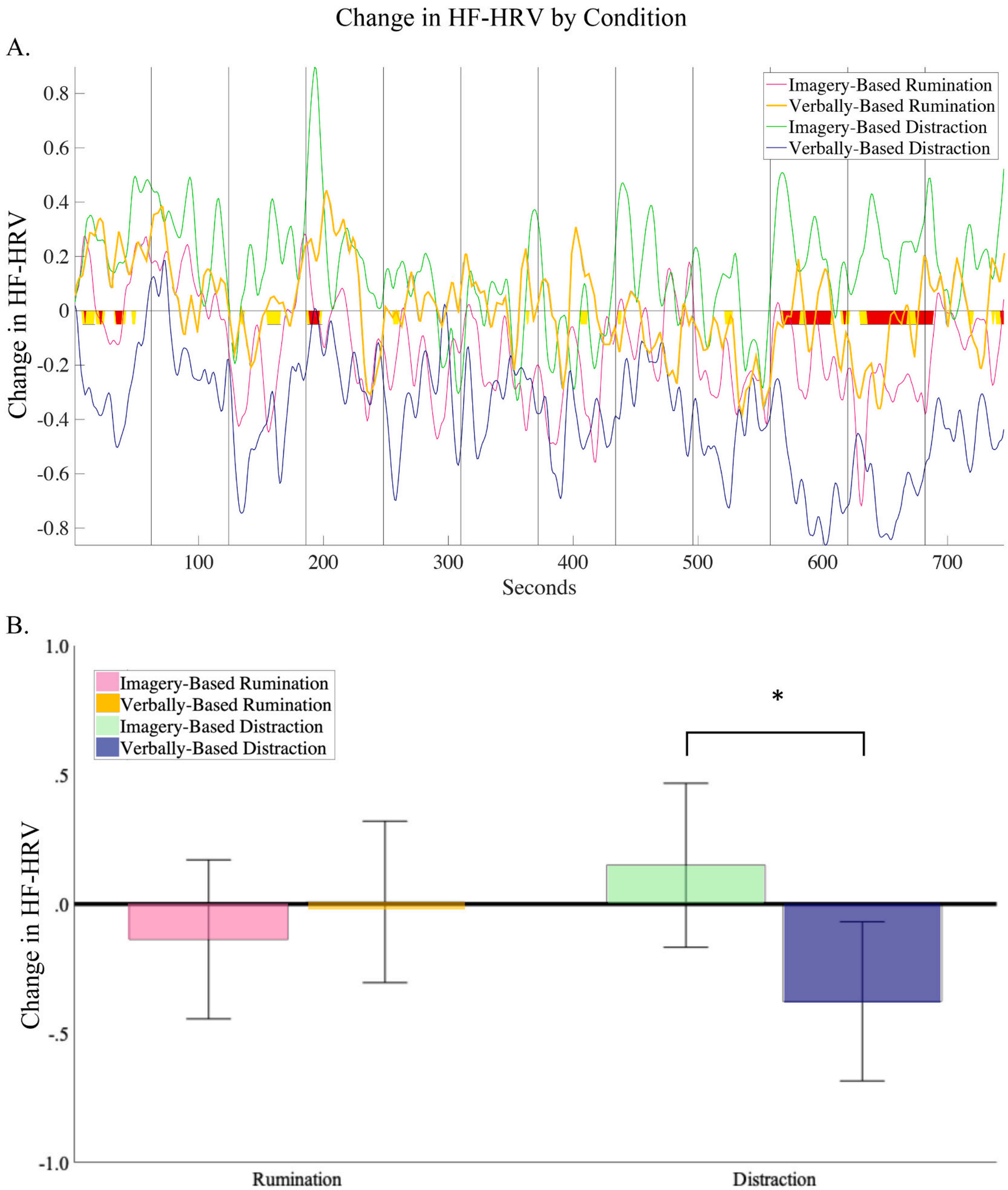

Fig. 3. HF-HRV change during the induction by condition. Positive values reflect increases in HF-HRV during the induction. Negative values reflect decreases in HF-HRV during the induction. Panel A shows waveforms of continuous HF-HRV change across the 12-min induction by condition. To evaluate the statistical significance of difference potentials among participants in each condition 2 × 2 ANOVAs were used. Areas highlighted in yellow show differences between conditions of $p < .05$; areas highlighted in red show differences between conditions of $p < .01$. To account for multiple comparisons, corrections developed by Guthrie and Buchwald (1991) were applied. Panel B shows mean HF-HRV change by condition. Error bars represent 95 % CI. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

imagery-based ruminators compared with verbally-based ruminators (Lawrence et al., 2018; Lawrence et al., 2022). It is possible that even though individuals perceive imagery-based rumination to be more aversive than verbally-based rumination, in reality it is the process of dwelling on maladaptive cognitions that maintains and exacerbates distress, rather than whether those cognitions take the form of mental imagery or verbal thought. An alternate hypothesis is that the experimental induction of negative affect (i.e., Cyberball) was not sufficiently strong or that the induction of rumination was not sufficiently long to observe differences between imagery- and verbally-based rumination. Imagery-based rumination may only emerge as particularly maladaptive after particularly stressful experiences or after longer time periods of time given that rumination is thought to exert its influence on depressive symptoms through prolonged dwelling.

Another possibility is that inducing imagery-based rumination in individuals who typically ruminate in the form of verbal thoughts does not elicit the same response as inducing imagery-based rumination in typically imagery-based ruminators. The two studies that documented a stronger rumination-depression relation for imagery-based ruminators compared with verbally-based ruminators had participants self-identify how they typically ruminate (Lawrence et al., 2018; Lawrence et al., 2022). In the present study, however, adolescents were randomly assigned to rumination conditions. Some research also has found that imagery-based rumination is only more maladaptive than verbally-based rumination for females and not males (Lawrence et al., 2018; Lawrence et al., 2022). Thus, differences in affective and physiological response to imagery- versus verbally-based rumination may be present when tested for females separately. Unfortunately, the present study was

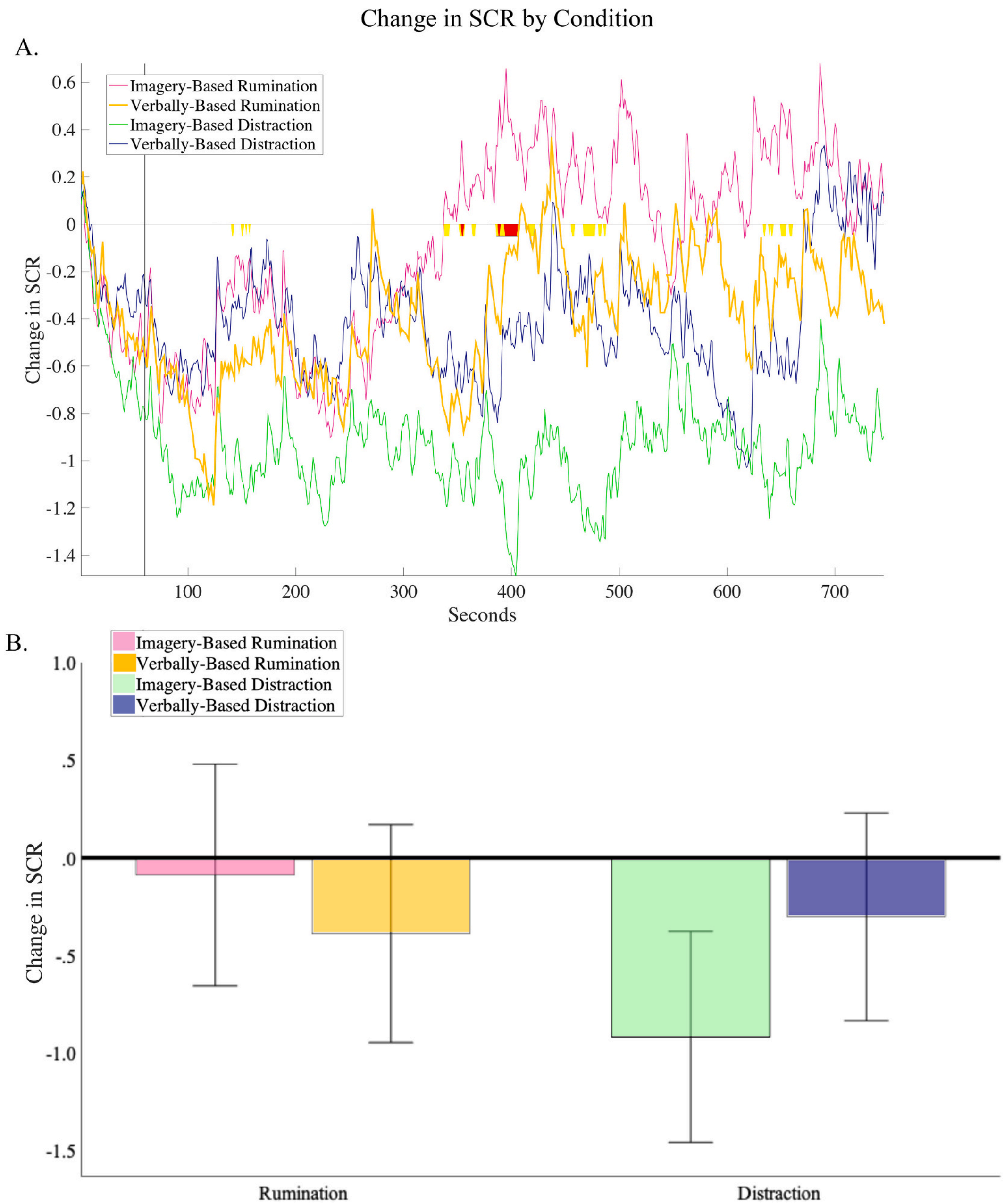

Fig. 4. SCR change during the induction by condition. Positive values reflect increases in SCR during the induction. Negative values reflect decreases in SCR during the induction. Panel A shows waveforms of continuous SCR change across the 12-min induction by condition. To evaluate the statistical significance of difference potentials among participants in each condition 2 × 2 ANOVAs were used. Areas highlighted in yellow show differences between conditions of $p < .05$; areas highlighted in red show differences between conditions of $p < .01$. To account for multiple comparisons, corrections developed by Guthrie and Buchwald (1991) were applied. Panel B shows mean SCR change by condition. Error bars represent 95 % CI. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

not powered to evaluate gender differences or differences based on adolescents' typical rumination style; future research with larger samples is needed to test these possibilities.

Finally, it is important to acknowledge that although there is some research to support the notion that imagery-based rumination may elicit a more aversive response than verbally-based rumination, there exists a broader literature on other forms of imagery- and verbally-based cognitive processes that is more mixed. Slofstra et al. (2018) for example compared adults' affective response to imagery- or verbally-based recall of autobiographical memories. They found that in their overall sample, there was no difference in affect change depending on whether participants recalled the event using mental imagery or verbal thought. Baker and Jessup (1980) even found results counter to expectations. College student participants experienced higher SCR in response to verbally thinking about compared to mentally imagining depressing, neutral, or pleasant scenarios. As such, additional research on imagery- and verbally-based rumination is needed to ascertain whether experiencing rumination in the form of mental imagery versus verbal thought leads to a different response, or perhaps for whom or under what conditions, this different response is observed.

In line with hypotheses and prior work (e.g., Lawrence and Schwartz-Mette, 2019), imagery-based distraction elicited different responses than verbally-based distraction. Specifically, affect improved and HF-HRV increased more so in the imagery-based distraction condition compared with the verbally-based distraction condition. One possible reason that imagery-based distraction may be more helpful than verbally-based distraction is that mental imagery may demand greater cognitive load and attention than verbal thought (Ghanbari et al., 2020; Heath, 2020). Imagery-based distraction may therefore reduce the cognitive resources available for other, more maladaptive imagery-based processes (e.g., intrusive images or imagery-based rumination; e.g., Iyadurai et al., 2020), allowing for greater affective and physiological improvement. Mental imagery also is more similar to real perception than verbal thought (Dobson and Markham, 1993; Holmes and Mathews, 2010). Mental imagery may be a superior means of distraction compared with verbal thought if mental imagery elicits the same affective and physiological response as really experiencing the distracting content. For example, if an adolescent distracts themselves by bringing to mind an enjoyable social event with friends, they may be more likely to experience the positive affective and physiological response felt during the actual social event when they mentally imagine that event versus when they verbally think about it.

It is important to note that differences in SCR response to imagery- and verbally-based distraction were not statistically significant. One explanation is that differences among conditions in SCR response may take longer to emerge (see Fig. 4, Panel A). Longer periods of imagery-based distraction or perhaps more comprehensive imagery-based interventions may be needed to observe differences in SCR to imagery- versus verbally-based interventions. Although most studies to compare response to imagery- and verbally-based treatments find response to imagery-based interventions to be more adaptive, this literature is not entirely consistent. As one example, Reiss et al. (2019) compared college students' heart rate and blood pressure response to a social evaluative stressor before and after receiving one of two anxiety interventions: cognitive behavioral therapy (CBT) with relaxation training or CBT with imagery rescripting. Counter to expectations, heart rate and blood pressure response to the stressor did not differ between the intervention groups. Taken together, findings suggest that imagery-based distraction elicits greater affective improvement and increases in HF-HRV following the stressor of Cyberball but that additional research is needed to identify the length and type of imagery-based intervention that could be optimally helpful.

5.1. Limitations

The present study found rumination to result in similar affective, HF-HRV, and SCR response regardless of whether ruminative cognitions took the form of mental imagery or verbal thought and highlighted imagery-based distraction as a potentially effective way to intervene, but this study is not without limitations. First, most adolescents reported some degree of mental imagery and verbal thought in all conditions. This is in line with prior research finding that the majority of individuals report both verbal thought and mental imagery when ruminating (e.g., (Lawrence et al., 2018). Although induced to do otherwise, adolescents may have an at least partially fixed tendency to employ both mental imagery and verbal thought when ruminating. To build on the present study it may therefore be beneficial to inquire about natural tendencies to experience mental imagery and verbal thought during induced rumination and distraction.

Second, this study was not powered to test age or gender differences in findings. As noted previously, prior research suggests that imagery-based rumination may be especially problematic for females compared with males (Lawrence et al., 2018; Lawrence et al., 2022), highlighting the need for future research examining how gender identity relates to response to imagery- and verbally-based rumination and distraction. Finally, it is important to acknowledge that distraction is not always an advantageous approach in clinical contexts. During exposure therapy, for example, distraction may limit opportunities to learn that one is capable of tolerating distress. That said, distraction provides short-term relief that may then allow for more advanced or comprehensive skill use.

5.2. Clinical implications

Results provide additional evidence imagery- and verbally-based rumination result in similar affective, HF-HRV, and SCR responses following a stressor and thus warrant assessment in clinical contexts. Asking clients about the tendency to dwell on negative experiences both in the form of verbal mental sentences and mental images could add important information when considering depression risk and determining how best to intervene. Findings from this study also suggest that using mental imagery to distract oneself following a negative experience could be a particularly fruitful way to potentially provide relief and reduce the tendency to ruminate. Helping clients practice forming and maintaining adaptive mental images in mind could be even more advantageous relative to the verbally-based distraction strategies typically used.

CRediT authorship contribution statement

HRL designed the study, collected and analyzed the data, and wrote the paper. GJS and RSM assisted with design of the study, provided feedback on statistical analyses, and in critical review of the manuscript.

Funding

This project was supported by a Graduate Student Research Grant from the Association for Behavioral and Cognitive Therapies and a training fellowship from the Society for Psychophysiology Research awarded to HRL. HRL also was supported by a grant from the American Foundation for Suicide Prevention (PRL-0-095-19) and RSM was supported by a grant from the National Institute of Mental Health (R15MH116341) during preparation of this manuscript.

Conflict of interest

None.

Acknowledgements

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jad.2023.02.066.

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