TouchEmotion: Augmented Reality Interfaces Leveraging Metaphorical Emotional Trajectories for Emotion Regulation

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Emotion regulation skills are crucial for wellbeing, yet mastering them is not trivial. Because of wearability, private passthrough display, and ability to keep users connected to their surroundings, Augmented Reality (AR) technologies have potential for supporting on-the-spot emotion regulation. We designed TouchEmotion, an AR design exemplar consisting of three prototypes aimed to support metaphorical emotional trajectories for regulating anxiety, anger, and boredom. We employed Snap Spectacles to design interactive animations and touchpad interactions, which we examined through an exploratory study with 18 participants. Findings indicate potential of AR technologies and in particular of metaphorical emotional trajectories coupled with touch-based interactions for on-the-spot regulation of three discrete negative emotions. We advanced a design space for on-the-spot emotion regulation technologies, and proposed five design implications: nature-inspired slow transitions, frictions to support frustration tolerance, layered randomness to support surprise, and finger-worn devices integrated with AR technologies for increased acceptance in public contexts.

CCS Concepts: • **Human-centered computing → Human computer interaction (HCI)**; **Interaction devices**.

Additional Key Words and Phrases: Emotion Regulation, Augmented Reality, On-the-stop Emotion Regulation Intervention, Metaphor, Metaphors, Wellbeing

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1 INTRODUCTION

Emotion regulation consists of monitoring, evaluating, and modulating one's emotional state in daily life, representing an essential skillset for mental wellbeing, albeit not trivial to develop, as reflected in the increasing worldwide prevalence of mental health conditions [1, 13, 28, 61], as well as problematic behaviors [164] in a broad range of domains from physical activity and nutrition, to screen time or personal finance. We adopt the definition of emotion regulation as processes to effectively modulate or manage one's emotional experience and response to emotional situations by increasing, maintaining, or decreasing both negative and positive emotions [59]. Given the significant impact of negative emotions on wellbeing, much research on emotion regulation has targeted negative emotions (such as anxiety) [120], which have also received growing HCI interest in recent years [35, 133]. HCI findings have shown the value of various technologies for supporting therapy-based interventions for emotion regulation in offline settings, which requires however a certain investment of time and space [133]. For instance, researchers explored the challenges of

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developing digital cognitive reappraisal interventions [78] and their co-design with young people [3]. Prior work has also suggested that playing through a Cognitive Behavioral Therapy (CBT)-based psychoeducational game [4, 79] requires sit-down time, usually in a private space, for entering a Virtual Reality-based emotion regulation intervention [115, 124, 156] as well as non-trivial time for setting it up. However, due to the unpredictable nature of human emotions, there are many emotionally charged situations in daily life, such as unexpected conflicts in the workplace or negative memories triggered by an encountered street scene, which can benefit from immediate, on-the-spot emotion regulation support [133]. Most available on-the-spot options take advantage of the portability of devices such as mobile phones

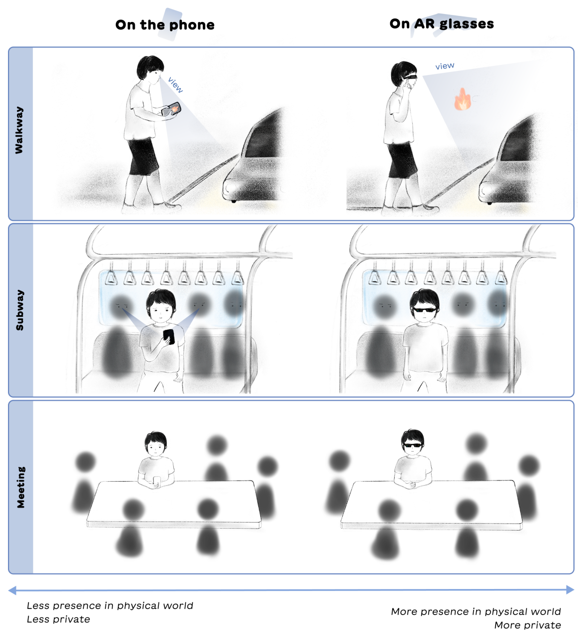

Fig. 1. Illustration of emotion regulation interfaces on mobile phone (left), or AR glasses (right) used in three scenarios of walking on street (top), travelling on subway (center), and attending a meeting (bottom).

[50, 118], on-body wristbands (e.g., Apple Watch [30]), and personal electronic devices (e.g., Fidget Spinners) [133]. Such developments also beg the question: what other technology platforms could we leverage for on-the-spot emotion regulation support. The potential adoption of portable wearable AR glasses in daily life [76, 122], their increased use in health domain as shown by Oun et al.'s systematic review [112], and yet limited use for emotional regulation [134] offer a promising space for such exploration. Moreover, several commercial AR glasses have become available, such as Google Glass, Snap Spectacles, and Apple Vision Pro, including more recent affordable ones such as XReal Air, AR glasses represent an interesting, less explored technology for supporting emotion regulation in-situ and on-the-spot [145]. Moreover, on-the-spot AR glasses may support greater connection with surroundings by blending virtual elements into reality through a heads-up display and overlay graphics [115, 141].

For example, in the walking scenario depicted at the top of Figure 1, users can engage in emotion regulation support while connecting with their surroundings, which can address the challenge of losing a sense of the real world when using mobile devices, such as phones and smartwatches. Imagine a future scenario where AR glasses become regular eyewear; users can even engage with emotion regulation support during a meeting. In this case, users can sense the meeting context while regulating their emotions toward a better state. This can also enhance privacy with AR glasses' private-view display (Figure 1 bottom). Consequently, this work explores the feasibility and potential of AR glasses for emotion regulation in everyday life.

On the mechanism front, Slovak and colleagues [133] highlighted an interesting and under-explored future research direction in emotion regulation: how we can deliver emotion regulation support by designing interaction mechanisms to guide users through *emotional experience trajectories* rather than simply providing biofeedback on emotional states. Such trajectories would still be seen as experiential rather than didactic (or information-based or cognitive) interventions within the [133] taxonomy, highlighting key points at which the system provides support to facilitate changes towards emotion regulation. While innovative, this concept of emotional experience trajectories has not yet been extensively applied in design of technologies for emotion regulation.

To advance design thinking in this space, we also draw upon HCI work on *trajectories of user experience*, according to which users navigate paths through an experience, whether intentionally designed, or occurring serendipitously [11]. Furthermore, Tennet et al., [142] also suggested that trajectories can map the emotional journey, akin to Russell's circumplex model of affect [125], thus forging a path between different emotions. By integrating these different HCI perspectives on trajectories, we are curious as to whether we can design an AR experience that maps the transition of an emotional trajectory from a less ideal, unregulated emotional state toward an ideal, regulated emotional state. Could such an experience help people regulate their emotions by following our designed paths, or might they navigate their own paths during such experiences.

During the emotional mapping for the experience design, we employed metaphors' potential to support the understanding of key discrete emotions and their regulation by mapping them to specific objects, natural elements and their changes [81, 86, 87, 133]. We aimed to design what we called *metaphorical emotional trajectories* which we define as metaphor-based experience trajectories intended to support change towards an ideal emotional state (i.e., less ideal state –> transition –> ideal state). Such trajectories involve mapping the initial, transition, and end states to metaphorical representations with the aim to support emotion regulation. For example, in designing for anger regulation, we mapped the *burning fire* as the less ideal state and the *extinguished fire* as the ideal state. We created an experience where users navigate from experiencing the burning fire to the process of extinguishing their fire by triggering rain.

To embody this vision, we used Snap's Spectacles[1] to prototype AR metaphorical emotional trajectory experiences. Crafting a digital experience that integrates graphics, sound, music, and interactions is crucial [67], so we made full use of the Spectacles' device capabilities: (1) rendering audio-visual metaphorical representations of emotions, and (2) utilizing the touch pad as an interaction input for users engaging with the metaphorical experience. Thus, we designed TouchEmotion, a set of three AR prototypes (Lotus, Fire, and Bubble) that allow users to engage with metaphorical emotional trajectories for regulating three basic emotions using touch input (Figure 2). We focused on three main emotions whose working definitions are further outlined: (i) anxiety as the emotion associated with threat, and experienced as tension or worry [41], (ii) anger as the emotion associated with goal-obstacle or unfairness and the urge to act antagonistically [83], and (iii) boredom as a low arousal emotion of dissatisfaction associated with insufficiently stimulating situations [103].

Our work focuses on the following three research questions:

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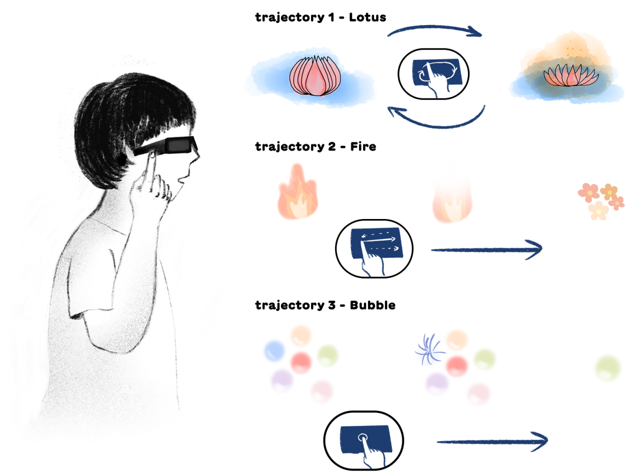

Fig. 2. Three metaphorical emotional trajectory experiences designed for Lotus, Fire, and Bubble prototypes for regulating anxiety, anger, and boredom, respectively, through continuous and slow finger movements, swiping, and tapping, respectively.

- What metaphors and their audio-visual representations can be used to regulate negative emotional states such as anxiety, anger, and boredom.
- How can we design interactions to support users in engaging with the metaphorical emotional trajectories for regulating anxiety, anger, and boredom.
- What is the feasibility of AR prototypes to implement such experiences for in-situ interactions.

Our iterative design process involved a pilot and a main user study. First, we sought input from lab members to refine the design, followed by an in-lab formative study. During the study, participants tried out the three prototypes in the context of evoking relevant undesired emotional states, so that we could obtain situationally useful feedback about their designs. We conducted interviews and collected their reported emotional states before and after they tried out each prototype, using the Positive and Negative Affect Scale (PANAS). Both qualitative and quantitative data were collected to understand the impact of the prototyped designs, and to explore how experiencing such metaphorical emotional trajectory experiences may support emotion regulation.

Figure 3 illustrates the emotional trajectories for Lotus, Fire, and Bubble prototypes over time, from unregulated to regulated emotional states regarding anxiety, anger, and boredom, respectively, together with participants' answers illustrating these states.

This paper's key research contributions include:

- TouchEmotion as an innovative interactive system for on-the-spot regulation of negative emotions.
- Metaphorical emotional trajectories as a new construct to support the design of emotion regulation technologies and fresh insights into their value.
- Advancing a design space for on-the-spot emotion regulation technologies.
- Novel design implications for emotion regulation technologies.

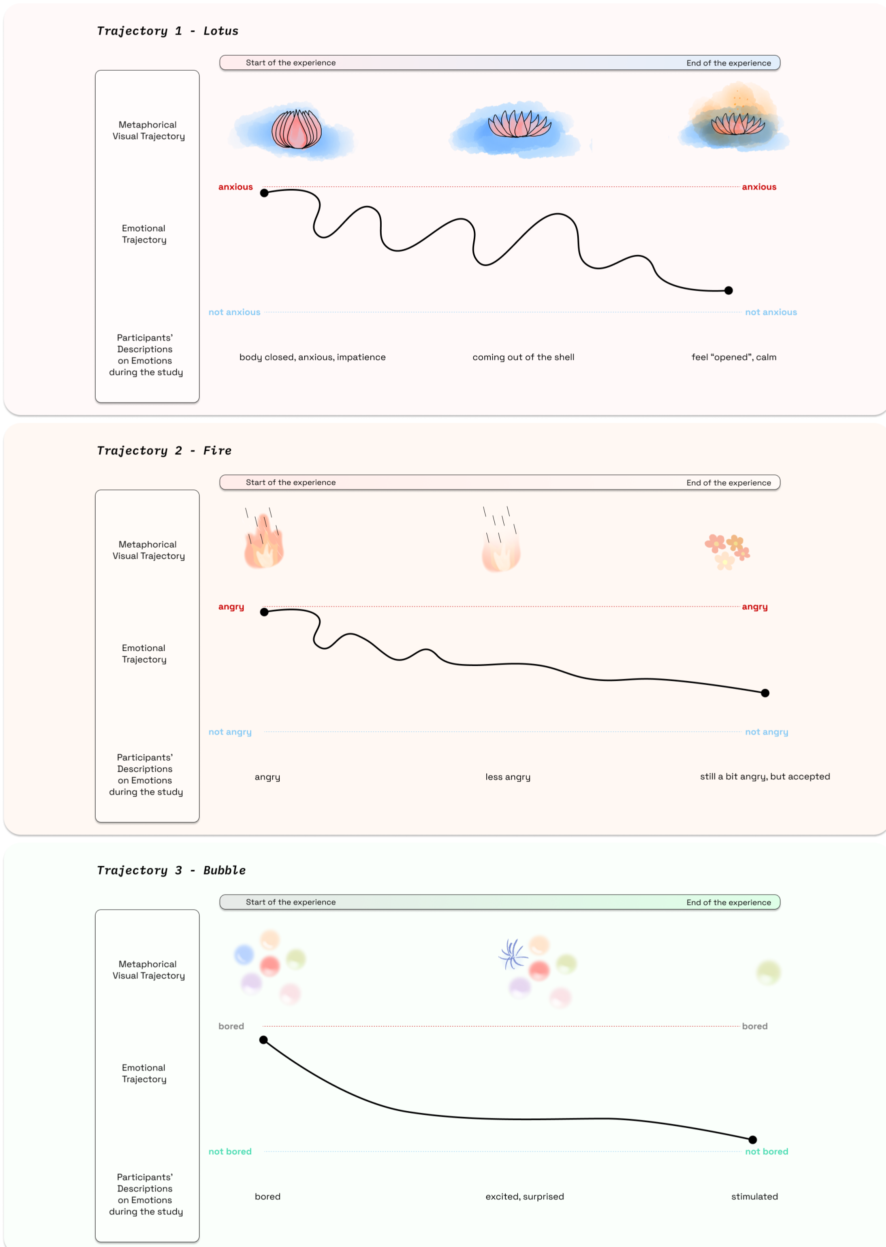

Fig. 3. Three metaphorical emotional trajectory experiences for Lotus, Fire, and Bubble prototypes from unregulated emotional state, at the start of experience (left) to regulated emotional state at the end of experience (right) for the three emotional states of anxiety, anger, and boredom, respectively, together with participants' answers illustrating changes in these states.

2 RELATED WORK

We draw upon HCI research on emotion regulation focusing on on-the-spot emotion regulation technologies as well as the metaphorical representations of bodily states in such technologies. We also reviewed research on emotional metaphors and user experience trajectories in HCI.

2.1 On-the-spot Emotion Regulation Technologies

According to a recent review of emotion regulation technologies [133], existing work in HCI can be classified into on-the-spot and offline systems, when considering *when* and *where* the technologies provide the emotion regulation interventions. For on-the-spot interventions, support is provided during everyday emotional situations, while offline interventions aim to support the development of emotion regulation strategies in deliberate training contexts rather than ad-hoc in daily life. Slovak and colleagues' review [133] also draws from the distinction of emotion regulation processes as implicit or automatic and outside one's awareness, and explicit or consciously leveraged.

For on-the-spot support, emotion regulation systems typically follow two steps: (i) initiating the intervention, and (ii) delivering the intervention. Regarding the first step, or *who/what initiates the on-the-spot intervention*, some works expect that users will recognize the need for emotion regulation and activate the system themselves (*user-initiated*) [49, 94, 106]. For example, BioFidget [94] is a smart spinner whose colors users can change based on their tracked heart rate, and which if high, the spinner triggers a slow breathing in-the-moment intervention guiding users through colored rhythmic light. Other systems determined the need for emotion regulation at specific moments (*system-initiated*), often using bio-sensing techniques such as electrodermal activity (EDA) [50, 118, 136], heart rate [31, 151], galvanic skin response [149, 153] or breathing rate [52] to trigger intervention delivery. In our work, we expect users to recognize their need for emotion regulation support.

In terms of the second step — delivering the actual emotion regulation intervention, one commonly used mechanism is *providing 'target feedback'* via haptic interaction [24, 31, 53]. For instance, BoostMeUp [31] utilizes the Apple Watch to offer users subtly perceptible haptic 'taps' on the wrist, aiming to regulate emotions. Another predominant mechanism is *guiding users toward slower breathing patterns* [94, 106, 107, 113]. BioFidget [94], for example, invites users to participate in respiration training through thoughtfully designed tangible and embodied interactions. BreathTray [106] promotes calm respiration by offering continuous monitoring and feedback integrated into the desktop. Alternatively, the work presented in [118] introduces a bio-sensor-based reminder within a mobile application, while [49] provides cognitive scaffolding via a mobile app.

Given the need for on-the-spot emotion regulation support, we observe that most such interventions are delivered via easily accessible technology platforms such as mobile phones [49, 118, 136], wristbands [24, 31], and computer desktops [53, 106, 107], while BioFidget [94] uses a fidget spinner, and in-car devices are employed for in-car situations [6, 113]. Other scholars developed shape-changing textile installation for emotion regulation [70], or smart toys, with integrated haptic sensors and actuators, which need to be calmed through stroking movements to help regulate from anxious heartbeat towards purring vibration [72, 143]. HCI scholars have also focused on mixed reality systems for emotion regulation such as ARCADIA which integrates gamification and whose evaluation indicated therapeutic potential [137].

Beside these common technologies, AR glasses have received less attention. One noticeable exception, is a recent study [141] which explored the use of smart glasses for breath-based mindfulness practices on-the-go. This research illustrates the viability of portable wearable AR glasses for emotion regulation support in everyday settings, benefiting from the fact that these devices do not occlude the wearer's view. Still, AR for emotion regulation support remains largely underexplored. Our work aims to address this gap and to consider how AR glasses can support on-the-spot emotion regulation.

In terms of emotion regulation strategies, previous *on-the-spot* technologies predominantly involve biofeedback (e.g., through deep breathing or 'target feedback' as haptic interaction). These works rely on providing feedback through representations of users' emotional states via heart rate, EDA, or other bio-sensing measures, in order to guide users consciously (explicit emotion regulation) or unconsciously (implicit emotion regulation) towards ideal bodily rhythms such as breathing patterns. The related AR on-the-go work [141] also focused on mindfulness-based breathing guidance through audio-visual animations. As indicated by [133], there is one interesting future exploration direction: how we can deliver emotion regulation support by designing interaction mechanisms to guide users through emotional experience trajectories [12, 142], rather than simply providing biofeedback on emotional states. Therefore, we aimed to design a digital experience that maps the transition of an emotional trajectory from a less-ideal, unregulated emotional state toward a regulated emotional state.

Also, most on-the-spot emotion regulation systems have focused on anxiety or stress-related emotions [24, 31, 53, 94, 106, 107, 113] leveraging haptic-based feedback or biofeedback for slow breath training. Although emotion regulation supporting slow-breathing or haptic feedback might also be applicable to anger due to its high arousal and low valence nature, less work has explored anger regulation. Additionally, boredom is a common but less explored emotion in HCI research on emotion regulation. Considering that anger and boredom are commonly triggered emotions in the workplace, potentially leading to depressive complaints, distress, and counfterproductive work behavior [42, 154], our AR on-the-spot feedback may offer alternative ER support for these emotions in the workplace. Therefore, we selected anxiety, anger, and boredom as our target discrete emotions for our prototypes.

2.2 Metaphorical Representations of Bodily States in Biofeedback-based Technologies

An increasing body of HCI research on emotion regulation technologies has leveraged biofeedback through biosensors capturing for instance heart rate or breath rate to provide audio/visual or haptic feedback. Metaphorical representations have been commonly used in biofeedback system for emotion regulation [133]. Our review of such technologies indicate the prevalence of those mapping bodily states to abstract representations such as screen brightness and volume of ocean sound [53], warm/cool tone and saturation of ambient light colors [167], vibrations' frequency or intensity and warm/cool thermal actuators [152], or spatial metaphors such as up and down swiping patterns in drivers' seat cover [6, 113], and less use of representational metaphors such as flowers [22]. Such feedback is often tailored to users' resting baseline [6, 53, 113]. For example, BrightBeat aims to modulate the high breathing rate during stressor tasks to lower breathing rate represented through calming frequency at which screen's brightness and sound volume oscillate rhythmically in the moment [53]. Other systems supporting slow breathing rate integrate respiratory sensors to provide feedback on desktop screen for instance from dim to bright when target rate is reached [107], or by displaying on the system tray the current breath rate with gamified feedback in red or blue, for above or below resting rate and calm points [106].

Beside those focused on breathing, other class of emotion regulation technologies leverages heart rate sensors and provides training on heart rate variability, a landmark indicator of emotion regulation [165]. ambienBeat is a wearable for emotion regulating integrating heart rate sensor with rhythmic haptic feedback, visual feedback as changes in screen light from dark to bright white, and sound feedback as heartbeat sound [24]. Another example is BoostMeUp, a smartwatch application integrating heart rate sensor to provide haptic feedback as personalised slower heart rate during stressed [30], while EmotionCheck is a wearable providing vibrations at a slower heart rate without the integration of biosensors [29]. Emotion regulation systems focused on heart rate also include tangibles. Relaxushion is a smart cushion which provides proxy breathing motion – slow and deep integrating accelerator to measure breath [7]. Biofidget is an interesting example of tangible technology as a smart spinner integrating heart rate sensor with visual feedback to guide slow breath through change of color of a peripheral rhythmic light from white for inhalation to multicolor for exhalation with hue increases with the increase in the speed of the spinner which can be flicked with one's finger or blown into [94]. Other systems integrate heart and breath sensors to provide haptic feedback as vibration patterns in drivers' seat cover [6, 113]. Not at least, DeLight provide changes in color and saturation of ambient light towards slow breathing [167]. Haptic biofeedback can also be personalized [104] for instance through users' selection of vibrations' frequency and intensity, or temperature of thermal actuators [152]. In their study, Umair and colleagues [152] showed users' preference for low intensity, low frequency vibrations - similar to slow paced heartbeat, suggesting their value for regulation through entrainment, i.e., synchronization with slow bodily rhythms. Thus, through mapping physiological responses (such as breathing or heart rate) into abstract metaphors in different modalities (e.g., visual and/or auditory), users are able to control their 'invisible' physiological signals [104, 148, 152]. Such abstract mapping has also been identified to a lesser extent in meditation technologies, where nature-based representations were more prevalent [38]. For example, *Inner Garden* [124] used the representational metaphor of Zen gardens by mapping breathing patterns to environment elements (sea, weather and time), while *Life Tree* [115] is a VR breathing intervention that supports users to control the growth of a virtual tree by practicing the pursed-lip breathing technique. Djokic and colleagues [44] proposed MetaVR, a conceptual design integrating VR and natural language processing in order to leverage embodied metaphors of verticality for multimodal interactions aimed to support wellbeing. Another example, is the design of Mindful Moments system integrates AR based feedback which leverages both abstract and representational visualizations with different complexity, as well as nature or man-made sound to explore their impact on mindfulness training [141]. Daudén Roquet and Sas [37] employed material speculation to identify embodied metaphors for different mindfulness states, i.e., being grounded, mind wandering, mindfulness and associated bodily experiences. They leveraged these metaphors to design *WarmMind* [38], a system delivering neurofeedback through thermal patterns to support subtle awareness of the meditation states, and attention regulation.

2.3 Emotional Metaphors and User Experience Trajectories

Metaphors support the understanding of abstract or new concepts through concrete terms. According to Lakoff [85], conceptual metaphors support 'understanding one domain in terms of another'. For example, the metaphor of *love as journey* involves the understanding of one domain of experience such as the emotion of *love*, in terms of another domain of experience, *journey*. We can talk about moving through time with the conceptual metaphor *time is space*, as if we were moving through space, allowing us to 'look back' on past events [16, 25, 121]. We are also able to think about the degree of intimacy in relationships in terms of physical proximity via the conceptual metaphor *social distance is spatial distance* [99, 166]. Metaphors enable us to understand the less tangible and thus less easily accessible target concepts (love, time, social distance) from the perspective of a more concrete or tangible and thus a more easily accessible source concept (journey, space, spatial distance).

Clinical psychotherapy has long-acknowledged the value of metaphors for supporting patients to better understand and regulate emotions [92]. For instance, when a patient describes their feeling of depression with the metaphor of 'walking in a black hole,' the therapist may provide an alternative metaphor such as 'walking in a tunnel.' The alternative metaphor acknowledges the current feelings but also introduces a new perspective to support regulation [81]. In light of the above insights, we asked ourselves if we can translate such emotion metaphors from their verbal modality into digital experiences to help people regulate their emotions.

Trajectories are based on the idea that users navigate paths through an experience, whether intentionally designed or occurring serendipitously [11]. Benford and colleagues [12], in their review of four interactive art experiences, suggest that trajectories tend to be continuous, extending backwards to reveal a coherent history, and forwards to suggest future actions and routes. These trajectories encompass various hybrid structures: *space*, *time*, *roles*, and *interfaces*. They also emphasized that continuity should be addressed with various transition considerations. In terms of *space*, technology offers a spectrum of possibilities for merging the real and virtual worlds. The *time* aspect combines story time, plot time, schedule time, interaction time, and perceived time, influencing the overall event timing. Hybrid *roles*, including participant and spectator for the public, and actor, operator, and orchestrator for professionals, define individual engagement. Moreover, multiple *interfaces* facilitate interaction and collaboration. Tennet and colleagues [142] extended this work on physical experiences to soma design which a focus on trajectory mapping of feelings (e.g., comfortable vs. uncomfortable, familiar vs. strange, inside vs. outside). They also pointed out that trajectories can map the emotional journey, akin to Russell's circumplex model of affect [125], thus navigating a path through different emotions. Our work aims to employ trajectory mapping in emotional journeys to support emotion regulation, a new research direction suggested by [133].

To summarize, previous work on emotion regulation technologies focused mostly on abstract metaphors mapping target heart or breath rate to audio/visual or haptic modalities for regulating primarily stress. Less work however has explored representational metaphors for regulating other negative emotional states, and their design rationale especially from the lens of emotional metaphor trajectories.

3 DESIGNING TOUCHEMOTION PROTOTYPES: EXEMPLARS FOR AR-BASED EMOTION REGULATION

We employed a Research-through-Design process [51, 169] to prototype TouchEmotion. The primary aim of our project is to explore the feasibility and potential of AR glasses to engage with audio-visual metaphorical emotional trajectories in support of emotion regulation. As such, our prototypes serve as proof of concept. We use the touchpad on the AR glasses as an example of touch input to facilitate physical interaction with these metaphorical trajectories. Admittedly, not all AR glasses come equipped with touch input. In this context, we consider 'touch input' as just one method of supporting users' engagement with metaphors; other gestural inputs could also be applicable (e.g., a connected mobile phone as the touch input, or a smart fidget ball as the gesture input).

Inspired by such work on trajectory experiences [8, 142], we were interested to explore how to design for metaphorical emotional trajectories, both in the form of audio-visual representations, and touch-based interactions.

Given the emerging space of on-the-spot emotion regulation technologies, particularly AR-based ones, we position TouchEmotion as a design exemplar, aimed to illustrate the design principle of emotional metaphorical trajectories, and inspire future design thinking in this area. Similar to previous approaches [39], we argue that such design exemplars are not design solutions ready to be explored in terms of effectiveness, but ather exploratory prototypes representing placeholders within this novel design space which can help us better understand it.

Next, we elaborate on how we selected the metaphors for each prototype and how we designed for their audio-visual metaphorical emotion trajectory experiences, along with the touch-interaction mechanisms. As an overview, for regulating anxiety, we draw from spiritual [138] and mindfulness practices [62, 105] and identified the lotus metaphor for calmness. For anger regulation, we looked at linguistic research on emotion metaphors [82] and conceptual metaphor theory [87] indicating the common association of anger with fire, and for its regulation we draw from research on the restorative qualities of nature [58, 108] in particular water. For regulating boredom, we draw from playful experiences [43, 96] and chose the analogy of popping bubble wrap bubbles. Each of these three conceptual designs and their rationale are further detailed in the next sections.

3.1 Lotus Metaphor: Regulating Anxiety

3.1.1 Lotus: Metaphor for Calm. Lotus is a commonly used metaphor in religious practices of different cultures. For examples, the Lotus pose (a cross-legged sitting meditation pose from ancient India) is used in yoga. The ninth-century Buddhist monument of Borobudur in Indonesia uses the lotus as the metaphor for being 'spiritually charged,' where different stages of life development correspond to images of the lotus flower [54]. In Buddhist culture, the lotus represents bodily and spiritual states: the blooming lotus symbolizes spiritual enlightenment, tranquil minds and self-awareness [138], as well as 'rebirth' and the creation of an ordered universe without chaos [159]. While more prominent in Easter spirituality, the sacred symbolism of lotus has been also acknowledged in other religious from ancient Egypt and Hinduism [100] to Christianity [14] indicating its value as cross-cultural symbol. Borrowing from these rich meanings, mindfulness practices have been developed to guide people towards imagining the lotus flower as opening and closing in rhythm with one's breathing [62, 105]. The lotus flower has also been used in HCI research on ER technologies [23, 84]. Beyond its spiritual meaning, lotus as a flower metaphor is also supported by research in environmental psychology showing the significant health benefits of natural environments for alleviating stress [108], and by clinical research on the benefits of nature-based interventions for anxiety [58]. We chose lotus as the metaphor for working toward calm from anxiety in our AR experience.

We also designed sound and music to support the visual metaphor of the lotus. Chang [19] analyzed Toshio Hosokawa's piece *'Lotus under a Moonlight'* highlighting that piano sound represents the lotus flower, the background instruments represent the water and nature, while a slow tempo evokes tranquility.

Inspired by such work, we chose to use a slow tempo in our sound design to convey a 'calm feeling' when depicting the lotus metaphor. We employed the piano to represent the lotus and used a string instrument to create the ambient sound. Additionally, we incorporated a zen-bell sound to represent 'self-awareness' when the lotus blooms. In this prototype, users can listen to a peaceful piano melody accompanied by string instrument harmonies. When users succeed in making a lotus bloom, a Zen bell will play as a rewarding sound effect.

3.1.2 Slow Continuous Finger Movement to Regulate Anxiety. When we surveyed anxiety interventions, such as mindfulness meditation [114], we found that slowing down movement [63] plays an important role in the process. In analogue approaches, effective mindfulness meditation strategies include slow breathing [63, 80], and slow walking [57]. HCI work has also leveraged slowness via slow continuous hand movement like those involved in mandala coloring [39], slow, continuous slow finger movement [21], or slow stroking movements [72]. In affective interfaces, people also prefer to personalize vibrotactile feedback for stress regulation with low frequency vibrations resembling slow heart rate [152]. Such previous research suggests the value of slowness for emotion regulation, since impatience or speed might induce anxiety [65]. Therefore, when designing for emotional trajectory experience to regulate anxiety, we metaphorically mapped the slow speed and continuous finger movement to the blooming state of the lotus flower. At the beginning of the emotional trajectory (Figure 4), we assume users are in anxious states (this system aims to be *user-initiated or for on-the-spot emotion regulation support*). Thus, we designed the initial state of the lotus as a closed state. In contrast to the closed state, the ideal final state of a less anxious or calm state is the lotus in an open state. We designed the canonical trajectories by guiding users to move their fingers in a slow and continuous circular motion on

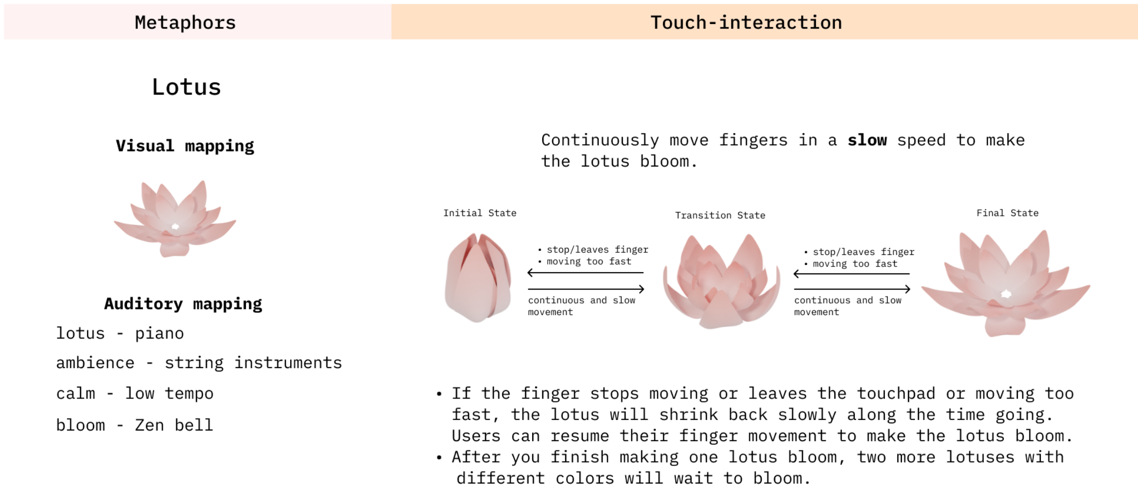

Fig. 4. Dynamic visual metaphor of Lotus consists of three states, including the initial state (closed lotus), the transition state (semi-opened lotus), and the final state (fully opened lotus). Users need to continuously move their fingers, at slow speed, in order to make the lotus bloom; otherwise, the lotus will close back.

the AR glasses touchpad. If they move too fast or stop, the lotus flower will close back to the initial state. We anticipate that this metaphorical emotional trajectory would help users reflect on their emotions and experientially learn that calmness can be achieved through slowness.

3.2 Fire Metaphor: Regulating Anger

3.2.1 Fire: Metaphor for Anger. Linguistic research on emotion metaphors, also shown their use across cultures, with anger metaphors including those such as *anger is hot fluid in a container*, *anger is a burden*, and *anger is a natural force*, and particularly *anger is fire* [82]. According to conceptual metaphor theory [87], the *anger is fire* metaphor maps anger to fire due to their similar features based on our embodied experience (anger springs up rapidly, heats up our bodies, can grow out of control). If anger can be metaphorically represented through fire, could a ‘fire extinguishing’ experience help regulate anger? To explore this, in our design, we represented fire in both visual and auditory modalities. When designing the beginning, ending, and transition states of this emotional trajectory, we integrated the visual animation of ‘burning fire’ (Figure 5), with the corresponding burning fire sound. For the initial state, we designed the audio-visual representation of rain as a metaphor to regulate anger. The design choice for representing water to extinguish fire was informed after considering and discarded other representations such as that of water being poured from a can which required pouring agent. Rain representation also provided the benefit of natural environment and its restorative quality [58, 108]. In the final state, we designed a scene where a fire is extinguished and small flowers (albeit not Lotus) bloom, symbolizing a transition to a less angry state. This is because blooming flowers are often seen as metaphors for positive emotions [66, 168]. In this context, the flowers serve as a general metaphorical concept, visualized as common four-petaled flowers in our design.

In this prototype, the sound of rain plays at the beginning of the experience. When the user succeeds in extinguishing the fire and making the flowers bloom, the sound of birds chirping will play as a rewarding sound effect.

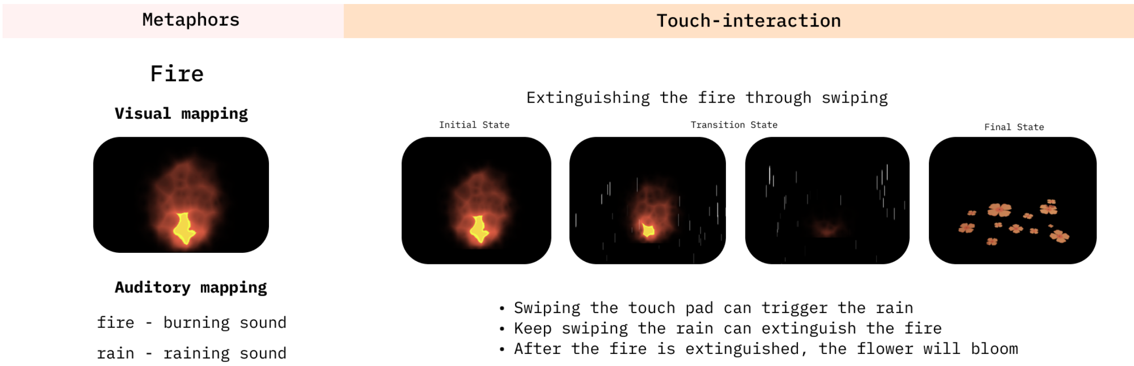

Fig. 5. Dynamic visual metaphor of Fire consists of three states, namely the initial state (burning fire), the transition state (falling rain triggered by swiping action with weaker fire), and the final state (fully extinguished fire with blooming flowers).

3.2.2 Swiping to Extinguish Fire and Regulate Anger. Among clinical interventions that involve the human body and its movement, effective ones for anger regulation include psychomotor therapy [10], and those leveraging physical activities such as exercise or sport [75]. Such activities for the regulation of anger are most beneficial when they involve bodily movements that do not resemble aggressive actions [116, 128]. These findings indicate the value of designing the finger movement for our touch-based interaction on the Spectacles' touchpad, possibly with more energy or speed, compared to the one designed for regulating anxiety. Based on these findings, we decided to use a free-form swiping action to support the regulation of anger. Users can press as hard as they like (though the Spectacles do not detect relative pressure), and can move at different speeds, although we envisage quicker movements compared to the ones for anxiety regulation. In this emotional trajectory, to achieve this final state, we invite users to swipe in order to trigger the rain which will extinguish the fire.

3.3 Bubble Popping Metaphor: Regulating Boredom

3.3.1 Bubble Popping: Supporting Surprise and Excitement. HCI research on games has shown the importance of surprise in designing for playful experiences [71] and of the latter as opportunities to alleviate boredom [9, 88]. Boredom is an ephemeral state, which may arise frequently in everyday life, so it is important to learn how to coexist with boredom and discover 'interesting aspects' within mundane objects or situations. Bubbles have the metaphorical meaning of transience, which is an apt way to represent the temporary arising of boredom. Therefore, we used bubbles as design opportunity to provide surprise and excitement as a means for regulating boredom. This design choice leverages the analogy with the rich experiential qualities of popping bubble wrap bubbles as a prototypical playful experience [96]. Previous work has also suggested that popping plastic or soap bubbles are experiences marked by physicality, agency, and multi-sensory qualities [43]. In this prototype, a chill music loop plays as background music. When users tap a bubble, a bubble pop sound effect is triggered.

3.3.2 Tapping for Bubble-popping to Regulate Boredom. With the intention of conveying the idea that *'we need to learn how to coexist with boredom and discover 'interesting aspects' within mundane objects or situations,'* we designed bubbles in different colors to represent the notion that seemingly boring things might be interesting if we pay attention to

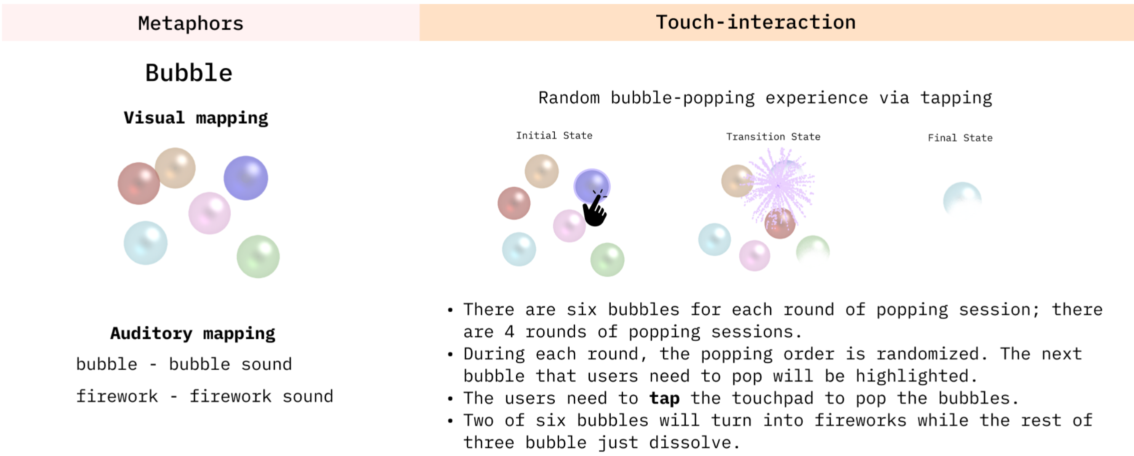

Fig. 6. Dynamic visual metaphor of Bubble consists of three states, including the initial state (six floating bubbles), the transition state (two of six bubbles will turn into fireworks while the rest of four bubbles will merely dissolve by tapping actions), and the final state (all bubbles are dissolved).

them. Additionally, we incorporated a ‘surprise’ element after popping the bubble to communicate that what appears mundane might hold unexpected delights.

In our visual design, we decided to use multiple bubbles of different colors: red, orange, yellow, green, purple, and pink, shown simultaneously. We tested out putting different numbers of bubbles within view, and found out that 6 offers a sweet spot: the largest number we can use before the view becomes crowded. For stimulation purposes, we choose a bright color palette. The bubbles are all 1cm in diameter. In the initial state of the emotional trajectory experience, there are six colorful bubbles floating around. By tapping a random bubble, a fireworks effect occurs, and the color of the fireworks matches the bubble from which it emerges. To introduce ‘surprise’ in the metaphorical emotional trajectory, we implemented a randomized popping order based on tapping input. Our design incorporates two layers of randomness to represent ‘surprise.’ Each round of the popping session consists of six bubbles, and there are a total of four rounds (Figure 6). The first layer of randomness introduces a randomized popping order for each of the six bubbles throughout the four rounds. In other words, users will not know which bubble will be popped next. The second layer of randomness involves randomly selecting two out of the six bubbles to reveal fireworks when popped, while the remaining four bubbles simply dissolve. In the end, all the bubbles popped, symbolizing the disappearance of boredom.

4 PROTOTYPE IMPLEMENTATION

In order to develop the TouchEmotion prototypes we created 2d assets with a combination of Figma[2] and Blender[3]. In addition, we also used developed animated gifs in Adobe After Effect[4] Music was generated with Logic Pro[5], and ambient sound used in AR experiences was sourced from online sound library[6]. Finally, we used Snap Lens Studio[7] to

[2]https://www.figma.com/
[3]https://www.blender.org
[4]https://www.adobe.com/products/aftereffects.html
[5]https://www.apple.com/logic-pro/
[6]https://freesound.org/
[7]https://ar.snap.com/en-US/lens-studio

prototype (compose all these assets and make them interactive based on design decisions) the Lotus, Fire, and Bubble experiences. Additional details for the implementation of each prototypes are further provided.

4.1 Lotus Prototype

In order to detect the dynamics of the finger movement, such as whether it is continuously moving, whether it is fast, slow or it stops moving, we tracked the touch input on the Spectacles' touchpad. For this, we calculated the touch position change per frame to detect the finger movement. The touchpad's coordinates range from 0 to 1 unit. We also tested which values of change per frame are perceived as slow, or as fast, and determined the following two ranges of values: 0.02 - 0.15 unit/frame are perceived as slow movement of finger on touchpad, and over 0.8 unit/frame are perceived as fast. In addition, we also explored what values of change per frame are suited to represent the speed of flower opening, and closing. We found that the range: 0.15 - 0.8 unit/frame as appropriate.

To detect whether the finger has stopped its movement, we determined if the touchpad's coordinate remained unchanged for five consecutive frames (an ideal number after trial and error). If so, we classified it as stopped movement. We identified a finger's movement as continuous, for as long as the touchpad is touched, and the finger has not stopped moving. For implementing flower blooming, and flower opening in real-time with finger touch, we programmed the play forward of the animation of lotus blooming which was initiated when a slow, and continuous movement of finger was detected. We also programmed flower closing in real-time with finger touch, by playing in reverse the animation of lotus blooming. This was initiated when the finger's movement was detected as fast or when it stopped. Regard sound, users can listen to a peaceful piano melody accompanied by string instrument harmonies while interacting with the lotus interface, and when they succeed in making a lotus flower bloom, a Zen bell will play.

4.2 Fire Prototype

The interaction mechanism for the Fire prototype is straightforward: when the finger is swiping, the rain will be triggered; as the user swipes, the fire will be extinguished a bit; after the fire is fully extinguished, the flowers will bloom (Figure 5).

We detected the user's swipe when their finger moved from the left side to the right side or vice versa by calculating the x-axis value. For more engaging animations of fire, we used shader graph within fire effects to transform a simple flame texture into one of a burning fire. We have also used a series of noise nodes, and color ramp, as well as a 'fade' parameter within the shader graph that multiplies the noise to control the volume of fire. Then we changed the 'fade' parameter of the fire to make it gradually disappear when the touchpad detected the finger swipes.

We also downloaded a rain sound and a bush fire recording from a free sound website[8]. In order to make the ambient sounds more natural and avoid the feeling of looping the same sound source, we added a dynamic envelope in Logic Pro [9] ensuring also that the volume varies in time.

4.3 Bubble Prototype

To represent bubbles, we used simple spheres as the meshes for the bubbles, and six materials in different colors were applied to the bubble meshes. A transparent material was used for each bubble, and we applied six textures with six different colors to them. In each round, when users tap a bubble, we used a random number generator within the range

[8]https://freesound.org
[9]https://www.apple.com/logic-pro

of 0 to the number of existing bubbles. The randomly generated one will be tapped. We wrote a shader for achieving a dissolving effect; fireworks animations were rendered in Blender with the particle system for a flame effect.

With respect to sounds, we chose the bubble pop sound, and firework sound from an online sound library[10]. The randomness of the bubble popping interaction was implemented with a shuffle function, which ensured the random selection of the next bubble to be popped.

5 PILOT USER STUDY

After finishing the prototyping, we ran a pilot session in the lab, in which we sought to get feedback and suggestions for how to refine the AR experiences. Six lab members tried the three prototypes on the Spectacles. We acknowledge the trade-off of the low cost of such a convenience sample, with the risk of positivity bias as participants close to researcher may aim to please. To mitigate this, participants' emotional reactions were also observed while interacting with the prototypes, in addition to being asked to describe their experiences with each prototype, in particular how their designs could be improved by pointing out perceived limitations.

Based on their feedback, we made some adjustments to the timing of the Lotus interaction. We realized that people needed about 1 minute to fully experience the opening and closing of each lotus flower–anything longer felt too long for a single flower. In order to extend the full experience of this prototype and ensure more enduring engagement, we decided to design the experience as consisting of a sequence of 3 lotus flowers that people can open up, one at a time.

In terms of the Fire prototype, lab members mentioned that the speed of fire being extinguished was too fast so that the experience ended before they actually felt any emotional change. They also pointed out that dealing with anger is difficult, because sometimes anger is still there even though they took efforts to pour out the 'fire'. Such feedback inspired us to realize that regulating anger may be a non-linear process, whose speed decreases in time. Thus, we decided to design for such non-linearity of putting out the fire; specifically, the fire-extinguishing speed will be faster initially and slower in the end. Behaviour research and therapy studies [140] have pointed out that acceptance strategy is an effective approach to regulating anger. Through such non-linear design, we hoped users would feel a sense of uncontrollability when it comes to regulating anger, and then learn how to accept experiencing the anger fully as a normal response without trying to tightly control it.

For the Bubble prototype, our intention was to let users pop the bubbles randomly to support their surprise or boredom alleviation. However, people said that they were confused about which bubble would pop next, and wanted the AR prototypes to give them an indication. To satisfy their expectations, in the next iteration, we iteratively highlighted each of the next bubbles to pop. Some lab members also preferred to have some preparation time for familiarizing themselves with the prototypes, so we added a 15 second intro loading animation, to give people time to prepare for the real interaction experience.

6 FORMATIVE USER STUDY

To explore the feasibility and potential of our 3 interactive prototypes for emotion regulation, we conducted a formative user study in which each participant interacted with each prototype. The study also included interviews for collecting participants' thoughts and feelings about the AR prototypes, and self-reported measures of emotions, captured using PANAS, a valid and reliable questionnaire consisting of 20 items (10 positive and 10 negative emotions) rated on a 5-point Likert scale [162]. The main objective of the study was to gather participants' feedback about the metaphorical

[10]https://freesound.org

emotional trajectory experience and determine whether and how audio-visual metaphors with touch-based interactions may support the regulation of three discrete emotions of anxiety, anger and boredom.

It is important to note that our study should not be viewed as a summative evaluation, but rather as a part of the design process aimed at eliciting rich response from participants toward understanding and revising the design space that the current prototypes begin to explore. More specifically, our within subject design involved a single group with before and after measurements of emotional states, representing thus a pre-experiment best suited for "exploratory aims, formative evaluation (improving what you do) and trying out new ideas, rather than robust impact evaluation" [68]. In other words, our prototypes are foremost intended to probe a less explored design space [15, 77, 126] so that we can investigate their feasibility, lower the risks of failure associated with premature summative evaluation, in order to "*learn about the ingredients of a successful solution*" [68] rather than making claims about their effectiveness. In addition, given the novelty of our prototypes and their less explored design space, finding a suitable existing system to be used with a control group is not trivial. A similar argument has been made for the SelVReflect system, also explored through a pre-experiment which can inform future work on similar systems and their evaluation through experimental studies [157]. Pre-experiments have been used in HCI to explore for instance attention regulation [39, 97] or reflection [157] being much needed to help us answer first questions such as *why and how different designs could work*, before asking *if they do work* [15, 68, 77, 126]. Future work could focus on the exploration of the effectiveness of our revised prototypes.

6.1 Participants

We recruited 18 participants through university mailing lists and posters around campus, 7 identified as women, 10 as men, 1 as unstated; age range between 22 to 31, with average age of 24.56; 12 participants had previous game design experience while the remaining 6 participants had no such experience. In addition, only 6 participants had previous AR experience.

6.2 Procedure

Participants were initially introduced to the AR glasses, their functionalities, and the touch interactions for each prototype. The study comprised of seven parts: (1) emotion elicitation, (2) pre-interaction self-report of emotional state using The Positive and Negative Affect Schedule (PANAS)questionnaire [162] , (3) interaction with one of the three AR prototypes, (4) post-interaction self-report of emotional state using the PANAS, (5) interview regarding the experience with the specific prototype, and (6) rest period. Parts 1-6 were repeated three times, corresponding to each prototype, with the order of shown prototypes varied to counteract order effect, followed by (7) final interviews (Figure 7).

Developed on non-clinical populations [162], PANAS consists of 20 items (10 positive emotions and 10 negative emotions) measured on a 5-point Likert scale. By capturing general descriptors of positive and negative emotions, PANAS can also capture those pertaining to depression or anxiety [102]. The scale has strong psychometric properties of reliability and validity as shown in studies with both non-clinical [33] and clinical populations [45], and has been extensively used in emotion research [160] including emotion regulation [119]. PANAS scale has been also much used in HCI research as shown by a recent systematic review of affective haptic systems [155]. As mentioned earlier, we did not have a control condition in this study, because we were not yet conducting a summative evaluation of the effectiveness of a finished system. Rather, we aimed to engage participants in a set of prototyped experiences in order to elicit rich feedback that could inform future design and insight about this novel design space.

The emotion elicitation phase of the study was included, because we wanted to have participants experiencing the prototyped designs in an emotional state that was closer to the target use case. We chose, however, to conduct the

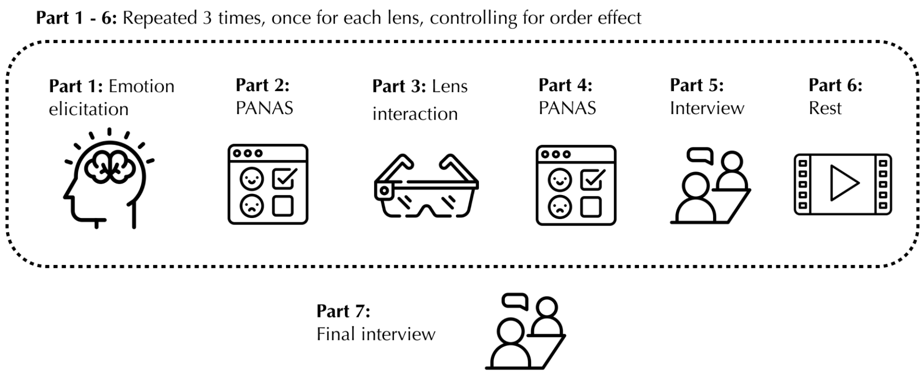

Fig. 7. Study procedure consisting of seven parts (Icons: ©Flaticon © Freepik): (1) emotion elicitation, (3) interaction with one of the AR prototypes, which was both preceded (2) and followed (4) by self report measures of emotional state using the PANAS questionnaire, (5) interview about the experience with that specific prototype, and (6) rest time. Parts 1-6 were repeated three times, one for each prototype, while accounting for the order effect. The study concluded with a final interview (7).

formative study in the lab, rather than out in participants' environments, because it was more practical to support the device, and to ensure that participants had a similar set of basic experiences on which to provide feedback.

Emotion researchers have developed various methods for eliciting emotions, including external stimuli like photos or videos, and internally generated emotions through the recall of autobiographical memories [74, 123]. To help ensure that participants were in the emotional state targeted by each prototype, we employed a standard emotional elicitation method. Participants were asked to recall autobiographical memories related to anxiety for the Lotus prototype, and anger for the Fire prototype. In order to protect participants and to prevent potential retrieval of traumatic memories, we asked participants to recall medium rather than high intensity emotional experiences of anxiety or anger. For eliciting boredom, we utilized a video featuring a monotonous tutorial on Microsoft Word [11], based on previous research which suggested its effectiveness in eliciting boredom compared to the memory elicitation method [98].

After interacting separately with each one of the three prototypes, and completing the PANAS questionnaire, both before and after each prototype, we interviewed each participant about their experience with that specific prototype, its visualization, and touch-based interaction, the emotional changes that they may have experienced, and any usability issues. Before experiencing each prototype, participants were assigned a rest task. This is a standard post-elicitation task providing time for cooling down and for resetting emotional state to a baseline [91]. For this, we used a video depicting nature content, i.e., coral reefs and sea life, since previous findings indicated that watching such relaxing, aquatic content leads to better recovery from negative affect, compared to sitting quietly [117]. After participants experienced the three prototypes, we conducted a final interview asking them to compare their experiences across the three prototypes, and about the use cases in everyday life of AR glasses as well as the three prototypes. The whole study lasted around 1 hour, with no time gap between the parts described in Figure 7. To eliminate the order effect, 18 participants were equally assigned to different sequences: Lotus - Fire - Bubble, Lotus - Bubble - Fire, Bubble - Lotus - Fire, Bubble - Fire - Lotus, Fire - Lotus - Bubble, and Fire - Bubble - Lotus.

[11] https://vimeo.com/685986455

6.3 Data Analysis

Interviews were fully transcribed, and analyzed using Atlas/ti [135] using grounded theory approach [139]. In order to develop a codebook, two coders first performed open-coding on five randomly selected interviews, identifying and labeling similarities across participants' experiences with Lotus, Fire, and Bubble prototypes. Such initial codes included those on users' understanding of emotional metaphors such as the mapping of lotus to calm or anger to fire, and of different touch-based interactions for regulating the three emotions. We also noticed participants highlighting design features they enjoyed experiencing such as low intensity color and sounds of Lotus prototype, and the slow movement of interacting with it, or the stimulation of Bubble interface. The initial codes were iteratively revised through conversations within the research team, and by coding the remaining transcripts, cleaning the redundant codes and merging similar codes. Thus, we revised the codebook weekly for several months to ensure consensus. At the last stage, we also followed an iterative approach while performing axial coding where we organized the codes within broader emerging themes, and identified respective quotes under these themes as detailed in Findings section.

6.4 Positionality and Reflexivity

We acknowledge that no research is value free [129] and that positionality is important particularly for qualitative research concerning wellbeing or mental health technologies [73]. Here, we reflect on our positionality and its potential impact on how we have approached our research. The first author has a background in computer music, game design and HCI, with a focus on the design and implementation of interactive experiences to support emotional expression and emotion regulation through AR, VR, and video games. The second author has background in HCI and expertise in interaction design for affective health, particularly for emotional awareness, regulation, as well as mindfulness technologies and their metaphor-based interfaces. The third author has a research practice at the intersection of games and HCI, taking a Research through Design approach to designing prototypes of technologies to support social and emotional wellbeing and thriving. All authors work in a Western context, reflecting WEIRD variables with study participants: Western, education, industrialized, rich and democratic [95]. With respect to research methods, the authors have a rich collective experience of mixed methods. While the first author has less experience with qualitative methods, the second and third authors have extensively used qualitative methods and data analysis. Potential biases in data analysis due to researchers' values grounded in their respective research expertise were mitigated in part by the first author's initial engagement in the analysis of lived experiences of emotion regulation, thus likely to bring forward fresh, less biased perspectives, and in part by the other authors' expertise in conducting, and reflecting on qualitative data analysis and outcomes.

7 FINDINGS

Here we present initial results of participants experiencing the three prototypes in our formative study. These findings are not meant as summative evaluation of the effectiveness of a completed product, but rather, insights about the design space that these prototypes explore. In addition to describing participants' perception of each prototype, in this section we also examine the perceived social aspects of their engagement with the prototypes.

7.1 Lotus Prototype: Impact on Reducing Anxiety

7.1.1 Blooming Lotus: Visual Metaphor for Awareness of and Regulation of Anxiety. Most participants reported that they perceived the images of the lotus flower as representation of their emotional states, and that, through changing the shape of the lotus, participants felt they were changing their emotional states.

For example, seven participants (P1, P2, P7, P10, P11, P13, P16) mentioned that they projected themselves onto the lotus flower and watching how the lotus looks like and how was transforming helped them 'see' their emotional states. For instance, 3 participants (P2, P9, P10) described feeling tenseness in their chests at the start of their interaction with the Lotus prototype, when they were anxious following the anxiety elicitation stage; and how such tenseness mapped well to the lotus's initial closed state. Other participants mentioned that the lotus flower reminded them of their current emotional state: *seeing the lotus flower and the little circle around [...] made me aware that I was physically being impatient*' (P11). In contrast, the lotus blooming was perceived like opening the body to let go of anxiety: '*I got was like, coming out of my shell a bit [...] or like opening up*' (P2). These findings suggest that participants understood both the mapping of the lotus to their anxiety state, as well as how the changes in the shape of the flower mapped to their regulation of anxiety: from the closed lotus or anxious state, to blooming lotus or an improved emotional state. Through such mappings, participants were able to witness the materialization of the usually hidden process of emotion regulation into the changing of the shape of the lotus flower from closed to open.

7.1.2 'Muted' Visual and Auditory Elements Support Anxiety Regulation. Interview outcomes indicate participants' overall appreciation for the low intensity colors and sounds in the Lotus prototype. For instance, six participants reported that they enjoyed the low contrast colors of the lotus flowers: '*I liked how light they were*' (P2). '*I think the color is good. It's the low contrast color, and it also helps me calm down*' (P17). One participant mentioned that the round shape of the lotus petals also evoked pleasant feelings: '*I also like the shape [...] each petal of the lotus is kind of round, is not very pointed, it makes me feel good*' (P7). Such findings suggest that the roundness and muted colors of the lotus flowers support anxiety regulation which echo previous findings on affect regulation [150].

Most participants also mentioned the link between calmness and the sound aspects of the Lotus prototype. Indeed, twelve participants reported that they felt more calm when listening to the slow-paced music during their experience of the Lotus prototype: '*focus on the lotus and it's almost like magic. And the music also helps me feel calm*' (P4).

7.1.3 Slow Movement-based Interaction For Regulating Anxiety. Findings indicate that after trying out the finger interaction on the Lotus prototype, participants gradually built an understanding of how controlling their finger movement led to changes in the shape of the lotus: continuous and slow finger movements would lead to the lotus blooming, but fast or discontinuous movement would lead to the lotus closing up. Participants reported on the importance of paying attention to such movement and its continuity: *'[the lotus] would sometimes close up if I kind of like stopped. Thought is like, if you lose your focus, something you stop [the louts] just shrinks back*' (P11). Participants also highlighted the importance of slow finger movement on the Spectacles' touchpad for instance by synchronizing it with their slow breathing in order to make the lotus bloom:*'I really focused on the way it was opening up. Let me breathe and totally kind of reach this state of calm [...] just being aware of what's in the moment [and] that I'm better than I was*' (P2).

Interestingly, some participants mentioned mapping their in and out breathing to the lotus flower closing and opening, then discarding this mapping when they realized that slow finger movement was sufficient for maintaining the lotus flower open: *'Because focusing our breathing, I thought it was breathing to certain extent, with it shrinking and growing back up'* (P2). The experience enables users to learn experientially that slowness leads to the blooming of the lotus, symbolizing calmness. This suggests their understanding of the metaphorical emotional trajectory (from closed lotus to opening lotus).

By collecting participants' pre and post self reports of their emotional state with each prototype, we were able to triangulate our qualitative findings with quantitative ones. For this, we ran three one-way repeated measures Multivariate Analysis of variance (MANOVA) test, with Time as independent variable, with two levels: before and after the use of each prototype, and three dependent variables as PANAS aggregate scores for anxiety, anger, and boredom, respectively.

For anxiety, we computed its aggregate score by averaging the ratings of 4 PANAS items: scared, nervous, jittery, afraid. This decision was grounded on previous findings such as the 'afraid factor' identified through empirical exploration of the factorial structure of PANAS model [102], as well as items from the 'fear scale' from the 60-item PANAS-X questionnaire [161]. The MANOVA test showed $F(3, 15) = 24.83, p < .001$), and that the Lotus prototype led to significantly lower anxiety ($F(1, 17) = 81.83, p < .001, \eta_p^2 = .83$)

from the value of $M = 3.35, SD = 0.85$ to the value of $M = 1.76, SD = 0.68$, supporting the effectiveness of the Lotus prototype for regulating anxiety as highlighted in users' experiences described above.

7.2 Fire Prototype: Impact on Reducing Anger

7.2.1 Extinguishing Fire: Visual Metaphor for Awareness of and Regulation of Anger. Most participants reported that they interpreted the representation of fire as their anger: ' *I'm aware that the fire felt like a symbolic representation to me [...] I felt myself concentrating [...] like my anger [was] the fire*' (P2). Most participants also understood the value of rain in extinguishing fire, as a representation of them calming their anger: '*[Fire] felt very symbolic. The flame that I was looking at was a visual representation of what I was actually feeling [elicited anger]. And that rain was supposed to, over time kind of just start to light [anger] out, until it eventually died out'* (P11). In contrast to the other prototypes, participants did not make specific comments about the visual and sound qualities of the fire and rain elements, as such.

7.2.2 Swiping Movement-based Interaction for Regulating Anger. Compared to the interaction mechanisms for the Lotus and Bubble prototypes, the one for the Fire prototype was perceived as less intuitive by some participants, especially those who increased the speed of swiping. For example, P2 mentioned: '*I thought that rubbing fast would make more pouring rain and drown [...] the fire [...] but it didn't feel like it*' (P2). This led these participants to experience a less clear mapping between their swiping actions and the rain extinguishing the fire: *I hope there is more responsiveness based on touching interaction*' (P8). Indeed, for the design of the swiping-based interaction, we deliberately did not account for changes in swiping speed, as previous research has shown, aggressive bodily movements have been suggested as counterproductive for anger regulation [116, 128].

An interesting outcome is that because of this challenge, participants perceived that they may have limited control over their anger, or in other words, limited control over extinguishing the fire through increased swiping speed which did not work: '*It was different from how I thought it was gonna be. I want more control, but I didn't have control of the situation*' (P11).

In turn, they learned to *accept their anger*: '*I was more like, instead of [being] angry [say] Okay, it's fine*' (P2). Interestingly, this allowed them to down regulate anger: *I probably am still angry but in a nice way; just controlling it [while] playing with your anger.*' Such findings suggest that when people engage with their metaphorical emotional trajectory such as extinguishing the fire, they gain awareness of anger, acceptance of it and ability to regulate it. Moreover, one participant, a student counselor, suggested that the Fire prototype may be a counseling tool:'*you can't* *always have immediate gratification [so the Fire prototype can better support the visceral understanding of] 'something being out of our control'* (P2).

In our MANOVA test we also included as a dependent variable an aggregate anger score which we computed by averaging the ratings of 2 PANAS items: hostile and irritable. This decision was based on previous findings which identified these two emotions among anger's related emotions [90], as well as among those from the 'hostility scale' from the 60-item PANAS-X questionnaire [161]. Results showed a significant multivariate effect of time, ($F(3, 15) = 15.99, p < .001$) and that the Fire prototype led to significantly lower anger after using it ($F(1, 17) = 45.91, p < .001, \eta_p^2 = .73$) from the value of $M = 2.72, SD = 0.94$ to $M = 1.78, SD = 0.75$, indicating the potential of this prototype for regulating anger.

7.3 Bubble Prototype: Impact on Alleviating Boredom

7.3.1 Bubble Popping: Visual Metaphor for Awareness of and Regulation of Boredom. Findings indicate that most participants interpreted the bubble representations as akin to bubble wrap and the overall experience as an AR version of popping bubble wrap. The popping of bubbles was perceived as playful and enjoyable by several participants, as in this illustrative quote: *'enjoyment and awe in things from childhood [...] When you get older, you're expected to be serious, not to find joy in little things [...] but here I am, able to play with bubbles all day'* (P10).

7.3.2 Sensory Richness: Colours and Animations Support Boredom Regulation. Most participants reported that the bubbles were visually stimulating.

In particular the variety of bubbles' five colors, motion (bubbles floating), and unexpected animation (bubble popping and turning into fireworks) were key in supporting an interesting experience while interacting with the Bubble prototype. Specifically, four participants (P5, P7, P9, P10) reported that they enjoyed the richness of the Bubble prototype through its different five colors: *'I really liked this one, because that gives me like more color than the previous two (prototypes)'* (P7). In addition, six participants (P2, P5, P7, P8, P10, P15) mentioned that they liked the motion of the bubbles: '*this low movements of bubbles [I like it] that they were not [...] fixed [but] moving slowly; that's what I liked*' (P5). Nine participants (P0, P1, P5, P7, P10, P11, P15, P16, P17) reported that they also liked the visual effects of the fireworks explosion after a bubble faded away: '*I like explosion particles. That was the main thing, seeing kind of like, trail down [...] You know, see how beautiful they are? pretty'* (P2). When asked about how the Bubble prototype could be improved, participants requested further richness, through even more colors, different bubble sizes, and visual effects: '*maybe more effects, maybe like different, different things could happen with the bubbles*' (P10), '*I liked how light they were. I mean, I do wish there was like some darker ones just kind of like a variety [...] Yeah, and then also with the shape, I thought they were relatively the same size. Maybe like one a little bit smaller or bigger*' (P2).

7.3.3 Tapping-based Interaction to Pop Bubbles for Regulating Boredom. An interesting finding is the perceived high affordance of the tapping for interacting with bubbles. In particular, participants perceived bubbles as their boredom state, and tapping-based interaction as a way to engage with, and alleviate boredom (P11, P13). For example P2 mentioned: '*I was [...] trying to play with [bubbles and] see what happens*'. The curiosity triggered by the visual elements of the Bubble prototype motivated participants to engage in tapping behaviour. Moreover, the random visual elements of fireworks showing up after popping the bubbles further captured participants' interest and curiosity, as illustrated in the following quote: '*the visual changes and seeing the bubbles explode was what influenced my touch [such as] let me tap once to see what happens, and then tap again and then tap faster, and then it's sort of like seeing that reaction*' (P2). Many participants reported that they were *curious* about what would happen after popping the bubble: '*I really enjoyed that. And I didn't realize that because I was analyzing what bubble I was trying to pop and how I was doing that. I realized it* *makes me being alert*' (P11). These quotes indicate that value of the emotional trajectory of interacting with the bubbles: interest in their sensory richness, augmented by the surprising quality of their randomness explosion as fireworks.

In our MANOVA test we also included as a third dependent variable the aggregate non-boredom score which we computed by averaging the ratings of 4 PANAS items: interested, alert, attentive, and determined. For this decision we leveraged previous work describing boredom as limited focused attention and interest [36, 47]. MANOVA results indicate a significant multivariate effect of time ($F(3, 15) = 8.48, p = .002$), and that the Bubble prototype led to significant increase in non-boredom ($F(1, 17) = 24.54, p < .001, \eta_p^2 = .59$) from the value of $M = 1.50, SD = 0.54$ to $M = 2.54, SD = 0.82$. These outcomes support the value of Bubble prototype for regulating boredom.

7.4 Envisaged Sociality: Daily Life, Contexts, Shared Experiences with TouchEmotion

This section describes participants' views on how they may envisage the use of the TouchEmotion prototype in their lives, highlighting issues of privacy across social contexts, and of shared experiences.

7.4.1 Daily Life Use. Findings indicate participants' appreciation for AR technology illustrated by the TouchEmotion prototype in terms of wearability, ability to blend virtual and physical realities, and to create a space for emotion regulation in daily life. In terms of wearability, some participants liked the light, portable size of Snap spectacles. Findings indicate that its portable size is a key factor for some participants and thus, for using TouchEmotion in daily life: *'it's just like a pair of glasses for myself* (P2), while others expressed dislike of their appearance as *'weird glasses*'. The ability of AR for blending the virtual and physical reality was valued by participants, particularly for supporting emotion regulation. For example, P10 mentioned: *'I've been reading about [AR] I think this is just cool technology for emotion regulation'* (P10). Within this blended reality, participants noted the value of accessing a proximal, immersive place for emotion regulation: *I probably use it [...] let me put [AR glasses] on [...] do that sort of mental zone out with it'* (P2).

7.4.2 Social Contexts: Privacy. Findings indicate mixed views with respect to the envisaged social contexts for using the TouchEmotion prototype. On the one hand, some participants (P1, P4, P6, P14, P15, P17) felt comfortable and expressed willingness to use TouchEmotion in public spaces such as those for leisure *'I imagine being in a coffee shop would be a nice experience'* (P4), study or work: *'I can use this for example when we finish one course, or a meeting we want to be inspired to work on... you might want to use this to help you to keep awake'* (P14). On the other hand, some participants mentioned that using them in social settings may be problematic (P3, P5, P7, P10, P12). This could be because regulating emotions in public may be imposing: *'don't want to bother others'* (P5), or due to perceived inappropriateness and potential embarrassment given their look and feel as heavily styled sunglasses (Figure 2) *'feel conscious about wearing weird glasses*' (P10).

An important finding however is the impact of the type of discrete emotion being regulated on the social context of using the TouchEmotion prototype, in particular their willingness to use it in public or private spaces, i.e., own bedroom (P2). Thus, some participants (P0, P2, P9) did not mind the idea of using the Bubble prototype in public spaces but would prefer using the Lotus and Fire prototypes in private, as they consider anger and anxiety more private emotions: *'for feelings like anger and anxiety, I would prefer to be alone, but for boredom, being around others could be entertaining'*. This is interesting, highlighting limited socially acceptance of negative emotions.

7.4.3 Shared Experiences. We also explored whether and how participants might want to share their emotion regulation experiences with others. Findings indicate three reasons for sharing such experiences: to increase others' awareness of their emotional states, to legitimize the efforts required for regulation of negative emotions, especially anger and anxiety, in order to elicit emotional support, and to co-regulate these emotions. For example, some participants mentioned that TouchEmotion prototypes offer an implicit way to share feelings: '*sometimes we have to [...] express our feelings [and the prototypes] can show [them] okay today I'm a little bit bored, so I'm just going to explode this small bubbles [...] so don't come to me you know I will do that.'* (P5). Other participants pointed out that sharing these emotion-relevant interactive experiences could also help communicate the need for emotional support from friends (P8).

Participants also indicated that emotion regulation is taxing, and such effort can be shared, so that it is legitimized and supported: *'I would love for my parents to be able to see [...] because they [...] think that I don't try to like regulate my anger. But I think if they actually saw me working hard and like trying to be better than maybe they would be nicer about it'* (P12).

An interesting rationale for sharing the experience of using the prototypes was mentioned for the purpose of coregulation particularly of anger within close relationships such as romantic or familial ones: '*It might be good for couples, honestly. I could see it being used in couples therapy* ' (P3).

8 DISCUSSION

We now revisit our research questions in light of our key findings, articulate their novelty, and conclude with advancing a design space for on-the-spot emotion regulation technologies.

8.1 Audio-visual Metaphors for Regulating Negative Emotions

The first research question focused on audio-visual metaphors for supporting regulation of negative emotional states of anxiety, anger, and boredom. Our findings indicate the value of the Lotus, Fire and Bubble prototypes and their metaphors to support awareness of, and regulation of anxiety, anger, and boredom respectively. In particular, they show the value of mapping the changes of lotus flower from closed to open in order to change the emotional state of anxiety to calm, a design for which we draw inspiration from Buddhist meditation tradition [54, 58, 138, 159], the value of extinguishing fire to regulate anger for which we leveraged emotional metaphors for linguistics [82] and conceptual metaphor theory [87], and the value of popping bubbles to regulate boredom for which we leveraged the value of surprise and playfulness [9, 71, 88] of popping bubble wrap bubbles [43, 96].

In terms of specific qualities of these audio-visual metaphors, findings showed the value of muted colors and low tempo music [19] and zen-bell sound to signal effective anxiety regulation, of rain and fire sound to regulate anger, and of sensory richness reflected in bubbles' bright colors, random popping order, and surprising animation (i.e., random fireworks following the popping of a few bubbles) for boredom regulation. From the pilot study, we also learned about the temporality (duration and frequency) and agency of these microinterventions for emotion regulation, so that for Lotus prototype we used 3 flowers to extend the interaction to 3 minutes, and for Fire prototype we used a non linear pattern for extinguishing fire which is slower at start. In addition, for Bubble prototype we balanced surprise and agency, by highlighting the next bubble that user could pop. While most prior work has focused on audio-visual metaphors for affective interfaces aimed to support stress regulation [148, 152], or for mindfulness interfaces [22, 26], our work presents novel findings which extend such efforts in three new directions concerning (i) less explored regulation of anger and boredom, (ii) the value of lotus metaphor for regulating anxiety, and (iii) the importance of articulating the design rationale for these metaphors. First, we explored also the regulation of two other less investigated discrete emotions [46, 101] of anger and boredom. In particular, we extended work on emotion regulation technologies, from those focusing mostly on high arousal negative emotions, i.e., stress, to those for regulating negative emotions with different levels of arousal [125]: anxiety and anger are high arousal, while boredom is low arousal emotion. Second, while lotus metaphor has been previously explored in mindfulness technologies for instance through the mapping of closed and open lotus flower to inhale and exhale, respectively [22] our work extends such mapping to regulation of anxiety. Third, we also extend previously limited work [37] on the value of articulating the design rationale of mapping the changes of emotional states to changes in metaphorical representations. Furthermore, we argue that users' perceived value of our metaphorical representations is grounded in our sensitive design which provided suitable materializations for the representation of these negative emotions and more importantly of the positive ones ensured by regulating them.

Our findings suggest the value of such audio-visual metaphors for supporting regulation of different negative discrete emotions, both high and low arousal ones. This opens up design opportunities for audio-visual metaphors of a broader range of negative emotions [125] particularly less explored low arousal ones such as sadness or grief [128].

8.2 Touch-based Interactions for Regulating Negative Emotions

Our second research question focused on designing touch-based interactions on AR glasses' touchpad to support users' engagement in metaphorical emotional trajectories for regulating anxiety, anger, and boredom. Our findings indicate the particular value of slow and continuous movement for anxiety regulation, and its learnability, as users understood that both speed (slow rather than fast) and continuity (continuous rather than paused movement) matter for enacting the metaphorical emotional trajectory of opening the lotus flower. For this design, we draw inspiration from mindfulness meditation research showing the value of slowness [114] reflected in both breathing [63, 80] and body movement such as walking [57]. Our findings also echo previous HCI ones emphasizing the benefit of both slow [21, 39, 72] and continuous hand or finger movement [21, 39], or of vibrotactile feedback for slow heart rate [152] or slow breathing [104] to regulate stress. With our novel findings, we extend this body of work towards leveraging slow continuous movement as touch-based interaction for engaging with the audio-visual metaphor of lotus flower blooming as part of metaphorical emotional trajectory for anxiety regulation. Interestingly, our findings indicate the potential of slow breathing to be leveraged in the design of this trajectory albeit not for direct mapping of breathing patterns to flower opening and closing as previously explored [22] but for broader regulation of anxiety. This opens up novel opportunities for integrating biosensors in AR-based technologies for emotion regulation.

For anger regulation, we explored swipe-based interaction which allowed for increased movement compared to slow continuous movement which we leveraged for anxiety regulation. Our findings indicate the value of this interaction for regulating anger, particularly for experiencing the acceptance of anger and its less controllable quality. This design decision was informed from findings on anger regulation interventions involving increased [10, 75, 116] albeit not aggressive body movement [116, 128]. The value of force involved in actions such as shaking, tearing or cutting for regulating negative emotions, their visibility, and duration has been previously suggested by HCI research on regulation of grief [128].

Key for our design was the use of swipes as discrete movements. Although these could be performed with different force, speed, or acceleration, participants learned to understand that increasing these does not lead to quicker extinguishing of fire, and thus regulation of anger. Indeed, the design of the swipe-based interaction did not account for any increase in movement's speed, force or acceleration as our metaphorical emotional trajectory for anger regulation accounts only for the number of swipes, each one leading to increased rain, and subsequently weaker fire until it becomes extinguished.

The perceived mismatch between increased user's touch-based movement and the constant rate at which the fire was being extinguished led users to experientially learn of, and appreciate the reduced control they have over their anger, and that anger regulation is a process which cannot be impatiently hurried but needs to take its time. This is an important new finding that opens up design opportunities to leverage such tension when designing for anger regulation technologies.

With respect to boredom regulation, the tap-based interaction for popping the bubbles was perceived as the most intuitive of the three interactions, drawing from similarity with the analogous gesture of popping bubble wrap or soap bubbles. Our findings also indicate two new insights regarding the value of the two layers of surprise associated with this tap-based interaction: (i) random choice for the bubble to be popped up next, and (ii) two random bubbles to be popped with follow-up fireworks. While both ensured surprise, the latter also supported enjoyment, and the former maintained users' interest and curiosity. Interestingly, the randomness of the bubble to be popped next highlights a tension between control and surprise, and the value of not knowing at the moment of tapping which bubble will pop. This in turn, it opens up new design opportunities for alleviating boredom.

8.3 Feasibility of AR Technologies for Emotion Regulation

The third research question explores the feasibility of AR prototypes to support on-the-spot emotion regulation. Findings indicate participants' appreciation for AR-based technologies to support novel spaces for emotion regulation in daily lives. This is an important new finding which extends the range of emotion regulation technologies from the dominant focus on tangibles [6, 72, 94, 113, 143] and wearables [29, 30, 104, 152]. The quantitative analysis of PANAS scores also showed significant positive changes in emotional states of anxiety, anger, and boredom from before to after the use of each prototype, complementing qualitative findings while further indicating prototypes' potential for emotion regulation.

Findings also indicate that their current form factor may hinder acceptance of AR technologies. In addition, the touch-based action we designed for the touchpad on glasses' temple would still be noticeable to others and thus not private, because people need to raise their arms and move their fingers on the device. Possible solutions opening up new design opportunities could be touch-based actions on an alternative touchpad accessory (e.g., mobile phone, fidget toys) while the visual metaphors would still be displayed within the 'regular-looking' AR glasses.

Participants also envisaged the use of TouchEmotion across a range of social contexts particularly for regulation of boredom, and in private contexts for regulating anxiety or anger. Our outcomes confirm those on the limited social acceptability of negative emotions, particularly high arousal ones such as anger or anxiety, and especially when expressed by women [132]. Given the purpose of emotion regulation technologies to directly support adaptive emotional responses, their low pre-use acceptability [109] in public contexts for regulating less socially acceptable emotions is interesting and a challenge that future work should explore ways to address. In terms of sharing TouchEmotion experiences, these were envisaged to support others' awareness of one's negative emotions and effort to regulate them, and to elicit emotional support or co-regulate.

8.4 Towards a Design Space for on-the-spot Emotion Regulation Technologies

In the light of our literature review and study findings, we now integrate key outcomes to advance the design space for on-the-spot emotion regulation technologies. Figure 8 shows this space which we organized based on user input modalities on the X axis, and system output modalities on the Y axis. User input consists of physiological responses such as heart or breath rate, and finger or hand movement. For instance, physiological responses have been captured through integrated biosensors such as heart rate [6, 20, 24, 30, 94, 113, 152, 167] or breath rate [7, 53, 104, 106, 107]. In terms of system output and its modalities, emotion regulation technologies leveraged mostly haptic feedback [6, 7, 20, 24, 29, 30, 72, 104, 113, 143, 152] and less so audio/visual feedback [53, 94, 107, 167]. Within this design space, we have placed key examples from the state-of-the-art, illustrating different technologies from tangibles and wearables to desktop, ambient and biosensors. For example, most such systems are tangibles [6, 7, 20, 72, 94, 113, 143], wearables [29, 30, 30, 104, 152], or desktop [53, 106, 107], and ambient light [167] often with integration of bio or haptic sensors/actuators.

By reflecting on this design space, we can see that the two left quadrants have been most explored through technologies leveraging users' heart or breath rate as input, with system output in both haptic as well as audio visual modalities. In contrast, the two right quadrants have been less explored. These focus on technologies for emotion regulation which use finger or hand movement as user input. Interestingly, the few emerging works in this space appear to leverage slow hand movements such as strokes for calming an anxious pet in the form of a smart toy [72, 143], or steady flicking of a smart spinner through finger movements [94]. Previous HCI work on mindfulness technologies leveraging movement has also argued for the value of slow, continuous hand movement such as those involved in mandala coloring whose practicants reported wellbeing benefits particularly when living with depression or anxiety [39]. Together with insights from our findings, this emerging work suggests the value of such movement qualities, and of future work needed to understand how they can be supported through innovative interactions, across a range of technologies to support emotion regulation. One such promising technology is AR, as indicated by our study. To note, some of these examples are present in more than one quadrant, such as Biofidget [94] which users can interact with by movement: spin by finger flicking with deep exhale, or by breathing: blow with deep exhale. This indicates the potential of integrating both movement and physiological data as user input, extending the functionalities of these emotion regulation technologies.

To conclude, particularly important is the limited exploration of technologies using movement as user input, for both haptic and audio/visual output modalities. Our findings indicate the feasibility of AR technologies to extend this exciting, yet less explored design space.

9 DESIGN IMPLICATIONS

In this section we present five design implications for AR-based emotion regulation technologies including guidelines for designing metaphorical emotional trajectories, nature-inspired slow transitions for anxiety regulation, frictions to support frustration tolerance for anger regulation, layered randomness to support surprise for boredom regulation, and finger-worn devices integrated with AR technologies for increased acceptance in public contexts. We also reflect on how these design implications may extend to other classes of emotion regulation technologies, beyond AR.

9.1 Design of Metaphorical Emotional Trajectories

We introduced the concept of metaphorical emotional trajectories to support the design for user experience with emotion regulation technologies. This builds on the broader concept of user experience trajectories [11, 12] leveraged for soma-based design [142] and whose value for mapping emotional journey during emotion regulation has been long-argued in clinical psychotherapy [81, 92], and more recently in HCI [133]. Metaphorical emotional trajectories also draw from conceptual metaphors and their embodied, sensoriomotor qualities [55, 87] relevant not only for externally representing emotions but also for interacting with such external and more "objective" representations instead of internal affective states [34]. We illustrated this concept with three metaphorical emotional trajectories for the regulation of discrete negative emotions of anxiety, anger, and boredom. Grounded in our findings indicating prototypes' potential

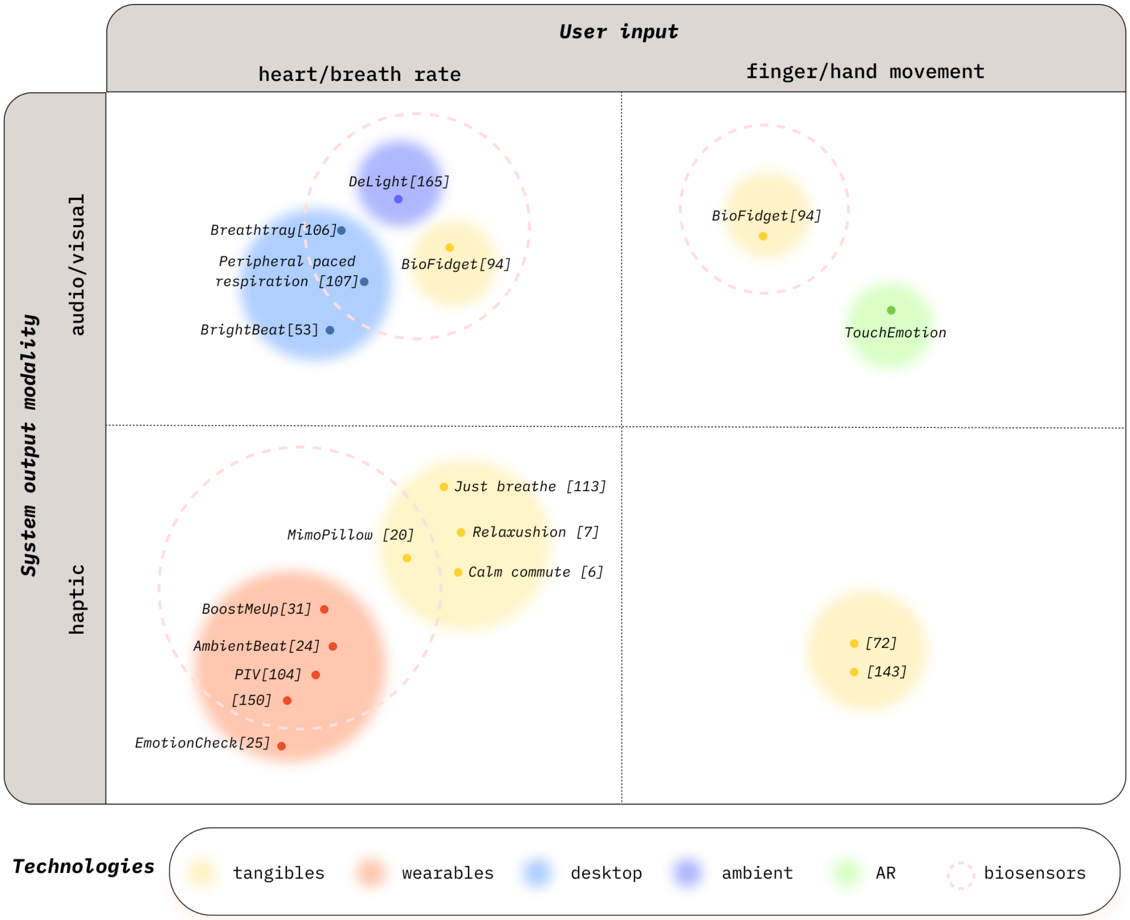

Fig. 8. Design space of technologies for on-the-spot emotion regulation organized by user input: physiological responses such as heart or breath rate captured through biosensors, and finger or hand movement. System output consists of two main modalities: audio/visual, and haptic. The different technologies in this space are represented in the Legend and include desktop, wearables, tangibles, ambient light, and AR. The area of each circle depicting different type of technology within each quadrant, is proportional with the number of papers depicting prototypes of such technologies for on-the-spot emotion regulation.

for regulating each of these emotions, we articulate several design guidelines for designing metaphorical emotional trajectories in general, and then with specific design implications to support regulation of anxiety, fear, and boredom, respectively.

More broadly, for the design of metaphorical emotional trajectories, we suggest the value of ***articulating their rationale and the source of emotional metaphors*** for instance from cognitive linguistics [82] or conceptual metaphor theory [34, 87], and the verbs associated with emotions and their metaphors [48, 127]. Since such metaphors are language-based, they can be expressed through ***representational materializations in audio-visual modalities***. For these, we can use both AR as well as other screen or sound based interfaces such as mobile apps. The chosen representational forms should be able to change so that they transition from an initial unregulated state to a final regulated state, i.e., closed to open lotus flower, fire to extinguished fire, bubbles to popped bubbles. Future work could compare the value of such representational metaphors for emotion regulation with that more explored abstract representations of emotions through spatial metaphors [6, 34, 113], sound qualities [34, 53], color brightness [34, 53], or hue [167] (see [141] for such comparison for mindfulness technologies), or vibration qualities and patterns [6, 7, 20, 24, 29, 30, 104, 113, 152].

We also suggest extending the embodied quality of metaphorical emotional trajectories by ***leveraging users' slow movement-based input*** to enact the transformation of negative high arousal emotions such as anxiety and anger from an unregulated to a regulated state. For these, we can use not only AR bur also haptic interfaces such as actuators embedded in wearables. User input through movement has been less explored in regulation technologies, albeit nascent work has also emphasized slowness [39, 72, 94, 143].

We also argue for the ***sensitive mapping of user movement-based input to enact the changes of the audio-visual representations*** from an unregulated to a regulated emotional state. Such mapping explicitly engages the body in emotion regulation process, leveraging thus prior findings on the impact of motor behaviours on emotion regulation, particularly through voluntary changes in movements' intensity, or specific movements, postures, or facial expressions [131]. For such coupling, we can also leverage HCI research on metaphorical movement sonification showing for instance the value of naturalistic water- or wind-based sounds to support body movement qualities such as fluidity and agency, as well as joy of movement [93]. Finally, we suggest designing for the ***temporal aspect of metaphorical emotional trajectories as micro-interventions***. Here we can think of short duration, i.e., around 3 minutes, and cyclic changes such as the 3 lotus flowers, or 6 bubbles, as well as speed of metaphors' change, i.e., slow for anxiety and anger, and acceleration of such change, i.e., nonlinear for anger.

9.2 Nature-Inspired Slow Transitions

For anxiety regulation, our findings echo those beyond HCI on the natural environment's restorative quality [58, 108] while extending the limited HCI work in this space. For instance, a recent review of over 100 papers focused on engaging with nature through technologies has shown the limited work on nature on demand interventions consisting of video/audio recording or virtual simulations of nature for emotion regulation [163]. To further extend the design space of anxiety regulation we suggest leveraging additional audio/visual nature-based calmness related metaphors involving interactions with natural elements such as water, air, light, or with fauna [144]. Beside AR, we can explore here other audio/visual interfaces. We can also draw inspiration from nature-based representational metaphors explored in mindfulness technologies [26, 27, 115, 124] and how they may be leveraged for anxiety regulation.

9.3 Frictions to Support Frustration Tolerance

Our findings on Fire prototype indicate the value of designing for user's movement-based input which allows but does not account for increased force and speed, which in turn hinders impulsivity and ensures the slowness of anger regulation process. This design implication could be leveraged for AR, as well as other touch-based interfaces. Anger therapy has also highlighted the need to address frustration intolerance for instance through rationale emotive interventions supporting the acceptance of frustrations and discomfort as unavoidable in everyday life [64, 158]. Interventions such as "courting discomfort" progressively engage patients with frustration inducing situations in order to strengthen the ability to tolerate frustration [64]. The plead for discomfort design has been also made in HCI for both designers of affective health technologies [147] as well as users in order to support behavior change for wellbeing and health [130]. For this, we can also draw from HCI work on design friction intended as deliberately introduced challenges in user interaction in order to break habitual behaviors and prompt reflection [32] particularly for digital wellbeing [2].

Emotion research has also identified the relationship between anger control and motor control, with the former leading to more accurate performance in motor control tasks such as those for holding a joystick-controlled cursor on visual target [17, 18]. We can imagine new opportunities to introduce friction through slower user input movements required for instance to follow a specific spatial path, or through slow changes in the visual representations of metaphorical trajectories.

9.4 Layered Randomness to Support Surprise

Findings indicate the value of Bubble prototype for regulating boredom through layers of randomness in interacting with the bubbles, i.e., popping and fireworks, which ensures surprise and enjoyment. This is an interesting outcome, made possible by the ambiguous interaction through limited pointing, and the two distinct spaces namely the virtual space, and the interaction space provided by the AR glasses' touchpad instead of having for instance a single touchscreen for tapping on the next bubble to be popped. Such ambiguity can be leveraged by other technologies beyond AR which could decouple the input and output interfaces such as Anima prototype for regulating attention [40].

Our findings echo previous HCI outcomes on the complex relationship between curiosity, surprise, and wonder [56, 110]. They also provide a more nuanced account on the importance of hedonic attributes of interactive technologies such as stimulation, compared to pragmatic attributes such as predictability and simplicity [69]. We suggest the value of designing for layered randomness in order to prioritize surprise over control, or layered unpredictable interaction for technologies aimed at regulating boredom.

9.5 Finger-worn Devices to Increase AR Acceptance in Public Contexts

Despite the impact of our prototypes on emotion regulation, findings indicated challenges regarding the acceptability of AR technologies in public contexts due to their form factor and visible interaction on the glasses' touchpad. Addressing the latter could open the design space of emotion regulation technologies from the touch input on the smart glasses spectacle frames to touch input on external devices such as wristbands, sleeves, or rings [89], or haptic interfaces. Our findings also confirm previous ones on problematic social acceptance of AR technologies, given their perceived obtrusiveness in everyday settings, although touch-based interaction is preferred especially beyond the facial area [89]. We argue that given their small and discrete form, subtle interaction through tap, swipe, stroke or flipping gestures [89], rings [5, 111] are promising candidates for augmenting AR technologies for emotion regulation in public contexts. We can imagine novel interactions with AR-based audio/visual emotional metaphors through slow continuous swipes for anxiety and anger regulation, and taps for boredom.

10 LIMITATIONS

A limitation of pre-experiments relates to the lack of control group and its impact on internal validity. The latter could be partly mitigated by running short studies, in which the impact of confounding variables is limited [68]. Our study was short, so normal changes associated with maturation over passage of time were less of an issue, nor additional events could have taken place between the two measurement beside the interaction with the prototypes. We also consistently used the same valid measurement scale for emotional states, thus limiting the risk of inconsistent data associated with changes in instruments. We also acknowledge that the emotions we elicited in the study are likely to dissipate over time, even without the use of our AR-based emotion regulation interventions, and that future work should further explore their value for the regulation of naturally arising emotions, as well as the temporal dynamics of such regulation [153], through longitudinal studies. In addition, while our quantitative analysis of PANAS scores showed significant positive changes in the emotional states of anxiety, anger, and boredom, after the use of each prototype compared to before, we do not claim these outcomes as indicators of the TouchEmotion prototypes' effectiveness for emotion regulation, as future work is needed to explore this through experimental studies involving control groups. Our work has focused on supporting the regulation of negative emotions, given their significant impact on wellbeing and affective health. In addition, future work should also explore the regulation of positive emotions, as maintaining or increasing their intensity has been show as essential for supporting people's resilience [146]. Future work may also include measures related to other aspects of ER such as cognitive strategies [60]. Not at least, we focused on one type of AR glasses: XReal Air, which a recent review of AR technologies, from the perspective of YouTube videos from early adopters, showed XReal AI glasses being predominantly used for gaming and media consumption [145]. Future work on AR-based interventions for emotion regulation could explore other AR glasses, as well as the tradeoff between affordability and user experience.

11 CONCLUSION

We presented the design and exploration of TouchEmotion, an AR prototype consisting of Lotus, Fire and Bubble prototypes depicting *metaphorical emotional trajectories* for regulation of anxiety, anger, and boredom, respectively. Findings from an exploratory study with 18 participants indicate their value for emotion regulation. We advanced a design space for on-the-spot emotion regulation technologies, and proposed five implications for designing metaphorical emotional trajectories, nature-inspired slow transitions, frictions to support frustration tolerance, layered randomness to support surprise, and finger-worn devices integrated with AR technologies for increased acceptance in public contexts.

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