Towards a Model for Haptics as a Co-Regulation Adjunct in Cognitive Reappraisal

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Abstract A generally adaptive way to regulate emotions involves using reappraisal to change the motivational meaning of a distressing situation. Learning and using this strategy can be challenging, especially in intense situations and for vulnerable individuals. Technologies intended to facilitate learning and using reappraisal have mostly relied on verbal communication. Here, we consider the potential for complementing existing approaches with haptic technologies, on the premise that crafted touch interaction can increase intervention accessibility and adaptiveness, both during intense situations and over longer time scales. We discuss the psychological and physiological pathways through which a haptic intervention could make reappraisal easier to learn and use; then propose requirements for CHORA (comforting haptic co-regulating adjunct) technology and a research approach to its validation.

Keywords: affective haptics · emotion regulation technology · cognitive reappraisal · neurophysiological pathways

1 INTRODUCTION

Living in today's world can be an adventure; for many, its challenges heighten uncertainty and anxiety, in ways that span place, age and socioeconomic situation [16]. The skill of *emotion regulation* (ER) — volitionally altering positive or negative emotion in aspects such as intensity or duration [15] — is crucial for coping, resilience, and overall well-being. Poor ER can lead to sustained distress and harmful coping behaviours, affecting mental and physical health [36]. This paper makes a theoretically grounded case for using haptic technology (Figure 1) in a cognitively engaged approach to emotion regulation (Figure 2).

Gross's widely used framework [15] identifies five families of ER strategies: situation selection, situation modification, attentional deployment, cognitive change, and response modulation (Figure 1). Although most strategies can be helpful (adaptive) in some contexts, cognitive change strategies such as *reappraisal* tend to be both effective in the short term and healthy in the long term [25]. Reappraisal involves changing one's interpretation of a situation in a motivationally significant way, *e.g.,* by recognizing that the situation is not as

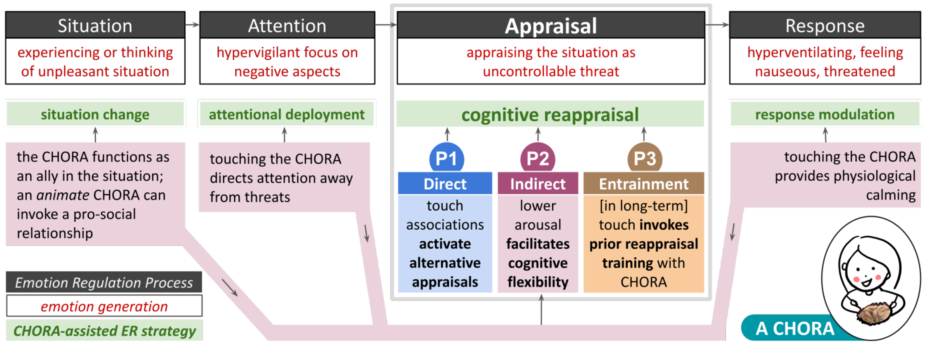

Figure 1: **Posited touch-centered mechanisms.** Three ways that haptic interaction with a CHORA could facilitate *cognitive reappraisal* (§4, P1-3).

bad as it seems or that it has a positive side [32]. It is a component of common evidence-based therapies such as cognitive or dialectical behaviour therapy (CBT, DBT). However, reappraisal can be hard to learn and apply, particularly in moments of high emotional intensity and for individuals with clinical vulnerabilities. Leveraging the full potential of reappraisal thus benefits from external support, including from technology tools [15,32]. Because of this need and high potential payoff, our research focuses on the ER strategy of reappraisal.

Current technologies designed to facilitate reappraisal are largely text-based (reminders, reflection prompts and conversational chat-bots [31]) and tend to work best in "offline" use (learning and practicing reappraisal outside of intense situations). Verbal modality can be hard to access "online": *within* high-stress contexts — interpersonal exchanges, even remote ones, or on-the-go frustrations. Their linguistic basis usually demands substantive cognitive resources, atop the required transfer from offline learning. We need complementary tools better suited for facilitating reappraisal *online* which do not rely on language.

Haptic technologies present a promising opportunity. Many forms of touch have been shown to strengthen our emotional exchanges, with other humans [8] animals [11] and even robots [4]. Building on evidence that touch provides comfort and alleviates stress [11], findings in neuroscience and psychology have begun to elucidate how touch, emotion, and cognition are interconnected [11,19]. Tactile stimulation can colour our perceptual experiences with affect, independently of conscious appraisal [22]; but may also act centrally, *e.g.,* as a safety signal [11].

We define this broad class of haptic ER support as **CHORA** technology: "comforting, haptic co-regulating adjuncts" spanning many forms and behaviours as needed by therapeutic approach or specific user — from an interactive robot, presenting as 'alive' to some degree (our approach), to a wearable appliance or prosthetic. To date, CHORAs used intentionally for ER have largely employed *response modulation* strategies [33], attempting to influence the body's physiological response in an emotional situation via direct physiological means. Past robot-form CHORAs that have been used for response-modulation ER include Paro [17], Haptic Creature [37], Huggie Bot [4], and Purrble [18].

CHORA technology has innate properties which are relevant to but unexplored for reappraisal facilitation. With suitable design, it can assist both with offline skill acquisition and online implementation via complementary pathways [31]: *direct* activation of alternative appraisals, *indirect* facilitation of cognitive flexibility, and *entrainment* (cognitive automation) of the skill. In addition, usage practice can support *tapering* of reliance on the technology over time.

This paper presents the rationale, context, and approach for a new research space to assess CHORA-based interaction for facilitating reappraisal. We contribute (C1) a theoretical foundation, identifying multiple and possibly interacting mental and physiological facilitation pathways; and (C2) proposed implementation steps to design, develop, and evaluate CHORA for reappraisal.

2 REAPPRAISAL IN EMOTION REGULATION

Regulation *adaptiveness* refers to a favourable balance between short-term effectiveness (*e.g.,* did the emotion change in the desired direction?) and mostly long-term side-effects of ER (*e.g.,* did the attempt preclude pursuing other important goals?) [2]. Maladaptive forms of ER (*e.g.,* avoidance and substance abuse) can hinder functioning and prolong distress; but ease and quick relief make them go-tos in taxing situations and for those with elevated risks, *e.g.,* pre-existing mental health challenges, creating a vicious cycle of aggravation [2].

Cognitive reappraisal, an adaptive form of ER, and its obstacles: Appraisal orchestrates how emotion and stress responses unfold in the body and the mind [3]. Altering appraisals can yield positive emotional and physiological responses to initially threatening and negative stimuli [15], enhancing resilience [7]. However, reappraisal success has preconditions and can be derailed.

To begin with, considerable cognitive flexibility is required both to *reconstrue* an ongoing situation (consider alternative interpretations) and to *repurpose* it (evaluate it in light of alternative goals and other motives) [32]. In both instances, initial construals and motives need to be inhibited and alternatives enhanced.

These cognitive operations become more difficult under high-stress conditions, especially for vulnerable individuals [32,27]. A stressful situation is usually cognitively taxing, leaving fewer resources for reappraisal; and also tends to involve high emotional and physiological arousal which can further interfere with cognitive flexibility. This affective state paired with inadequate social and emotional support [10,35] in adverse life situations can limit reappraisal [32]. We thus need ways to support cognitive flexibility during attempts of reappraisal in stressful moments.

Social co-regulation as a facilitator of reappraisal: Social support can aid reappraisal, and for many its use is natural and instinctive when available and fitting. For example, a caregiver's involvement during emotionally charged interactions contributes to young children's development of reflective ER, fostering emotional awareness and adaptive regulation strategies [30]. However, interpersonal co-regulation can be undermined by difficulties with emotional communication or trust, or a tendency to maladaptive behaviours such as venting and excessive assurance-seeking [9]. It can also impose on burdened caregivers.

Animals can be wonderful co-regulators [23], spurring research into how animal-like characteristics in robots can provide related benefits [37,13,18]; while also comprising a safe, controlled, and accessible platform for supporting individuals in their ER practices [13]. Preliminary studies point to reduced anxiety and depression markers [17], heightened coping abilities, and increased social engagement [17,29]. While indicating that a haptic stimulus is instrumental, these studies do not identify underlying mechanisms [28,13,11]. Our research agenda includes identifying the mechanisms linking touch and co-regulation.

3 THE CASE FOR TOUCH IN ER TECHNOLOGIES

How touch influences emotion: Signals arriving through our skin can influence our emotional state in multiple ways and on varying time scales. The opportunity we see in ER is in *affiliative touch*: positive contact relating to formation and maintenance of caregiving and social bonds [24]. While most studies of affiliative touch have been inter-human or with animals, we posit that similar processes could apply with a non-living tangible object under the right conditions: *e.g.,* a trusted partnership and/or mental projection of animacy. [17,13]

First and most immediately, activity in our skin receptors, particularly C-tactile afferent fibres, is associated with oxytocin release during affiliative, nurturing touch [34], stimulating physiological arousal, pleasant feeling, and prosocial interaction [8]. In parallel, incidental haptic sensations influence higher-order cognitive processing to shape our perceptions of individuals and situations [1], consistently with embodied cognition theory's premise that physical sensations can impact cognition [19].

In another part of the brain, affiliative touch is proposed to act more centrally by inhibiting the amygdala's fear response, a safety signal which opens the door to other cognitive processes that are less available in fight-or-flight mode [11]. Finally and most enduringly, affiliative touch has been linked to personal empowerment in long-term relational, psychological, and physical well-being [19].

Haptics relative to other ER support modalities: Prior ER technology research [31] focuses on building awareness (self-tracking), reminding (to take pre-defined actions), reflecting (prompt-based journaling), and providing emotional support (pre-defined messages, conversational chat-bots). These may not be accessible or convenient on the spot; they require users to actively engage with a digital device, often verbally (often infeasible in intense moments or interpersonal exchanges), and to verbalize complex emotions. A touch's proximal, intimate nature may deliver higher emotive impact compared to a verbal or audio channel [26]. Like verbal modalities, a CHORA can be situated as either 'pull' or 'push', able either to nudge and get the user's attention based on contextual indicators, or respond to their reaching out.

Haptic ER and physiological cueing: Haptic signals have often been used as a cue (*e.g.,* rendering a "calm" heartbeat for the user to mirror [38]) or to guide

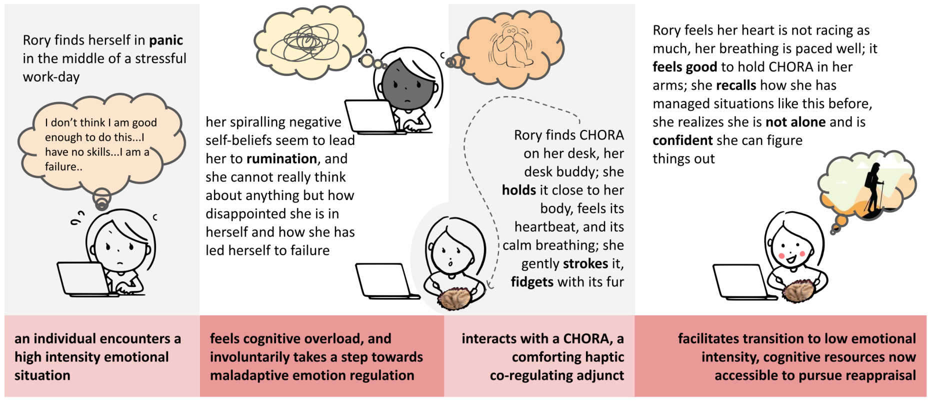

Figure 2: **A representative use-case:** Self-regulation using reappraisal strategy facilitated by a haptic social robot CHORA

an ER practice such as meditation [12] or managed breathing [20]. While useful, these physiological approaches do not leverage the touch-emotion connection.

Haptic interaction invoking cognition and emotion: A more holistic approach considers social and behavioural context and connection (a defining factor in interpersonal and human-animal touch interactions [19]), by invoking cognition via interpretation. For example, haptic social robots portray (designed) animate behaviours or a (projected) sense of animacy [37,4,18]. Humans can build social bonds with robots, particularly those engaging touch [13,17]. If this enables the robot to take the role of a partner or helper, it will be a more effective co-regulator. Likewise, we have observed zoomorphism elicits touch that is social, nurturing, and affiliative in the manner of interaction with a real animal [37].

Furthermore, just as for a real animal, a user's *interpretation* of the robot's physical behaviour is modulated by context and narrative, whether supplied by the designer or constructed by the user, or both [5]: whether they see a cat-like robot's quick breathing as 'scared' or 'happy' depends on their impression of the robot's situation. Thus, the design of both a CHORA's appearance, behaviour, and responses, and controlling the context within which it operates can explicitly leverage cognition, setting expectations that help a user understand it.

The degree and manner in which all of these factors (social bonding, nature of elicited touch, narrative framing, and their impact on reappraisal facilitation) need to be investigated.

4 POSITED TOUCH-CENTERED MECHANISMS

We posit three pathways through which a CHORA can facilitate reappraisal (Figure 1). We anticipate that these pathways could operate independently or synergetically, in a balance that will shift over time.

***P1. Activation of alternative appraisals* (direct):** Haptic interaction with CHORA facilitates reappraisal by activating information that is conducive to adopting a more positive appraisal. For example, pleasant touch sensations, animal-like appearance, and movements can evoke memories from a wider range of situations [11] (Figure 2). This increased cognitive access to different kinds of situations helps the person to see problems in perspective, focus on coping potential, look for possible up-sides, and discover other applicable reappraisals [32].

P2. Facilitation of cognitive flexibility **(indirect):** An animate (life-like) CHORA can function as an ally wherein the physical connection invokes a pro-social relationship and affiliative touch [13]; this can bolster the user in carrying out *situation change*. Haptic interaction with the CHORA can attract attention away from rumination (excessive focus on negative aspects and broader implications of the situation), improving the way the situation is appraised [21] through *attention deployment*. It can also provide physiological calming via stroking [11], hugging [4] or being exposed to a 'breathing' motion [28], leading to the kind of *response modulation* which has been documented above. The compounded and cascading effect of these three ER strategies can lower arousal, in turn facilitating cognitive flexibility and eventually *reappraisal* (Figure 1).

P3. Facilitation of reappraisal training **(entrainment)** → ***gradually reduced reliance*** **(tapering):** The CHORA can facilitate reappraisal training by helping maintain a lower arousal state and focus on the task, both *offline* and eventually *online* in the stressful moment. Once mentally associated with a reappraisal process, the CHORA can cue the adaptive response with less effort. Over time, we anticipate that the user will be able to *taper* their reliance, evoking the entrained process with successively smaller cues: *e.g.,* a small, passive CHORA variant, then eventually just a memory of the physical cue.

5 KEY ELEMENTS OF A RESEARCH APPROACH

In this section, we present steps through which researchers can build on and assess our posited theoretical mechanisms to construct, study, and eventually deploy CHORA systems in support of reappraisal. Our perspective is that of researchers in the fields of haptic human-computer and robot interaction (HCI and HRI), and affective computing, in collaboration with a psychologist expert in the theory and clinical application of cognitive reappraisal.

A. Form an interdisciplinary team. The team will need expertise in technical areas (likely including haptics and affective computing; with a robotic form factor, robotics and HRI); a psychology partner versed in theory or clinical practice, as the use-case and research stage requires; and direct experience in HCI and design [33]. The entire team requires knowledge of established ER models [15], reappraisal theory [32], and evidence-based therapies. As the research approaches real-world deployment, patients and/or their advocates need to be engaged more directly.

B. Collaboratively establish research objectives. The broad goal of developing a CHORA technology that can facilitate reappraisal leaves many possibilities. The theoretical pathways posited in §4 need to be empirically evaluated; for a large array of possible use cases, interaction paradigms must be designed

[Use Case] Therapist-guided-regulation: *In her therapist's office, Rory practices reappraisal with her CHORA. They are discussing a past traumatic event where Rory tends to get stuck, too overwhelmed to talk. Coached by the therapist, Rory wraps her arms around her cat-sized CHORA and holds it close to her body as she tries again. Her therapist uses a wireless app to adjust the CHORA's movements (breathing, heart rate) as she observes Rory's progress.*
[Use Case] Self-Regulation: *Rory proactively practices reappraisal before a meeting she is worried about. An app (didactic) linked to her CHORA guides her through a reappraisal session, prompting her to recall a high-intensity emotional situation and enter her perceived negative self-beliefs in a text prompt. The app then instructs her to reappraise her emotions, giving her examples to train with. During a 10-minute session, Rory holds the CHORA close to her body and pursues reappraisal. The CHORA adapts its movement in sync with the app's functions as well as Rory's physiological data (heart rate, skin conductance), providing Rory physiological comfort as she practises.*
[Design Requirements] A haptic social robot CHORA: For the above use cases, a researcher specifies a zoomorphic CHORA which is animate (breathes), off-body, allows for movement customization, and invokes the perception of agency by being responsive to the user's behaviour in real-time. The zoomorphism and animate behaviour (a breathing pattern to evoke a calmer time) are expected to create a pro-social user connection, attract attention, and down-regulate physiological response; this lower arousal will facilitate reappraisal (an *indirect* pathway). A soft, furry outer cover will activate cognitive associations, by recalling comforting, feelings from the past and giving access to alternative appraisals (a *direct* pathway.) This CHORA, whose interface allows both movement customization by the therapist or user and autonomous responses to the user's emotional state, will be used during reappraisal training and *entrainment*. A smaller and less active CHORA, related in shape and materiality, could support a *tapering* process.

Table 1: **CHORA use cases and requirements.** These persona-illustrated examples, also depicted in Figure 2, are set in two likely regulation contexts.

and assessed for acceptability, usability, and practicality. Pooling their respective motivations, expertise, and the potential for advancing knowledge at the intersection of their fields, the team must formulate specific objectives supported by the theoretical underpinning discussed in §2-3.

C. Formulate use cases for deploying a CHORA. To identify high-impact opportunities, researchers can apply Slovak *et al* [31]'s *how, when, and where* framework; a CHORA should be able to support both *didactic* (learning about an ER strategy) and *experiential* (using an ER strategy) facilitation. As illustrated in Table 1's examples and Figure 2's storyboard, use cases need enough detail relating to the specific context and targeted users to guide the establishment of the CHORA's purpose, type, and setting.

D. Identify design requirements for a CHORA use case. Each CHORA device will occupy a point in a large design space, addressing specific contexts

Property	Critical Purpose Served
Haptic Display	To activate posited ER pathways, a CHORA must be able to render appropriate haptic sensations and physical motion.
Sensory Capability	To respond to user touch, a CHORA will require sensing either in/on-device or nearby. Parameters of interest include device orientation, state, motion, touch location/patterns; along with user modelling, interaction attributes, and user affective state.
Behavioral Strategy	CHORA behavior (designed in accordance with the use case) must be computationally linked to sensed user context and input.
Control Interface	Developers, users, and/or health practitioners need to set up and customize the system. Interface needs will vary by use case and role; *e.g.,* system-level access for developers, and parameter selection/tuning for end-users.

Table 2: **Properties that define a CHORA system.** Researchers can deploy a puppeted CHORA to develop behaviours, sensing, and actuation.

and therapeutic approaches as well as individual and possible customizable preferences, as per the targeted use. CHORA design dimensions minimally include *appearance* (look and feel, including representation), *haptic modalities* (motion, force, vibration, thermal), *materiality* (such as textures and rigidity or compliance), *animacy* (convincing lifelike behaviour), *on/off-body design* (along with pull/push interaction), *responsiveness* (context-specific reactions), *customizability* (context-specific parameter change); and many variations in form and interaction. In this step, researchers can use Vyas *et al* [33]'s *usage specification*, *system specification*, and *technology* dimensions as a design reference. Researchers should consider how design choices will facilitate or obstruct each of §4's pathways. Cognitive science, psychology, and neuroscience expertise can help connect the dots between the chosen design and its pathway contribution. Table 1 shows an illustrative example.

E. Build (or buy) the CHORA. As is common in HCI-related research, prototype development might be intertwined with assessment in an iterative research-through-design approach or up-front based on confident specifications; and aim for an early minimally-functional model or a polished, stand-alone field-ready device. Some requirement sets might be addressable with an off-the-shelf product. At this early validation stage, platform customizability will likely be an asset to support evaluation-guided iteration.

Key technical challenges in this step may include practical methods for inferring a user's emotional context, creating haptically interactive and engaging behaviours, and establishing a framework for CHORA's personalization. These challenges particularly benefit from expertise in HCI, haptics, affective computing, machine learning, robotics, and HRI.

We propose defining properties and considerations to guide the researchers in building a CHORA in Tables 2-3.

Considerations	**Strategies for Implementation**
Interaction	Compose inviting physical attributes (shape, tactile qualities, movements). Design for social interaction, evolving behaviour based on user engagement.
Practicality	As context dictates, prioritize mobility (untethered), suitable or personalizable size, and comfort if needed for extended use.
Responsiveness & Animacy	Adapt interactions to user input and context cues; evolve behaviour over time.
Emotional Safety	Prioritize user-configurable safe-usage settings; be sensitive to the risk of triggering traumatic memories.
Technical Intrusiveness	Leverage user's existing technology (*e.g.,* smartphones, smartwatches) for didactic use-cases and progress tracking.
Privacy	Disclose all data use; collect only data that is needed. Securely store and transfer sensitive data; rely on local data for learning models, to minimize unneeded storage or transmission. Limit data access, and only with user consent.
Hygiene	Specify surface material cleanability based on multi-user context and type/hazards of use case.
Robustness	Create and adhere to electromechanical specifications for use case including sturdiness and battery life.
Long-term & Field Use	Implement a system for regular updates; enhance engagement and adapt to user patterns. To prevent over-reliance, design for gradual disengagement.

Table 3: **Considerations for developing a CHORA system.**

F. Assess effectiveness of CHORA-supported reappraisal pathways. Many evaluation approaches could illuminate the research questions in play. Mixed-methods studies [6] can triangulate different combinations of behavioural, physiological, cognitive, and neural activity in response to evoked stress, producing observation, physiological, and movement data; and self-reporting in the form of attentional scales, diary entries, and interviews, whose contents can be compiled to examine how haptic interactions with the CHORA can lower barriers to reappraisal. Table 4 is a partial checklist for a suitable study.

Initially, single-session or longitudinal controlled in-lab studies can evaluate aspects such as the impact, acceptability, and user adaptation to the CHORA technology; technical or algorithmic implementations; and effects of design variations against a control. Larger studies and study series can address the impact of design choices, along with the role of context and individual differences.

Eventually, we can move to more ecologically valid contexts. In-situ longitudinal deployment, co-designed with users and care teams, will be needed to understand CHORA's impact on users' day-to-day reappraisal practices. Eventually, with the demonstration of CHORA's effectiveness in facilitating reappraisal via

1. CHORA prototype developed or configured specifically for investigating the formulated research objective within a contextual use case.
2. Control chosen to serve as a point of comparison against which the effectiveness of CHORA is measured (*e.g.,* absence of CHORA; the presence of a comfort object, human, or pet; a set of instructions to regulate emotions).
3. Cognitive reappraisal task designed for participants' in-lab implementation of reappraisal during a negative emotional experience. Such a task should allow for repeated trials for optimum data collection [14].
4. Emotion elicitation protocol to simulate an ecologically valid negative emotional experience (e.g., stressful interviews, negative emotion recalls).
5. Evaluation metrics comprising of physiological, cognitive, and neural activity markers as well as self-reports, attentional scales, and interviews.
6. Data collection software configured or developed for administering the cognitive reappraisal task, emotion elicitation protocol, and logging study data from sensor suites/scales (*e.g.,* Psychopy, E-Prime, LSL, OpenSync).

Table 4: **Elements needed for an in-lab study.**

controlled studies, CHORA-supported interventions could be deployed therapeutically with practicing clinicians.

6 CONCLUSION

To verify and craft this new approach to haptic facilitation of mental health, building on these theoretical bases, posited mechanisms, and requirements, we require advances on three related fronts: (1) verifying and unpacking CHORA co-regulator mechanisms, (2) developing customizable, responsive technologies, and (3) deploying and evaluating them in real environments. Progress will require collaboration across many constituent fields, including clinician/patient networks in mental health and well-being communities. This agenda exceeds what one group could hope to achieve; pursuing it should yield benefits that extend to health and wellness beyond cognitive reappraisal.

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