Towards VAD-Based Emotional Reasoning in the Goal-Oriented Requirements Language

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***Abstract*—Goal-oriented modeling plays a central role in requirements engineering, serving as the primary mechanism for capturing and reasoning about functional and non-functional requirements. However, mainstream goal-modeling languages, including the Goal-oriented Requirements Language (GRL), provide limited support for emotional requirements, that is, the affective states that stakeholders experience when interacting with a system and the emotional outcomes that a system is designed to evoke. This gap is consequential because unaddressed emotional requirements can lead to stakeholder dissatisfaction, adoption failures, and ethically inadequate system behavior, particularly in socio-technical domains such as healthcare, education, and crisis response. To address this gap, this study presents the Emotion-Oriented Requirements Engineering (EmORE) framework, a VAD-based emotional reasoning extension for GRL that supports emotional requirements as quantifiable constructs within GRL models. EmORE integrates the Valence–Arousal–Dominance psychological model into GRL to quantify emotional states and provides dedicated visual notations and Valence-based visualization mechanisms designed in accordance with the Physics of Notation (PoN) framework and PRISE extension guidelines. To support the elicitation of emotional requirements, EmORE includes a structured emotional elicitation and mapping workflow that enables stakeholders' emotional feedback to be systematically collected, quantified, and mapped to relevant goal-model elements. To demonstrate the applicability of EmORE and the valuable insights that emotion-related information provides, a case study of a university learning management system was conducted.**

***Index Terms*—Emotion-Oriented Requirements, Goal-oriented Requirements Language, Requirements Engineering, Non-functional requirements, Human-centric RE, Physics of Notation, VAD Model, Socio-technical Systems**

I. Introduction

In recent years, requirements engineering (RE) has increasingly emphasized the role of human-centric factors across different RE lifecycle stages [1]. During the modeling stage, goal modeling provides a useful means of representing stakeholders' intentions and the relationships among functional and non-functional requirements. As goal modeling captures diverse stakeholder intentions, it provides a natural foundation for representing emotional requirements. Therefore, integrating emotional requirements into goal models has considerable potential to provide a new perspective on requirements analysis and prioritization. This is especially important in the design and development of socio-technical systems, where emotion-aware goal models can be used to demonstrate and assess human emotional and cognitive needs, thereby improving overall stakeholder satisfaction [1], [2].

Several studies in the goal modeling domain have highlighted the potential of incorporating emotions and other human-centric aspects into existing goal models. In parallel, methodological guidelines, such as the iStar Extensions (PRISE) guidelines, have been proposed to support the systematic design of human-centric modeling-language extensions [3]. However, existing studies exploring the integration of emotions into goal modeling remain in their early stages. Mainstream goal-modeling frameworks provide limited support for emotion-oriented goals. In contrast, emotion-centric modeling approaches, such as the People-Oriented Software Engineering model [4], primarily focus on emotions; however, their practical adoption in established RE modeling workflows remains limited. These approaches provide valuable insights into emotional goals but lack integration with mainstream RE notations and do not support quantitative reasoning or traceability, limiting their applicability in model-driven workflows.

From a model-driven perspective, extending GRL with quantifiable emotional constructs enables reasoning and traceability between emotional and functional goals. In the context of the goal language considered in our study, the Goal-oriented Requirements Language (GRL) [5], [6], currently lacks constructs, link types, or visual mechanisms for representing emotional states, as it was originally designed to capture functional and non-functional requirements rather than affective experiences. To address this gap, we propose EmORE, a Valence–Arousal–Dominance (VAD)-based emotional reasoning extension for GRL. The proposed emotion-related constructs and visual mechanisms are designed to adhere to the nine core principles of the Physics of Notation (PoN) framework [7] and align with the design principles of GRL, enabling seamless integration with existing elements. Existing emotion-elicitation methods, which are typically based on conventional psychological self-report scales, are difficult to integrate into goal-modeling workflows. Therefore, EmORE provides a structured elicitation and mapping process designed for direct integration with GRL models. Compared with iStar, GRL provides explicit constructs for contribution reasoning and quantitative analysis, making it a suitable foundation for

VAD-based emotional reasoning.

In summary, this study contributes (i) a VAD-based emotional reasoning mechanism for GRL, (ii) new visual notations and Valence-based visualization designed according to PoN and PRISE, and (iii) a structured emotional elicitation and mapping workflow. The remainder of this paper is organized as follows: Section II presents a motivating example. Section III discusses the background and related work on emotion-related goal modeling. Section IV introduces the design and application of EmORE. Section V presents the evaluation results. Section VI discusses the implications and limitations of the proposed approach. Finally, Section VII concludes the study.

II. Motivation example

To illustrate the gap that the EmORE framework aims to address, consider an online learning system designed to support students in completing their courses. In a standard RE process, the primary goal of this system is to support effective course management and communication. To operationalize this goal, an analyst would typically decompose it into system-oriented sub-goals: provide grading tools, provide holiday notification functionality, and ensure that user accounts are secure. Each sub-goal can be modeled, prioritized, and verified in a conventional GRL diagram.

However, this standard decomposition obscures the critical needs of stakeholders. For example, a course schedule change notification may be functionally delivered to students correctly and successfully; however, if the notification is sent too late or with unclear information, students may experience acute distress, such as anxiety, confusion, and a loss of perceived control. Simultaneously, the instructor may also be emotionally affected by continuously receiving students' requests for clarification or help in resolving scheduling conflicts between different courses, especially when the relevant scheduling information is already stored in the system but is not clearly communicated to instructors or students. These emotional states are not incidental side effects; when they systematically reduce stakeholder Valence or Dominance, they constitute measurable requirement failures that must be elicited, specified, and analyzed. The system has failed to deliver the required emotional outcome, that is, comprehension without distress, even while satisfying every functional and performance requirement it was given.

This failure is also invisible to standard GRL models. Consequently, without additional constructs or reasoning mechanisms, GRL cannot capture how functional behaviors propagate emotional impacts across stakeholders. The nature of the emotional harm (i.e., increased anxiety, confusion, and loss of perceived control) and the emotional goal that the system should have produced (i.e., a sense of reassurance and control) are not representable in the existing GRL constructs.

This example establishes the core argument of this study: in socio-technical systems where human factors are subject to significant emotional variability, emotional requirements constitute a distinct and essential class of requirements that must be elicited, specified, and analyzed alongside functional and non-functional requirements. The EmORE framework is designed to make this possible in the GRL-based modeling environments.

III. Background and Related Work

A. Emotion-Oriented and Human-Centric Requirements Engineering

Human-centric RE has increasingly emphasized that requirements models should capture not only functional needs but also human experiences, values, and affective responses associated with system use [1]. Within this broader direction, emotional requirements have attracted growing attention as researchers recognize that stakeholder emotions can influence system acceptance, trust, satisfaction, and long-term use.

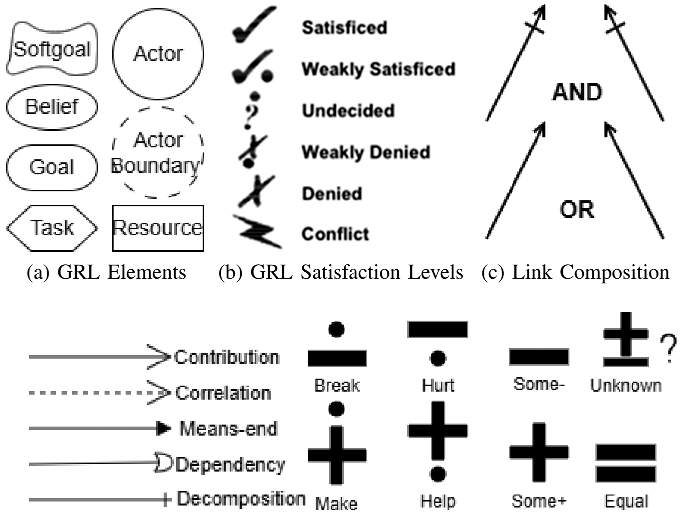
A recent systematic mapping study by Iqbal et al. [8] showed that emotion-related requirements have been investigated across different domains, elicitation instruments, and representation artifacts. This confirms that emotional requirements are an emerging topic in RE. Iqbal et al. [9] further grounded emotion-aware RE in the theory of constructed emotion through an industrial case study, showing that emotion theories can support the elicitation and validation of emotion-aware systems. These studies provide important evidence that emotions should be considered in RE. However, they do not primarily address how emotional states can be integrated into goal-model reasoning as measurable and traceable modeling information.

Beyond RE, affective computing and human-computer interaction (HCI) have long studied the role of emotion, experience, and well-being in human interactions with technology [10]–[12]. However, they typically focus on interaction design, affect recognition, user experience evaluation, or well-being-oriented design, while the systematic integration of emotional states into requirements models remains insufficiently addressed in the literature.

B. Emotion-Oriented and Human-Centric Goal Modeling

Prior work on motivational modeling and emotion-oriented requirements has established that emotions can be treated as meaningful concerns in goal-oriented analysis. Miller et al. [4] made an early contribution by extending Sterling and Taveter's motivational modeling framework [13] to incorporate personal and context-specific emotional goals, which they termed People-Oriented Software Engineering (POSE). POSE primarily targets the modeling of emotionally meaningful experiences and personal motivation. Meanwhile, Singh et al. [1] extended iStar 2.0 to model the human-centric aspects of end users, including emotions, personality, culture, language, and impairments, following the PRISE [3] guidelines. Their work demonstrates how goal-modeling languages can be systematically extended with human-centric information. EmORE builds on these methodological directions but differs in both its host language and analytical focus: it extends GRL and focuses specifically on VAD-based emotional reasoning.

Our selected host language, GRL, as part of the User Requirements Notation (URN) [14], provides a goal-oriented



(a) GRL Elements (b) GRL Satisfaction Levels (c) Link Composition

(d) GRL Links (e) GRL Contribution Types

Fig. 1. GRL basic elements.

modeling framework for representing intentional elements, stakeholder actors, and contribution relationships among functional(FRs) and non-functional requirements (NFRs). GRL builds on earlier goal-oriented modeling traditions, including iStar and the NFR framework, and has been standardized as part of URN to support goal-oriented requirements modeling and reasoning [6]. In this study, the GRL was chosen because it supports contribution-based reasoning and quantitative evaluation of alternative design decisions, making it a suitable host language for integrating measurable emotional information into requirements models. GRL is composed of intentional elements, such as goals, tasks, softgoals, beliefs, and resources; intentional relationships, such as means-end, decomposition, contribution, correlation, and dependency links; and actors. Fig. 1 shows the established elements, relationships, and graphical notations used in GRL [6].

GRL was selected because its contribution-based reasoning and quantitative evaluation mechanisms are well aligned with the goals of EmORE. This alignment supports the aim of EmORE: not only representing emotional concerns but also reasoning about how system elements contribute to desired or undesired emotional states. However, standard GRL does not provide dedicated constructs for representing emotional states, emotional goals, or the measurable gap between current and desired emotional experiences.

Existing emotion-oriented GRL extensions provide useful initial evidence that GRL can host emotional concepts. For example, Alkhomsan et al. [15] proposed extending GRL with emotion-oriented concepts using think-aloud protocols and a visualization strategy that introduces emotions as an additional actor. Their study is important because it demonstrates the feasibility of incorporating emotional concerns into GRL. However, EmORE has a different modeling objective from prior emotion-oriented goal-modeling approaches. Rather than representing emotions as a separate actor, EmORE aims to integrate emotional feedback directly into standard GRL model elements through VAD-based quantification, dedicated emotional notations, and traceable links between system elements and desired emotional goals. Our design treats GRL not merely as a visual notation but as a reasoning-oriented host language into which emotional states can be integrated as quantifiable and traceable modeling information.

C. VAD as a Requirements-Compatible Emotion Model

A central design decision in emotion-oriented requirements modeling is how emotional states should be represented in model-based analysis. Discrete emotion labels such as *"frustrated"* or *"anxious"* are useful for communicating stakeholder experiences, but they are difficult to compare, aggregate, or reason about systematically across model elements. Dimensional emotion models address this limitation by representing affective states in measurable dimensions. EmORE adopts the VAD model, in which *Valence* captures pleasantness, *Arousal* captures activation, and *Dominance* captures perceived control and agency [16]–[18].

VAD is suitable for EmORE because it supports the measurable representation of emotional states, comparisons between current and desired emotional states, and traceable mapping to GRL model elements. Existing elicitation instruments and methods, such as the Self-Assessment Manikin (SAM) [19], Positive and Negative Affect Schedule (PANAS-SF) [20], interviews, and think-aloud protocols, provide useful ways to collect affective information from users, but they are not directly designed for integration with goal-modeling workflows or contribution-based reasoning. Thus, EmORE uses VAD as a modeling bridge between stakeholders' emotional feedback and GRL-based requirements analysis, combining scenario-based elicitation, quantifiable VAD representation, GRL-compatible emotional notations, and traceable analysis of the relationship between system elements and desired emotional states.

Although the EmORE questionnaire is not a standardized psychological diagnostic instrument, it is grounded in dimensional emotion modeling and self-reported affect elicitation. It adopts VAD dimensions and a self-report rating format informed by instruments such as SAM and PANAS-SF [19], [20], and adapts them to RE by asking stakeholders to report emotions for concrete system-related scenarios they have experienced.

IV. Methodology

A. Eliciting and Quantifying Emotional Requirements Using VAD

A core methodological challenge in emotion-oriented RE is how to elicit stakeholders' emotional feedback and quantify it in a structured, analyzable form that can support formal requirements specifications. EmORE addresses this challenge through a scenario-based emotional elicitation and mapping workflow supported by a 5-point Likert-scale questionnaire [21]. The workflow is designed to support the collection of essential emotional feedback through two main components. The first component provides explanatory information about the VAD dimensions, including explanations of the five levels of each dimension and representative emotion words to help participants understand the scale. The second component includes potential system-related pain-point scenarios identified by the questionnaire designer. Participants were first asked whether they had personally experienced the scenario. This step reduced noise in the emotional data by excluding participants who would otherwise provide hypothetical or imagined responses, which may produce higher variance and lower reliability in self-reported affective ratings. They were then asked to provide (i) emotion words that best represented their feelings and (ii) ratings of their feelings across the three VAD dimensions. The emotion words provided by the participants served only as qualitative labels to contextualize their feelings. The quantitative VAD values used in EmORE were obtained directly from the participants' self-reported ratings. Because the questionnaire is intended as a lightweight RE elicitation instrument rather than a psychometric validation scale, redundant or contradictory verification items were not included. Instead, response quality was supported through scenario-experience filtering and completeness checking before aggregation; more systematic consistency checks remain future work. Fig. 2 represents the structured EmORE VAD-based elicitation workflow.

In the normalization stage, raw VAD ratings on the [1, 5] scale are linearly transformed into a [0%, 100%] scale using (1). This aligns emotional values with GRL's percentage-based contribution reasoning and provides a more intuitive representation. To avoid boundary ambiguity, values are classified using half-open intervals: [0%, 20%), [20%, 40%), [40%, 60%), [60%, 80%), and [80%, 100%], where the boundary belongs to the higher interval and 100% belongs to the final interval. When multiple responses are collected for an element, EmORE computes the unweighted mean for each VAD dimension. This simple aggregation keeps the method transparent and captures an aggregate emotional tendency rather than a detailed statistical distribution.

$$x' = \frac{x-1}{4} \times 100\% \tag{1}$$

B. Notation Design: New GRL Elements for Emotional Requirements

The next important methodological step is to integrate this emotional feedback into GRL for visualization. Two new elements and one new link are introduced in EmORE to represent new emotion-related information while minimizing visual complexity. The design of the EmORE extension was guided by PRISE [3] and Moody's PoN framework [7], which support systematic language extension and cognitively effective visual notation design.

In our previous study [2], we proposed extending GRL specifically with emotion-oriented goals, demonstrating that GRL framework is a viable host language for emotional constructs. However, this design reused the existing GRL softgoal notation to represent emotional goals. From a PoN perspective, this introduces a potential semiotic clarity issue because distinct conceptual categories, namely, quality goals and emotional states, are represented using the same visual symbol. The current EmORE design addresses this limitation by introducing dedicated notations for emotional constructs that are visually and semantically distinct from existing GRL elements.

The design of new notations for EmORE followed two methodological constraints simultaneously: (i) the new elements had to be semantically expressive enough to represent the distinct conceptual content of emotional requirements, and (ii) they had to be visually compatible with the existing GRL notation system, which has its own conventions for shapes, lines, and symbols. Therefore, we created a *High-Frequency Emotion* element, which is rendered as a pentagon. The pentagon is unused in GRL and other frequently used modeling notations, such as UML, and provides a distinct geometric outline that avoids visual overlap with existing constructs. As a container for the emotion words most frequently reported by stakeholders for a given goal or task, the unique contour of the pentagon supports perceptual discriminability even in reduced-scale or monochrome renderings. Fig. 3a illustrates the proposed notation for the High-Frequency Emotion element.

The *Emotional Goal* notation is represented as a heart shape, selected for semantic transparency because the heart is widely associated with affective states [7]. An Emotional Goal specifies the intended emotional state that the system should support or evoke for a stakeholder interaction. To clarify the requirement captured by the heart-shaped construct, its label should include the target VAD profile, such as *"V: Very Positive, A: Relaxed, D: High Control."*.This target profile represents the desired emotional outcome from requirements engineering compared with the current aggregated VAD profile collected from stakeholder feedback.

The *EmORE Link* connects system elements (tasks, goals, and softgoals) to emotional goals. It is visually distinguished from existing GRL link types by its heart-shaped arrowhead, a geometric element not employed in any existing GRL link, and annotations for each of the three VAD dimensions, which indicate the current deviation between the element's aggregate emotional state and the target emotional goal. This allows requirements analysts to read a goal diagram and immediately identify both the system elements associated with emotional requirements and the size of the gap between the current VAD level profile and the required one.

The *VAD Intensity Scale* used in the EmORE Link divides each dimension into five equal 20% intervals. We adopted a compact symbolic convention to express current emotional states and desired changes. The base symbol (e.g., V for Valence, A for Arousal, D for Dominance) denotes the system's current aggregate state for that dimension. Deviations from the current state are indicated by plus or minus markers

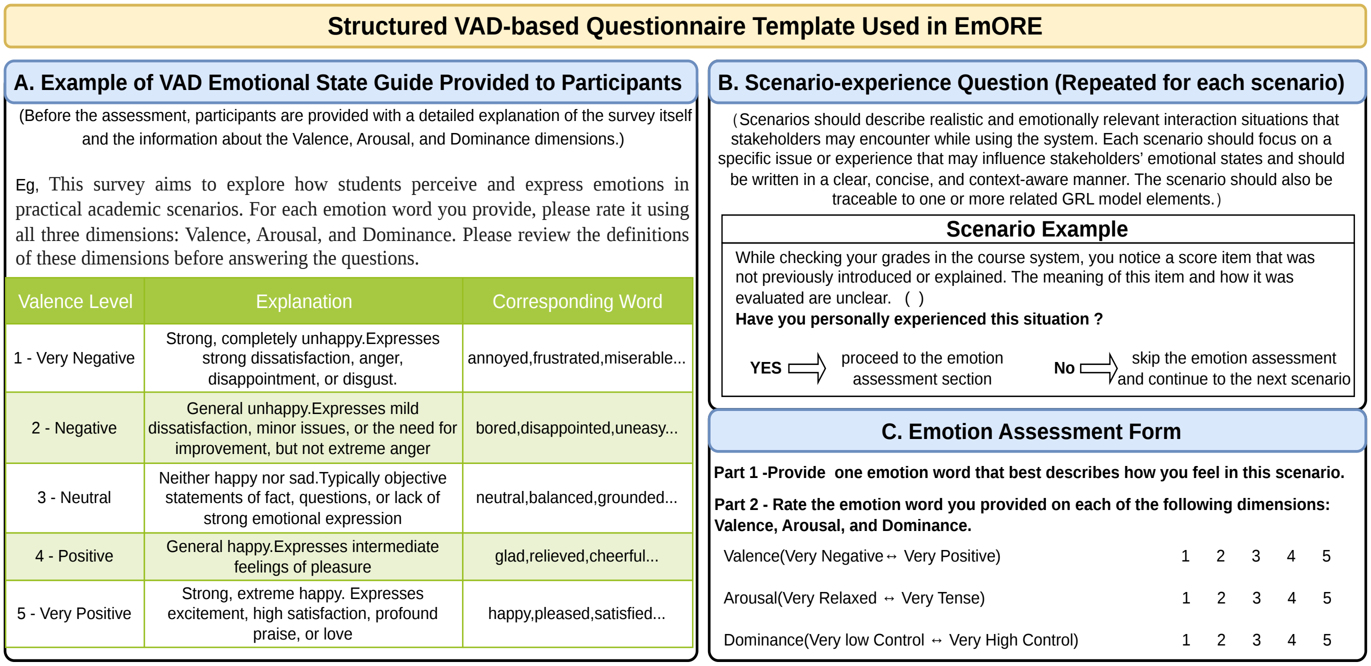
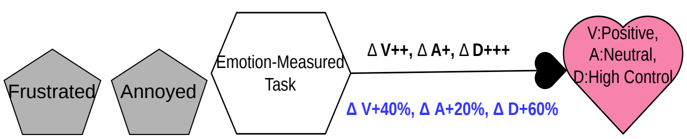


Fig. 2. Structured VAD-based questionnaire template used in EmORE. The Valence guide is shown as an example, while Arousal and Dominance follow the same format. The template includes (i) VAD dimension explanations, (ii) scenario filtering, (iii) emotion-word elicitation, and (iv) VAD ratings, enabling consistent and analyzable emotional feedback collection.



(a) High-Frequency Emotion element. (b) EmORE Link with VAD gap annotations.

Fig. 3. Examples of EmORE emotional notations, including the High-Frequency Emotion element, the Emotional Goal element, and the EmORE Link with VAD deviation annotations. In Fig. 3b, the Δ values represent deviations from the current aggregate emotional state to the target Emotional Goal.

appended to the base symbol: each additional plus (e.g., V+, V++, V+ + +) denotes a progressively stronger desired increase, whereas each additional minus (e.g., V−, V−−, V− − −) denotes a progressively stronger desired decrease. This notation encodes both the direction and magnitude of the desired change in a concise, human-readable form and is mapped to percentage ranges in TABLE I. Moreover, we support other equivalent notations for VAD levels in percentage form. Each symbolic level is mapped to a 20% interval. In diagrams, model users can use either symbolic or percentage-based representation to make both the categorical level and the precise measurement explicit. Fig. 3b illustrates how these new notations are represented and used.

C. Color-Based and Texture-Based Valence Visualization

Beyond the notation system, EmORE provides an independent visualization layer that communicates aggregate Valence through color or texture coding. The ten-shade palette in

TABLE I
VAD PERCENTAGE SCALE

Score	Valence	Arousal	Dominance
1 [0%–20%)	Very negative	Very relaxed	Very low control
2 [20%–40%)	Negative	Relaxed	Low control
3 [40%–60%)	Neutral	Neutral	Balanced control
4 [60%–80%)	Positive	Tense	High control
5 [80%–100%]	Very positive	Very tense	Very high control

Fig. 4 is not a separate elicitation scale, but a finer-grained visualization of normalized Valence values derived from the five-level VAD scale in TABLE I. Each 20% Valence level is divided into two 10% visual subintervals to distinguish lower and higher values within the same semantic level. Only Valence is encoded through the pervasive color/texture channel because it is the most immediately interpretable dimension for positive or negative model triage; Arousal and Dominance are represented through EmORE Link annotations because their desired directions are context-dependent.

To improve accessibility and avoid conflicts with other color encodings, such as GRL satisfaction coloring, EmORE also provides a texture-based alternative. Following Bertin's Semiology of Graphics [22], vertical and horizontal line textures distinguish positive and negative Valence, while line weight and spacing represent intensity. This dual coding preserves information when color cues are unavailable and supports perceptual discriminability and visual redundancy. Fig. 5 shows the texture display for colored notations.

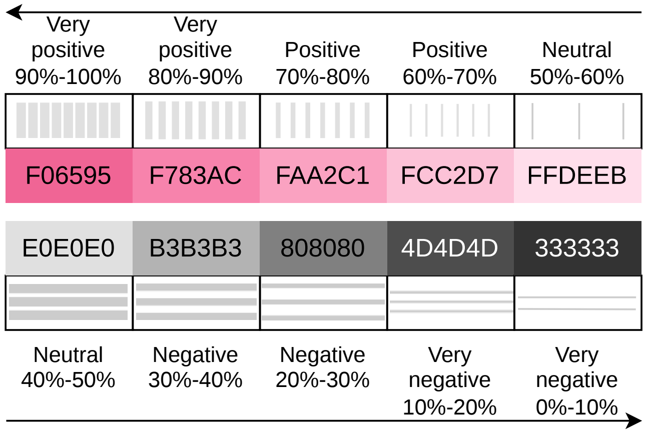


Fig. 4. EmORE color- and texture-based Valence visualization scheme. Pink shades represent positive Valence, gray shades represent negative Valence, and textures provide a color-independent alternative.

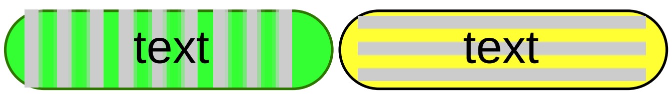


Fig. 5. The Performance of the texture display for colored notations.

V. Evaluation

A. Illustrative Case Study Design

To assess the feasibility and expressiveness of EmORE, we conducted an illustrative case study based on a university online learning management system. The system supports common teaching and learning activities, including sharing course materials, creating assignments, posting grades, submitting coursework, and facilitating communication of course-related information between instructors and students. This domain was selected because online learning systems are socio-technical systems in which functional success does not necessarily imply a positive stakeholder experience.

The purpose of this case study is to demonstrate how the proposed framework can be applied to a realistic requirements modeling context and what additional analytical information it can provide beyond standard GRL. Specifically, the case study evaluates whether EmORE can (i) elicit emotional feedback related to concrete system scenarios, (ii) map this feedback to GRL model elements, (iii) represent emotional information using the proposed notations and visualization mechanisms, and (iv) support preliminary emotional gap analysis for requirements reasoning.

The case study was developed in three main steps. First, one of the authors observed and used both student-facing and instructor-facing functionalities of the learning management system over four months. During this period, potential emotional pain points were identified through ethnographic observation, informal conversations with student users, and the author's direct participation in teaching activities as a teaching assistant. Second, these pain points were translated into scenario-based questionnaire items. Each scenario describes a concrete interaction in which stakeholders may experience emotional responses. Third, each scenario was mapped to one or more relevant GRL model elements. This mapping is necessary because emotional issues may arise not only from a single task or goal, but also from the interaction of multiple elements across different actors. TABLE II summarizes representative scenario abstractions derived from the EmORE VAD questionnaire and their corresponding GRL model mappings.

B. Emotional Feedback Collection and Aggregation

The questionnaire was distributed to students, and 50 valid responses were obtained. The participants included undergraduate, master's, and PhD students from diverse cultural backgrounds. For each scenario, the participants were first asked whether they had personally experienced the described situation. If they had, they were asked to provide an emotion word that best represented their feelings and to rate their emotional responses using the three VAD dimensions.

The collected responses showed that participants may use the same emotion word while assigning different VAD values to it, confirming the need to collect participant-specific ratings rather than relying only on predefined lexical emotion values. Following Section IV-A, mean VAD values were calculated for each scenario, normalized to percentages, and assigned to corresponding GRL elements through the scenario-to-model mapping.

Table III presents representative feedback for two scenarios. Due to space limitations, it lists only the three most frequent emotion labels for each scenario, their mean VAD values, and the overall mean VAD profile across all valid responses. The examples show that combining discrete emotion labels with VAD ratings captures both the measurable emotional profile and the qualitative meaning of stakeholder responses.

C. Application of EmORE to the GRL Model

After the emotional feedback was collected and aggregated, the resulting VAD values were mapped to the corresponding GRL model elements. Fig. 6 shows the EmORE-extended GRL model for the online learning system case study. The model illustrates how emotional feedback can be represented at two levels. First, Valence-based color visualization provides a rapid overview of emotionally positive and negative areas of the model. Second, EmORE Links provide more detailed three-dimensional VAD information by showing how current emotional states differ from desired emotional goals.

The Valence visualization reveals that both *"Provide holiday notification functionality"* and *"Multi-factor authentication"* received negative emotional feedback, but with different intensities. In particular, "Provide holiday notification functionality" received a lower aggregate Valence score ($\bar{V} = 25.89\%$), indicating stronger negative feedback. In a standard GRL model, both tasks may appear as ordinary system functions, whereas EmORE highlights that notification-related functionality is more emotionally problematic and should be prioritized for further investigation.

TABLE II
SCENARIO-BASED VAD QUESTIONNAIRE ITEMS AND THEIR CORRESPONDING GRL MODEL ELEMENTS

ID	**Scenario**	**Mapped GRL Model Elements**
S1	No instructions, guidelines, or supporting information are provided, and the online learning system material does not clearly specify the required tasks.	Provide course content; Provide assessment instruction; Provide complete course information to students.
S2	A new course activity or schedule change is added in the online learning system with short notice, and the scheduled time overlaps with the student's existing schedule.	Announce unexpected course changes; Manage personal schedule without conflicts.
S3	Midterm grades are visible in the online learning system, but no detailed feedback or explanation is provided.	Provide assessment results; Information clarity for assessment; Clearly understand grades and deduction reasons.
S4	The online learning system requires two-factor authentication for login, but the students' phones are unavailable or cannot be used at that moment.	Multi-factor authentication; Access account.
S5	As a statutory holiday approaches, you check the online learning system but cannot clearly determine whether the course schedules, deadlines, or class arrangements will change.	Find important scheduling information; Provide holiday notification functionality; Define holiday schedule policies.
S6	A score item appears in the course system that was not previously introduced or explained, making its meaning and evaluation unclear to students.	Provide assessment instruction; Provide assessment results; Information clarity for assessment; Clearly understand grades and deduction reasons.
S7	Across different courses, course materials and activities are organized differently, such as in Modules, Files, or Pages, making it unclear where to find the required information.	Provide course structure templates.
S8	The final exam schedule or location is not directly provided in the online learning system, requiring students to search for this information through other sources.	Find important scheduling information; Provide academic scheduling information on the university app; Publish exam schedule and location.

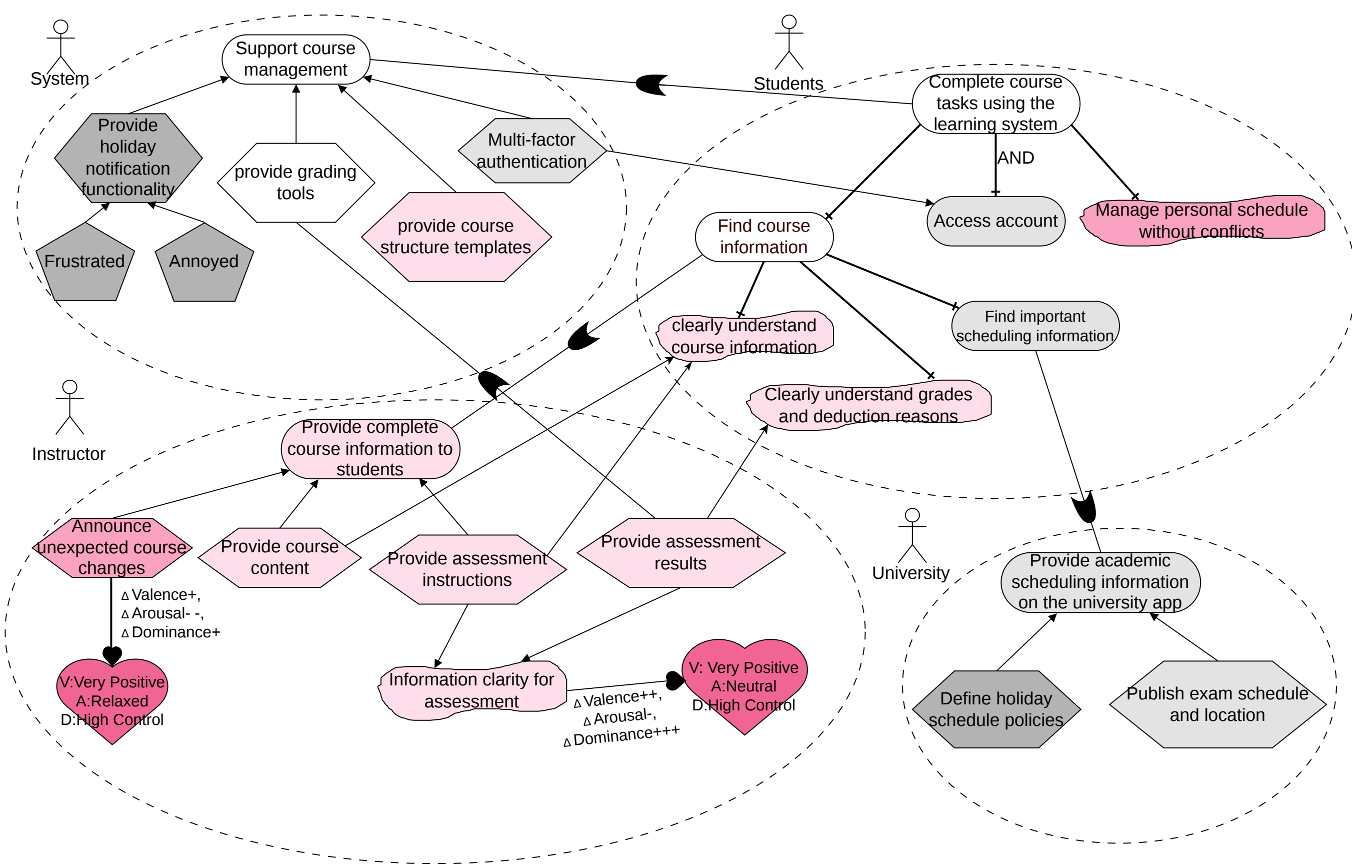


Fig. 6. EmORE-extended GRL model for an online learning system case study.

TABLE III
REPRESENTATIVE EMOTIONAL FEEDBACK FROM TWO VAD QUESTIONNAIRE SCENARIOS

Scenario	Top 3 Reported Emotions	Mean VAD for each Emotion	Overall Mean VAD Across All Responses (%)
S1 in TABLE II	Confused Neutral Anxious	(2.50, 2.75, 1.38) (3.33, 3.67, 3.33) (2.50, 4.50, 1.50)	(50.26, 54.55, 33.33)
S5 in TABLE II	Annoyed Frustrated Sad	(1.80, 3.00, 2.44) (2.20, 2.80, 2.60) (1.33, 4.33, 2.00)	(25.89, 49.11, 32.14)

EmORE Links further support VAD-based gap analysis. For example, if the designer aims to help students feel confident and in control when receiving assessment-related information, low Dominance for *"Information clarity for assessment"* suggests that improvements should not only make information available, but also help students understand and act on it. Possible responses include clearer grading rubrics, contextual explanations, and links to assessment criteria.

The emotional information in Fig. 6 can also suggest candidate requirement refinements. Negative Valence associated with "Provide holiday notification functionality" suggests that the system should provide contextual information for unexpected course changes, including the reason, affected sessions, updated modality or location, and possible schedule conflicts. Similarly, low Dominance in assessment-related scenarios suggests contextual explanations for new grade items and links to rubrics. These examples show how EmORE can reveal emotionally motivated refinements that may remain invisible in a standard GRL model.

D. PoN-Based Notation Design Rationale

In addition to the illustrative case study, the EmORE notation was designed using PoN as a formative design framework. The purpose of this step was not to report an empirical notation evaluation, but rather to justify the initial visual design of the proposed constructs. In particular, the High-Frequency Emotion element, Emotional Goal element, EmORE Link, VAD annotations, and Valence visualization were examined against selected PoN principles, including semiotic clarity, perceptual discriminability, semantic transparency, visual expressiveness, graphic economy, and visual redundancy.

This design rationale ensured that the proposed constructs were visually distinguishable from existing GRL elements while remaining compatible with the original GRL notation system. For example, EmORE introduces only two new elements and one new link type to preserve graphic economy, whereas color- and texture-based Valence visualizations provide redundant visual channels for accessibility.

To support future evaluations, we prepared a PoN-based notation evaluation instrument inspired by the System Usability Scale [23]. The items were derived from PoN principles rather than general usability criteria and covered the clarity of EmORE elements, distinguishability of the EmORE Link, interpretability of VAD annotations, usefulness of Valence-based color and texture visualization, and overall comprehensibility of the EmORE-extended GRL diagram. A full empirical notation evaluation with requirements engineers and goal-modeling experts has not yet been conducted and is considered future work.

VI. DISCUSSION

A. Role of the EmORE Emotion Elicitation Workflow

EmORE can support both new system development and the evolution of existing socio-technical systems. In new systems, it can be used during elicitation and analysis to identify desired emotional outcomes before design decisions are finalized. In existing systems, it can support requirements evolution by collecting emotional feedback from real usage scenarios and mapping it to GRL elements. Thus, EmORE is mainly positioned across elicitation, analysis, specification, and requirements evolution, while post-change validation remains future work.

A key contribution of EmORE is its scenario-based emotion-elicitation workflow, which is supported by a structured questionnaire template. EmORE measures emotions associated with specific system functions, stakeholder interactions, and model elements, rather than general affective states. It does so by introducing a lightweight elicitation template that connects emotional feedback to specific system scenarios. Instead of asking stakeholders to report emotions in isolation, the template asks them to reflect on specific situations derived from potential system-related pain points. This scenario-based structure supports two important aspects of the EmORE workflow. First, it helps stakeholders provide emotional feedback grounded in concrete system experience rather than abstract feelings. Second, it enables requirements analysts to map emotional feedback to the corresponding GRL model elements, making the collected emotional information traceable and usable in later modeling and analysis.

This design is especially important for model-driven RE because emotional feedback must be structured before it can be used in model reasoning. Therefore, the elicitation template acts as a bridge between stakeholder experience and the EmORE-extended GRL model. This supports the transition from qualitative emotional responses to quantifiable VAD values and, ultimately, to model-level emotional reasoning.

B. Design Implications for RE Practice

The illustrative case study suggests that EmORE can support requirements analysts in identifying emotional issues that are not visible in standard GRL models. In a conventional goal model, system elements such as "notification functionality", "authentication", or "assessment feedback" may be represented mainly in terms of functional contribution or satisfaction of non-functional goals. EmORE adds an emotional analysis layer by representing how stakeholders experience these elements.

Color- and texture-based Valence visualization supports rapid visual triage by highlighting the model elements associated with negative emotional feedback. This is useful for prioritization because emotionally problematic elements may not always be the most technically complex or functionally incomplete parts of a system. A function may be implemented correctly but still produce negative emotional outcomes if it is unclear, unexpected, or difficult for stakeholders to interpret.

The EmORE Link further supports the VAD-based gap analysis between the current emotional feedback and desired emotional goals. By separating Valence, Arousal, and Dominance, EmORE helps analysts distinguish different design concerns such as dissatisfaction, stress, and lack of control. After design changes are introduced, emotional feedback can be re-elicited, VAD values can be recalculated, and the model can be updated to support the iterative refinement of emotional requirements.

C. PoN and PRISE Alignment

The design of EmORE follows the PoN framework and PRISE guidelines as complementary methodological foundations. PoN supports the cognitive and perceptual evaluation of visual notations, whereas PRISE guides the extension of goal-modeling languages with human-centric concepts. TABLE IV summarizes how the proposed EmORE extension aligns with the selected PoN principles and PRISE guidelines.

This alignment is important because EmORE introduces new visual constructs into an existing modeling language. Without a structured notation-design rationale, new symbols could increase visual complexity, create ambiguity, or conflict with existing GRL syntax. Hence, the proposed design aims to preserve the original GRL notation while adding a small number of emotion-oriented constructs.

D. Limitations

This study has several limitations. First, EmORE is still at an early stage of development and has been demonstrated through a single illustrative case study in the online learning domain. Further studies are needed to assess its applicability to other socio-technical systems. Second, the scenario-based elicitation process depends on the analysts' ability to identify meaningful emotional pain points and map them consistently to GRL model elements. Incomplete scenarios or inconsistent mappings may lead to partial or biased emotional models. Third, although VAD provides a measurable and requirements-compatible representation of emotional states, it cannot capture the full complexity, context-dependence, and temporal variability of human emotions. The same stakeholder may respond differently depending on urgency, prior experience, workload, or social context. Emotions reported in a questionnaire may also differ from emotions experienced during real-time use. Therefore, EmORE should be interpreted as a modeling support mechanism for identifying emotional tendencies, not as a complete measurement of stakeholder affect.

The use of emotional requirements also raises ethical concerns. Emotional feedback should be used to improve stakeholder well-being, transparency, trust, and understandability, rather than to manipulate user decisions or exploit emotional vulnerabilities. Analysts should therefore treat emotional data as sensitive stakeholder feedback and align emotional goals with legitimate user interests.

TABLE IV
ALIGNMENT BETWEEN PON PRINCIPLES, PRISE GUIDELINES, AND THE EMORE EXTENSION

PoN Principle	**Related PRISE Guideline**	**EmORE Alignment**
Semiotic clarity	Define clear extension concepts.	Emotion constructs are separated from existing GRL concepts.
Semantic transparency	N/A	The heart shape intuitively conveys emotional meaning.
Visual expressiveness	N/A	Shape, color, texture, brightness, and annotations encode emotional information.
Perceptual discriminability	Use clear graphical representations.	New elements and links are visually distinct from standard GRL notation.
Graphic economy	Use the smallest number of new representations.	Only two new notation types and one link type are introduced.
Manageable complexity	Use simple graphical representations.	Emotion information is added without changing original GRL syntax.
Cognitive integration	Relate new concepts to original concepts.	EmORE Links emotional feedback and goals to existing GRL elements.
Dual coding / visual redundancy	Ensure textual and visual consistency.	Valence uses color or texture; VAD gaps use annotations.
Cognitive fit	N/A	The notation supports visual triage and VAD-based analysis.
N/A	Preserve the original syntax.	Existing GRL elements, links, and actor boundaries remain unchanged.
N/A	Ensure complete and conflict-free extensions.	EmORE adds emotion constructs without conflicting with GRL notation.
N/A	Conduct preliminary research before extension design.	The design is grounded in emotional RE, GRL, VAD, PoN, and PRISE.
N/A	Define clear extension concepts.	Each new construct has a defined meaning and usage guideline.

Finally, the proposed notation and visualization mechanisms have not yet been evaluated in a large-scale, independent user study. The current study provides a PoN-informed design rationale and an illustrative application; however, future work should evaluate the comprehensibility, usability, and analytical value of EmORE for requirements engineers and goal-modeling practitioners. Tool support also remains limited because existing GRL tools, such as jUCMNav [24], do not directly support the proposed EmORE elements, links, and visual encodings.

VII. Conclusion and Future Work

This study presented EmORE, a VAD-based emotional reasoning extension for GRL. EmORE introduces a structured emotion-elicitation workflow, dedicated emotion-oriented notations, an EmORE Link for VAD-based gap representation, and color- and texture-based Valence visualizations. These components allow stakeholders' emotional feedback to be represented as quantifiable and traceable modeling information within GRL diagrams.

An illustrative case study of an online learning management system demonstrated the feasibility of applying EmORE in a realistic socio-technical context. The results show that scenario-based emotional feedback can be mapped to GRL model elements and used to support emotional reasoning. In particular, Valence visualization helps analysts identify emotionally problematic elements, while EmORE Links support a more detailed analysis of the gap between current and desired emotional states across the VAD dimensions.

Future work will focus on broader empirical evaluations with independent requirements engineers and goal modelers, including a planned PoN-based notation evaluation survey. We also plan to develop a more systematic process for identifying emotional pain-point scenarios and refining scenario-to-model mappings, apply EmORE to additional socio-technical domains, integrate EmORE with GRL modeling tools such as jUCMNav, and explore persona-based and demographic-aware extensions to capture how emotional requirements vary across stakeholder groups.

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