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Article in Behaviour Research and Therapy · October 2025

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The physiological signature of imagery rescripting: Associations between heart rate and session-level outcomes^{☆, ☆ ☆}

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ARTICLE INFO

Keywords:

Imagery rescripting

Heart rate

Physiology

Process-outcome research

ABSTRACT

Objective: Imagery rescripting (IR) as an emotion-focused technique involves an evoking as well as a rescripting phase, which incorporates cognitive restructuring. The different components of IR might be characterized by different physiological patterns. The main aim of this study is to test whether clients' physiological arousal during the evoking phase and clients' physiological arousal during the rescripting phase follows specific patterns and predicts improvement on next-session outcomes.

Methods: The results are based on 108 therapy sessions from an imagery-based treatment with 64 clients with test anxiety. The treatment protocol involves two consecutive IR sessions of past events related to test anxiety. Clients' heart rate (HR) was continuously monitored, next-session outcome was assessed with the State Test Anxiety Measure and Outcome Rating Scale.

Results: Clients showed on average an increase in HR during the evoking phase and a decrease during the rescripting phase in the first IR session. These effects reduced in the second IR session. In addition, no latent subgroups were identified. Furthermore, an increase in HR during the evoking phase was significantly associated with lower next-session test anxiety and marginally associated with higher next-session well-being.

Conclusion: The results provide initial evidence that clients' physiological arousal during the evoking phase of IR might play a role in the effectiveness of IR.

1. The physiological signature of imagery Rescripting: Associations between heart rate and session-level outcomes

Imagery Rescripting (IR) is an emotion-focused technique in which distressing memories are activated with vivid sensory, emotional, and cognitive content; an evoking which also helps clarify unmet needs that still plague the client (e.g., Arntz, 2014). IR combines two phases: evoking and rescripting (Smucker et al., 1995). The technique begins with an evoking phase in which the client is asked to describe the imagined situation (e.g. an aversive memory from the past) in detail. The therapist can ask the client to describe the five sensory perceptions. The client is then asked to focus on themselves and report their emotions, physical sensations, behaviors (or behavioral tendencies) and cognitions. Once these have been clearly identified, the client is asked to adopt an observer's perspective in order to find out what they would

have needed (or will need) in this particular situation. Importantly, the aim here is to identify the client's emotional needs, not to undo the original situation. The re-activated experience is then 'rescripted' (i.e., changed in imagination in a positive, desired direction), so that the unmet needs of the vulnerable self are satisfied, at least in phase, which changes the meaning of the experience, and evokes fewer negative emotions (Mancini & Mancini, 2018). In order to do so, the client is asked to imagine the scene from the perspective of their present self and to step into the image to do whatever is necessary to satisfy the needs of their younger or vulnerable selves (Arntz, 2012; Arntz and Weertman, 1999; Holmes, Arntz, & Smucker, 2007). The main goal is to create a sense of empowerment and thus change the (negative) emotions associated with the aversive memory (Arntz and Weertman, 1999).

The effectiveness of imagery rescripting (and also other imagery work) may be partly due to its ability to simulate perceptual processes

This article is part of a special issue entitled: Imagery Rescripting published in Behaviour Research and Therapy.

^{*} The protocol of this study was published in Prinz et al. (2016, 2019). Part of the data analyzed in this study were published in Prinz et al. (2022).

^{☆☆} The datasets analyzed in the current study are available from the corresponding author on reasonable request.

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<https://doi.org/10.1016/j.brat.2025.104879>

Received 13 August 2024; Received in revised form 27 August 2025; Accepted 29 September 2025

Available online 4 October 2025

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and elicit reactions that are quite similar to real experiences (e.g., Holmes & Mathews, 2010; Ji et al., 2016). Consequently, as numerous laboratory studies have shown, imagery work evokes both strong emotional and physiological responses (Cuthbert et al. 2003; Henderson et al., 2018; Miller et al., 1987). While much of the research to date on the underlying mechanisms at work has been devoted to changes in memory representations, whether unconditioned stimulus reevaluation (e.g., Arntz, 2012) or memory retrieval (e.g., Brewin et al., 2010), the reciprocal relation between memory processes and autonomic functions (Bassi & Bozzali, 2015; Critchley et al., 2013; Hugdahl, 1996) has been neglected. A closer investigation of physiological arousal during IR is of theoretical and clinical interest, because it could offer new perspectives on the underlying mechanisms at work and also provide guidelines for IR in clinical practice.

Given the unique structure of IR interventions, we might expect different IR components (evoking and rescripting) to be characterized by different physiological patterns. Specifically, given that the earlier phase of IR involves evoking an aversive situation, we would expect physiological arousal to increase. However, avoidance strategies may make it difficult for some clients to evoke the aversive memory. In these cases, physiological arousal may remain unchanged. The idea that contextualizing all elements of the aversive experience leads to a more comprehensive image and better memory representation (Brewin et al., 2010) is presumably associated with increased physiological arousal. Transferring this idea into clinical practice suggests that clients may benefit from therapists providing more guidance and asking targeted questions. In contrast, the rescripting phase of IR involves processing and regulating the client's needs and emotions. Thus, we would expect physiological arousal to decrease. For example, laboratory studies have shown that both reappraisal (Griffin & Howard, 2022), as well as processing emotions through acceptance are associated with a decrease in physiological arousal (Low et al., 2008). However, when an aversive memory is activated, some clients may exhibit dysfunctional coping mechanisms such as rumination. Rumination has been shown to be associated with slower heart rate (HR) recovery after stressful events (Alado et al., 2014; Low et al., 2008). Therapists can support clients by guiding them to process and regulate their emotions more directly, for example by evaluating the appropriateness of their original emotional reaction.

To our knowledge, this physiological signature of IR has not yet been investigated in any study, and the studies most pertinent to this question have relied on client self-reports. For example, Dibbets and Arntz (2015) examined client-rated distress during IR at five timepoints (before the onset of the intervention, after closing their eyes for the intervention, and again after three, six, and 9 min). Even though the authors did not examine the different components of IR (i.e., evoking versus rescripting), but instead examined fixed time segments (3 min each), there was a clear increase in client-rated distress at time 3 and a slight drop from there to time 5. This study provides initial indications that clients experience the different components of IR as differently stressful.

The related literature on imagery exposure provides potential hints about the association between physiological responses during imagery rescripting and outcome. In one study, Halligan and colleagues (2006) investigated whether heart rate (HR) responses during imagery exposure were related to outcome. As an autonomic nervous system (ANS) parameter, HR is particularly suitable for analyzing emotional responsiveness (Del Piccolo & Finset, 2018). HR data allow for the examination of both sympathetic and parasympathetic functioning and accompanying emotional regulation (Thayer et al., 2009). When HR increases, it's typically associated with sympathetic activation, signifying heightened vigilance, active avoidance, and negative emotions (e.g., anxiety). Conversely, HR decreases with parasympathetic activation (Berntson et al., 2007), indicating positive emotions and enhanced cognitive processing (Tremayne 1990). Halligan and colleagues (2006) found that HR response was unrelated to change in client-reported distress. Further, higher HR during imagery exposure (but not client-reported

distress) predicted greater symptom reduction at treatment outcome. This is in line with other studies showing that self-report measures and physiological markers may be measuring different constructs (e.g., Lieberman et al., 2016; Mauss & Robinson, 2009).

In another study, Gramlich et al. (2021) examined the physiological signature of prolonged exposure in combat-related post-traumatic stress disorder. To do so, HR was collected every 5 min during the exposure session. The results showed an average decrease in HR over the course of the session. This study provides evidence that the physiological response changes during imagery work. Though IR differs from imagery exposure in many respects, its early phase – i.e., the evocation of an aversive memory – does overlap with it. In both techniques, clients are exposed (at least temporarily) to an aversive memory through imagery. Hence, we might expect increased ANS activation during the evoking phase of IR to lead to a better outcome.

Physiological arousal is a dynamic process and can vary from person to person even though they are exposed to the same stressor (Manuck et al., 1989). Indeed, it is important to explore whether clients might aggregate into different subgroups, which differ from each other both in their physiological change patterns and in their outcomes. Based on the aforementioned literature, we would expect that the majority of clients show an increase during the evoking phase and a decrease during the rescripting phase. However, it is also possible that some clients may stay at the same level of physiological arousal during both IR phases or experience no decrease during the rescripting phase, which may lead them to abort the IR, resulting in less symptom change. One way of investigating these different change patterns is to calculate individual slopes. A crucial advantage of this method compared to others (e.g., using maximal levels of arousal or analyzing arousal immediately before rescripting begins as a measure of hot spot activation at this point) is that it takes the individual length of IR, as well as the differing lengths of the evoking and rescripting phases into consideration. Calculating a slope across all available measurement times ensures that no information is lost and generates the most accurate change index possible.

The present study attempts to extend the existing literature tying physiological patterns to outcome in several ways. First, no study to date has investigated the changes in physiological arousal over the course of IR. Doing so will help us in identifying processes that may improve IR's effects, for example by emphasizing the importance of helping the client imagine the scene more vividly. Second, this is the first study examining these changes over the course of multiple IR sessions. Doing so enables us to investigate the degree to which these signatures characterize different clients and provides information on underlying processes.

With these aims in mind, the following hypotheses guided our work:

Hypothesis 1. HR change. Based on previous studies on imagery exposure (e.g., Gramlich et al., 2021), we expect client's mean HR to change during imagery rescripting. Based on theoretical ideas assuming a conceptualization of all aversive elements within the evoking phase (Brewin et al., 2010) and processing as well as emotion regulation during the rescripting phase (Arntz and Weertman, 1999), we specifically expect that HR will increase during the evoking phase and decrease during the rescripting phase. To test this, HR change is modeled as slopes over 30 s segments for both the evoking and rescripting phases.

Hypothesis 2. Patterns of HR change. Based on differences in processing and emotion regulation strategies and their associations with HR responses (e.g., Alado et al., 2014; Griffin & Howard, 2022), we expect clients to show differing HR patterns. Specifically, we expect to find subgroups of clients showing increased, decreased or unchanged HR during both the evoking and rescripting phases. Latent class analysis was carried out to identify patterns of HR change based on the two slopes generated across the evoking and rescripting phases.

Hypothesis 3. Predictive power of HR change. Drawing on the considerations of different HR change patterns (Hypothesis 2) and the association found between HR and outcome during imagery exposure

(Halligan et al., 2006), we expect an increase in HR during the evoking phase as well as a decrease in HR during the rescripting phase to be associated with better next-session outcomes, such as lower test anxiety and greater wellbeing. To investigate this, we computed two hierarchical linear models (HLMs) in which the HR slopes of the evoking and rescripting phases predicted test anxiety and wellbeing, respectively.

2. Methods

2.1. Study overview

The data were obtained from treatments carried out between 2017 and 2024 at a university outpatient clinic in southwest Germany. The treatments were phase of an open-trial study examining the effectiveness and underlying mechanisms of IR in a sample of students with test anxiety (Prinz et al., 2016, 2019). In this trial, clients were treated with a six-session protocol that combined imagery-based, as well as cognitive-oriented techniques. Sessions 3 and 4 of the protocol apply traditional IR on past test situations. For the purpose of this study, we used the HR data from these two sessions to investigate IR's physiological signature. A more detailed description of the IR method will be provided below. After the intake interview, but prior to the first session, each client was given a study information sheet and asked to provide written informed consent. They were briefed on the general objectives of the study, specifically focusing on testing an innovative treatment protocol utilizing IR for addressing test anxiety. However, they were not informed about the specific hypotheses of the present study. All clients were informed that the sessions would be videotaped, and their HR would be monitored throughout. Additionally, they were assured that participation was voluntary and they could withdraw from the study at any point without facing any negative repercussions. Participation incurred no expenses. This study was approved by the local research ethics committee.

2.2. Clients and therapists

Students were recruited for the study using flyers and a campus newsletter, both advertised for students with test anxiety in general. For inclusion, clients had to meet the following criteria: (1) show a Test Anxiety Inventory (TAI; Spielberg, 1980) score higher than 54 (one standard deviation above the average TAI score); (2) report no imminent risk for suicide; and (3) not currently be in any other form of psychological treatment targeting test anxiety. Of the initial 111 potential participants, 10 had a TAI score lower than 54 and were thus excluded from participation. Fourteen dropped out of study before treatment (most often because of scheduling difficulties), 6 after the first session, 4 after the second session, 1 after the third session, and 2 after the fourth session. If a dropout occurred after session 3, the data were not excluded from the present analyses. Of these 74 clients, no HR data was available for session 3 or 4 for ten clients due to technical problems. Thus, the present analysis is based on data of 64 clients.

The 64 clients were 19–57 years old, with an average of 25.0 years ($SD = 5.79$). The majority ($n = 54$; 84.4 %) was female. Clients differed in terms of the subjects of their university studies, with psychology, law, business studies, and computer science being the most frequent ones. The durations of their studies ranged from 1 to 16 years, with an average of 5.25 years ($SD = 4.09$). This non-clinical sample exhibited elevated test-anxiety scores, however, there were no reports of medication affecting the autonomic system. For more information see Table 1.

The 29 therapists in this study had different educational levels. Five were psychotherapy trainees with at least two years of clinical experience, one of whom completed their psychotherapy license during the course of the study, while the remaining 24 were masters' students in clinical psychology, with no prior clinical experience. The majority ($n = 23$; 79.3 %) was female. Clients were assigned randomly to their therapists. Each therapist treated between 1 and 6 clients ($M = 2.06$, $SD =$

Table 1

Sample characteristics: Demographic and clinical variables.

Variables	Mean	Range
age (in years)	25.0	19–57
academic year	5.25	1–16
	n	%
Sex		
female	54	84.4
male	10	15.6
Degree being pursued		
bachelor	43	67.2
master	10	15.6
other	11	17.2
Marital status		
Single	47	73.4
In relationship	14	21.9
married	2	3.1
divorced	1	1.6
Land of Birth		
Germany	59	92.2
Ecuador	1	1.6
Kazakhstan	1	1.6
Luxembourg	1	1.6
Austria	1	1.6
Belarus	1	1.6
Religion		
Roman Catholic	37	57.8
Protestant	15	23.4
Other	1	1.6
None	11	17.2

1.13). All therapists received extensive training in applying the six-session protocol. The training included reading and discussing the protocol, watching sample videos of experienced clinicians conducting IR with both actors and real clients suffering from test anxiety, and practicing each of the six sessions in role plays. Furthermore, therapists attended weekly group supervision throughout the entire treatment period. During group supervision, the recorded videos were viewed in part or in full, with a focus on IR. Training and supervision were delivered by one experienced clinical psychologist, with an expertise in conducting IR as well as the treatment protocol.

2.3. Treatment model and imagery rescripting

The content and tasks of all six sessions were detailed in the protocol (see Prinz et al., 2019). Imagery work was a phase of every session, alongside cognitively-oriented techniques (i.e., learning and test-taking skills). The imagery work within each session differed somewhat (session 1: safe-place imagery; session 2: imagery assessment; sessions 3–4: imagery with retrospective rescripting; sessions 5–6: imagery with prospective rescripting). At the beginning of each session, a 2-min baseline measurement was carried out during which the client was asked to visualize their safe place. For the present study, data from sessions 3 and 4 were included in the analysis, as these sessions included traditional IR. IR had an average length of 28.89 min ($SD = 9.6$), with the evoking phase lasting 13.28 min ($SD = 6.7$) and the rescripting phase 15.61 min ($SD = 8.1$). The IR used in session 3 and 4 is described in more detail below.

Prior to each IR, therapists provided a brief introduction to the specific technique to be used; these introductions were kept deliberately short to avoid possible demand effects. Clients were then invited to close their eyes; therapists also closed their eyes the majority of the time, or turned their chairs sideways so as to make the experience more private for the clients. Clients were asked to describe experiences as if they are happening in the here and now (i.e., in first person, present tense language).

During the evoking phase, the client was asked to enter a situation

which was related to their test anxiety in their imagination (e.g. an aversive memory from the past) and to describe it in detail. Therapist typically asked clients to note their sensory perceptions. The client was then asked to focus on themselves and report their emotions, physical sensations, behaviors (or behavioral tendencies) and cognitions. Once these were clearly identified, the client was asked to take an observer's perspective to find out what they would have needed (or will need) in this particular situation.

During the rescripting phase, the client was asked to re-enter the situation in their imagination as their healthy adult selves and to do whatever was necessary to satisfy the needs of their younger (vulnerable) self. If the client had difficulties performing the required action as the healthy adult, the therapist could ask the client for permission to offer help. Such help (provided if the client agreed) could involve suggesting possible actions or entering the scene to directly help the client's vulnerable self. A third person, real or fictitious, could also be brought in to help. This was left up to the client to decide which person or people (e.g., a good friend or encouraging grandparent) they found helpful. The rescripting continued until the needs of the vulnerable self were completely or at least partially met. Please refer for a case example to the supplemental materials.

2.4. Measures

2.4.1. State test anxiety, evaluation apprehension, and Efficacy Measure

The State Test Anxiety, Evaluation Apprehension, and Efficacy Measure (Lawrence & Williams, 2013) is a 6-item self-report measure and was designed to assess students' test anxiety, evaluation apprehension, and efficacy and was completed by the client before each session. For the purpose of this study, we investigated the state test anxiety (STATE-TA) measure, which consists of two items: I feel anxious about taking this test; I feel distressed and uneasy about taking this test. The items are answered on a 7-point Likert scale ranging from 0 (*strongly disagree*) to 6 (*strongly agree*). The two items were aggregated to create a total score. Internal consistency was high in our sample ($\alpha = .86$).

2.4.2. Outcome Rating Scale

The Outcome Rating Scale (ORS; Miller & Duncan, 2000) is a four-item visual analogue scale, measuring four dimensions: (a) overall, (b) individually, (c) interpersonal, and (d) socially. All four items can be aggregated into a total score. The ORS was developed as a brief alternative to the Outcome Questionnaire 45 (Lambert et al., 2004). In this study, the ORS was assessed before each session. Internal consistency was high in our sample ($\alpha = .89$).

2.5. Heart rate

ECG was recorded with ECG Module (Necker Meditec Karlsruhe, Germany) with a gain of 1230 and sampled also with USB-6002 at 500 Hz and 16-Bit resolution and stored as an ASCII file. The ECG was computed by analyzing the electrical currents detected by three Ag/AgCl electrodes; two placed on the right and left side of the torso (between last rib and pelvic bone) and one placed on the right collar bone (clavicle). HR data was derived by Kubios HRV premium software (Tarvainen et al., 2014). The software automatically performs QRS-complex peak determination. A visual inspection and manual editing of the data was completed by four graduate students and one postgraduate clinician to ensure proper removal of artifacts and ectopic beats. All editors participated in a training course and sessions were randomly assigned to the editors. HR data was averaged into 30-s segments. An estimated 20 % of the data had to be processed manually. No segments had to be excluded due to severe artifacts.

One hundred and eight sessions (out of $64 \times 2 = 128$) were available. Due to technical problems, 20 sessions were not recorded or available for analysis.

2.6. Analysis

Assessing clients' HR change rate. The HR data have a hierarchical two-level structure, with segments nested within clients. We calculated each client's mean HR change rate (i.e., the client-specific slope) for each session's evoking and rescripting phases. The slope of the evocation phase was calculated from the start of the IR until an observer was introduced or the situation changed. Accordingly, the slope of the rescripting phase was calculated from the end of the evocation phase until the end of the IR.

We modeled each client's HR as a function of the sample's intercept (y_{00}), as well as segment number (y_{01}), a Level 2 random effect (u_{0c} = representing between-client variability), and a Level 1 random effect (r_{cs} = representing between-segment variability):

$$\text{Heart Rate}_{sc} = y_{00} + y_{01} * \text{Segment Number} + u_{0c} + r_{sc}$$

This analysis was conducted twice for each session: once for client's HR during the evoking phase and once for clients' HR during the rescripting phase.

Assessing subgroups in HR change. Latent class analysis, carried out with the R package mclust (Scrucca et al., 2016), was used to identify patterns of change in HR. We used two variables to generate a change pattern: the slopes of the evoking and the rescripting phase. We started with a one-class solution and successively added one more class into each subsequent run. First, we chose the best model based on the criteria-based indices (Bayesian information criterion [BIC], the integrated completed likelihood [ICL]). Second, we tested the best k-class solution (based on criteria-based indices) to a model with k+1-classes using bootstrapped likelihood ratio test (BLRT). Third, we visually inspected the sample proportions for each class and rejected a best-fit solution if the smallest class contained fewer than 10 % of the total observations. For a similar approach see Fisher and Bosley (2020).

Assessing the association between HR changes in evoking phase, rescripting phase and next-session outcome. To test the association between clients' HR change during the evoking phase, rescripting phase, and next-session outcome we used an additional 2-level hierarchical linear model (HLM) with sessions nested within clients. In the first of these models, next-session STATE-TA $c(s+1)$ (i.e., the STATE-TA score in session s for client c) was modeled as a function of both the client's HR change rate during the evoking phase, the clients' HR change rate during the rescripting phase, as well as the STATE-TA score of the current session:

$$\begin{aligned} \text{STATE} - \text{TA}_{c(s+1)} = & y_{00} + y_{10} * \text{HR change evoking phase}_{cs} \\ & + y_{20} * \text{HR change evoking phase}_{cs} \\ & + y_{20} * \text{STATE} - \text{TA}_{cs} \\ & + u_{0c} + r_{sc} \end{aligned}$$

In the second model, the ORS served as outcome; in all other respects, this model was identical to the first model.

3. Results

3.1. Clients' mean change in heart rate

Clients' mean HR, standard deviation and value ranges for each session and phase (evoking and rescripting) are provided in Table 2.

Table 2

Clients' Mean Heart Rate, Standard Deviation and Value Ranges for each Session and Phase.

	Evoking Phase	Rescripting Phase
Session 3	$M = 82.22$ ($SD = 13.12$) Range: 52.97–138.37	$M = 81.49$ ($SD = 11.28$) Range: 52.60–123.47
Session 4	$M = 85.76$ ($SD = 12.57$) Range: 52.90–133.13	$M = 82.30$ ($SD = 10.68$) Range: 50.64–113.60

Table 3
Clients' mean slopes in heart rate over the course of treatment.

	Evoking Phase	Rescripting Phase	<i>t</i>	<i>p</i>
Session 3	<i>M</i> = .13 (<i>SD</i> = .29)	<i>M</i> = −.08 (<i>SD</i> = .10)	3.96	<.001
Session 4	<i>M</i> = −.01 (<i>SD</i> = .13)	<i>M</i> = −.10 (<i>SD</i> = .11)	4.24	<.001

Table 3 shows clients' individual change rates (slope ranges) as well as mean change rates for each session and phase (evoking versus rescripting). The average HR change rates of the evoking phase were significantly higher in session 3 compared to session 4 ($F = 10.44$, $p = .001$), no difference was found between the average change rates in the rescripting phases of the two sessions ($F = 1.937$, $p = .167$). In each session, the change rates differed significantly between the evoking phase and the rescripting phase. In session 3, the mean change rates for the evoking phase, ranged from $-.32$ to 1.13 ($M = .15$, $SD = .28$). The means change rates for rescripting phase ranged from $-.38$ to $.16$ ($M = -.10$, $SD = .11$). See supplemental materials for example subjects of changes in HR during IR in session 3.

3.2. Patterns of heart rate change

Table 4 shows the model fit indices. The increase in BIC and ICL from the one-to the two-class solution, indicates that the one-class solution is superior. In contrast, the BLRT of comparing the one-with the two-class solution was significant ($p = .001$), supporting the two-class solution. In the two-class solution, Class 2 had solely 3 members (4.69 %). Therefore, the two-class solution had to be rejected.

3.3. Estimating the association between change rate and next-session outcome

Because no subgroups in heart rate change were found, we estimated the association between change rate and next-session outcome. The results from the HLM analyses showed that solely the evoking phase change rate was marginally to significantly associated with both next-session STA_TA ($b = -.83$. CI $[-1.64$ to $-.02$, $p = .04$) and ORS ($b = 5.37$, CI $[-.43$ – 11.18] $p = .07$). Table 5 presents all results.

4. Discussion

The present study aimed to investigate the physiological signature of IR. To our knowledge, this is the first study examining changes in HR over the course of different phases in IR, and also the first to explore whether such HR changes are predictive of treatment outcomes. In their first IR session, clients showed, on average, an increase in HR during the evoking phase and a decrease during the rescripting phase. No different patterns of HR change for client subgroups could be found. However, changes in HR during the evoking phase were the sole predictor of both next-session outcomes. Below, we discuss the results related to each of the hypotheses in greater detail.

Our results support the first hypothesis that HR would increase during the evoking phase and decline during the rescripting phase. This finding is in line with the theoretical structure of IR, in which the evoking phase is used to explore all aversive content, which is invariably

Table 4
Bayesian Information Criterion, Integrated Completed Likelihood, and p Values in Bootstrapped Likelihood Ratio Test for up to three latent classes.

Number of classes	BIC	ICL	BLRT <i>p</i> value
1	79.38	79.38	
2	96.17	95.49	.001
3	82.13	78.01	.987

Note. BIC = Bayesian information criterion; ICL = integrated completed likelihood; BLRT = bootstrapped likelihood ratio test.

Table 5
Next-Session Outcome in STA-TA and ORS predicted by the HR Slopes during the Evoking Phase and the Rescripting Phase.

	STATE-TA	<i>p</i>	ORS	<i>p</i>
	<i>b</i> [95 % CI]		<i>b</i> [95 % CI]	
Intercept	4.35 [4.10–4.60]	<.001	26.03 [24.43–27.63]	<.001
Client's pre-session value	−.38 [−.59 to −.17]	.001	−.12 [−.34 – .09]	.256
HR slope during evoking phase	−.83 [−1.64 to −.02]	.044	5.37 [−.43 – 11.18]	.069
HR slope during rescripting phase	−.09 [−1.61 – 1.43]	.902	7.45 [−4.15 – 19.04]	.206

Note. STATE-TA = State Test Anxiety, Evaluation Apprehension, and Efficacy Measure, ORS = Outcome rating Scale, HR = Heart rate.

likely increase arousal, so that the hot spot (i.e., moment of greatest emotional impact) can subsequently be rescripted (Brewin et al., 2010; Hackmann et al., 2011; Uhl, 2025). Satisfying the emotional needs (at least in part) during the rescripting phase leads to reduced affect, which is physiologically reflected by a reduced heart rate (Uhl, 2025). This physiological signature was observed in both consecutive sessions, but the increase during the evoking phase was greatest in the first IR session. One possible explanation might be a modification of the fear network. Foa and Kozak (1986) postulate that an evoking of autobiographical memories and their associated affects (in IR during the evoking phase) in combination with the integration of corrective information (in IR during the rescripting phase) leads to an update of the fear network followed by a reduction in distress (Foa & Kozak, 1986; Smucker et al., 1995). The modification in the fear network may result in less arousal during the evoking phase in subsequent sessions compared to the first session. Indeed, if the increase during the evoking phase is not strong enough, there cannot be a strong decrease during the rescripting phase. Even though the same autobiographical memory is not necessarily rescripted every session, emotional memories are linked in a network (e.g., Catani et al., 2013) and similar to evoking therapy (e.g., Preusser et al., 2017) processing one event leads to (at least partial) processing of another untreated event. This is consistent with findings by Rameckers and colleagues (2024), the authors showed that the vividness as well as the distress of a traumatic event decreases as response to IR.

Our second hypothesis - namely, that clients could be categorized into different subgroups in terms of their HR changes during IR - was not supported; indeed, we were not able to identify subgroups which could be used to predict next-session outcomes. This was surprising as we had expected clients to vary considerably in their emotional processing and their physiological level within IR. For example, Uhl and colleagues (2024) showed in their study on emotion dynamics of clients with test anxiety, that the pre-treatment as well as post-treatment emotion dynamics differed between responders and non-responders. Even though physiological arousal may reflect only some aspects of emotion dynamics, we assumed that clients do not show the same physiological patterns. One possible methodological explanation might be lower-than-expected variance in the physiological patterns. The slopes showed little variance overall, somewhat more for the evoking phase ($SD = .29$) than for the rescripting phase ($SD = .10$). Clients in both phases did not differ enough from each other to identify different subgroups. They seem to differ primarily during the evoking phase.

This leads to the third hypothesis, namely that an increase in HR during the evoking phase as well as a decrease in HR during the rescripting phase would be associated with next-session outcomes. In partial support of this hypothesis, increased HR during the evoking phase - but not decreased HR during the rescripting phase - was associated with lower next-session test anxiety and higher next-session wellbeing. In regard to the aforementioned low variances, especially in the rescripting phase, this result is not surprising. The majority of clients (apart from outliers) showed lower arousal during rescripting

phase. The effectiveness of IR may be due (at least in part) to the fact that imagery evokes more emotions than a normal conversation (Holmes et al., 2007) and activates similar brain regions as real experiences (Holmes & Mathews, 2010). It is this rational, which allows successful rescripting. Clinically, this means that during the evoking phase, the therapist should support the client (if they are unable to do so themselves) in generating a comprehensive image of the event and increase the emotional arousal.

The finding that the association between physiological arousal during the evoking phase was stronger for next-session test anxiety compared to next-session wellbeing is surprising at a first glance. One would expect a decrease in test anxiety to be accompanied by an increase in well-being. In reality, there is a significant but only moderately negative correlation between the two variables ($r = -.35, p < .001$). A reduction in test anxiety may have an impact on the global well-being, but it does not necessarily mean that well-being increases to the same amount. It is unclear to what extent there is exclusively a decrease in negative emotions (e.g. fear) or whether alternative, positive emotions (e.g. hope) are created (Prinz et al., 2022). While test anxiety is very specific and targeted by the treatment protocol, well-being is more complex construct characterized by several different aspects.

4.1. Strengths, limitations and future directions

The present study is novel in several aspects. To our knowledge, it is the first study to examine the physiological signature of IR. Its use of continuously-collected HR data over the course of two sessions per client is an additional strength. It is also one of the first consider the specific tasks that, together, make up IR.

These strengths notwithstanding, several limitations of the present study are noteworthy. The results are based on a relatively homogeneous sample, which consists of students suffering from test anxiety. As such, the study's conclusions may not be easy to generalize to other populations. To address this, future studies with more diverse samples are required.

Furthermore, we wanted our clients to experience rescripting of aversive autobiographical memories, as these directly address their negative emotional beliefs. Notably, the memories retrieved here were rarely traumatic ones, and as such, may not have been distressing enough to evoke a strong physiological reaction. Since IR, though used extensively in treating trauma (e.g., Arntz et al., 2013; Hackmann, 2011), is actually suitable for a wide range of aversive experiences; thus, this is only a minor limitation. However, it would be interesting for future studies to see how the physiological signature changes within IR for traumatic experiences; in particular, we may expect and even stronger increase in the evoking phase and then a stronger decrease in the rescripting phase would be expected.

A further limitation concerns the variation in clients' exams. In a screening interview, all clients confirmed taking an exam and the study was designed with client's semester schedules in mind. This means that the examination period started a few weeks after the last sessions. However, clients varied in their total number of exams as well as in their specific dates. We prioritized having a uniform time period elapse between treatment and follow-ups and do not have a sufficiently large data set to control for the period between treatment and exam. This is a limitation of the present study, as we do not know exactly how these time intervals affected test anxiety in the sessions. In a study by Prinz et al. (2019), which examined the treatment's effectiveness, a multiple-baseline open trial design was implemented to control for test anxiety. Test anxiety might be strongly time-related and increase as exams near. However, the results suggested less of an influence of treatment timing than of the effectiveness of the treatment. Future studies could avert this problem by enrolling only participants who share a fixed academic schedule.

Though the current study focused on sympathetic and parasympathetic influences (assessed using the HR index) on emotional

regulation, future work could benefit from collecting Galvanic Skin Response data. This measure solely examines sympathetic arousal, targeting client emotional activation during IR. In this context, additional client anxiety ratings could serve as a control for emotional reactions.

5. Conclusion

The present study contributes to the expanding body of research aiming to examine the working mechanisms of IR. Our findings highlight the necessity of exploring the physiological processes involved during IR to gain a deeper understanding of its underlying mechanisms of action. This knowledge could facilitate the development of strategies to enhance the efficacy of IR in therapy. The present study provides preliminary evidence that physiological arousal increases during the evoking phase, that it decreases during the rescripting phase, and that the extent of the change during the evoking phase is related to therapeutic change.

CRedit authorship contribution statement

Jessica Uhl: Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Wolfgang Lutz:** Writing – review & editing, Supervision, Funding acquisition. **Eshkol Rafaeli:** Writing – review & editing, Supervision, Methodology, Conceptualization.

Funding

This work was supported by the German Research Foundation (DFG) under the project number 660/19-1.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Wolfgang Lutz reports financial support was provided by German Research Foundation. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.brat.2025.104879>.

Data availability

Data will be made available on request.

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