A Review and Framework for Designing Interactive Technologies for Emotion Regulation Training

by

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Abstract

Emotion regulation is foundational to mental health and well-being. In the last ten years there has been an increasing focus on the use of interactive technologies to support emotion regulation training in a variety of contexts. However, research has been done in diverse fields, and no cohesive framework exists that explicates what features of such system are important to consider, guidance on how to design these features, and what remains unknown, which should be explored in future design research. To address this gap, this thesis presents the results of a descriptive review of 54 peer-reviewed papers. Through qualitative and frequency analysis I analyzed previous technologies, reviewed their theoretical foundations, the opportunities where they appear to provide unique benefits, and their conceptual and usability challenges. Based on the findings I synthesized a design framework that presents the main concepts and design considerations that researchers and designers may find useful in designing future technologies in the context of emotion regulation training.

Keywords: Emotion regulation; Interactive technology; Descriptive literature review; Design framework

Dedication

I dedicate this thesis to my parents, for their unconditional support and love that enabled be to pursue my dreams, even when they took me to the other side of the word.

Acknowledgements

I would like to thank Dr. Antle for her support and guidance throughout this process. It was a great honor to work with you. This process could not have been the same without those inspiring conversations about parenting, philosophy, and life.

To my committee, Dr. Bernhard Riecke and Dr. Carman Neustaedter, thank you for your invaluable feedback.

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List of Acronyms

SFU	Simon Fraser University
LAC	Library and Archives Canada
ER	Emotion regulation
ADHD	Attention Deficit Hyperactivity Disorder
DSM	Diagnostic and Statistical Manual of Mental Disorders
HCI	Human-Computer Interaction
EEG	Electroencephalogram
BCI	Brain-computer interface
IEEE	Institute of Electrical and Electronics Engineers
ACM	Association for Computing Machinery
VR	Virtual Reality
CBT	Cognitive Behavioral Therapy
ASD	Autism Spectrum Disorder
SIGCHI	Special Interest Group on Computer–Human Interaction

Chapter 1.

Introduction

1.1. Emotion Regulation

Emotion Regulation (ER), is the process by which individuals modulate their emotions, consciously or unconsciously (Thompson, 1994). It is considered a key element of healthy psychological functioning (DeSteno, Gross, & Kubzansky, 2013) and has as much impact on life circumstances as IQ and family social status (Sanders & Mazzucchelli, 2013). In contrast, emotion dysregulation is failure to achieve emotion regulatory goals (Jazaieri, Urry, & Gross, 2013). Previous research proposed links between emotional dysregulation and different forms of psychopathology. More than one-third of young adolescents with Attention Deficit Hyperactivity Disorder (ADHD) would be considered to exhibit emotion dysregulation (Mennin, Holaway, Fresco, Moore, & Heimberg, 2007). Different symptoms of anxiety disorders such as intensity of emotions and poor understanding of emotions are correlated with various aspects of emotion dysregulation (Mennin et al., 2007). While emotion dysregulation is positively correlated with diverse behavioral and personality disorders, it is considered to be a transdiagnostic characteristic with manifestations that vary across diagnoses (Bunford, Evans, & Wymbs, 2015). Emotion dysregulation is implicated in more than half of the disorders in the Diagnostic and Statistical Manual of Mental Disorders (DSM) that need immediate attention (e.g. mood disorders and psychotic disorders) and all the DSM personality disorders and mental retardations (e.g. personality disorder and schizoid personality) (Gross & Levenson, 1997).

Emotion regulatory skills develop in childhood and are built up incrementally over time. In part, their development depends upon learning to regulate emotions through healthy attachment relationships between children and parents or caregivers (Engels, Finkenauer, Meeus, & Deković, 2001). By early adolescence, with adequate support, sophisticated cognitive abilities that are associated with ER develop. In adulthood, individuals with strong ER skills understand that expressions of emotions are governed by social and contextual rules and they are able to regulate their own responses within the boundaries of these contexts (Gross & Muñoz, 1995). Learning to regulate emotions without adequate supports and/or strong adult role models can be difficult. Because ER is an invisible mental process, it can be difficult to learn and practice (Antle et al., 2018). A key aspect of learning to regulate emotions involves identifying which environments are likely to trigger certain emotional experiences, how to recognize these experiences, and how to modulate the emotional experience and response (Gross & Muñoz, 1995). In adulthood, emotion regulatory training such as mindfulness has been associated with positive psychological health benefits, such as perceived stress (Prakash, Hussain, & Schirda, 2015).

1.2. Interactive Technologies and ER

Interactive technologies offer unique opportunities to support ER training. Technological platforms can make proven ER interventions that are currently conducted in workshops and therapy sessions more scalable and accessible. For example, bio-apps have the potential to make invisible mental processes that are associated with emotion regulatory state more visible (Antle et al., 2018). Recent technological developments enable devices to easily measure biological, neurological, and/or behavioral markers about an emotional state. Interactive technologies can use this data to support and guide learning through feedback generated by a range of intervention and/or therapeutic models. Feedback may come in different modalities (e.g. haptic, visual, and audio), representational forms (e.g. graphs and numbers, progress of a video game, and movement of tangible objects) and timing (e.g. immediate, random, and longitudinal). There are a plethora of approaches for ER training available on different platforms (e.g. desktops, mobile devices, wearables, and tangibles). If well designed, these interactive technologies may enable opportunities to learn and practice skills that are associated with ER in different ways, and during different contexts of everyday experience. As such, they can supplement ER learning from parents and caregivers and provide autonomous training as children age into adolescence and become adults.

1.3. Research Gap

A considerable amount of research has been published on interactive technologies for ER training. However, there are still many challenges in this quickly growing field. Previous review studies have focused on specific categories of technologies for ER training such as video games (Jerčić & Sundstedt, 2019; Villani et al., 2018), usability aspects of brain-computer interface systems (Vasiljevic & Miranda, 2020), and mindfulness (Prpa, Stepanova, Schiphorst, Riecke, & Pasquier, 2020; Sliwinski, Katsikitis, & Jones, 2017; Terzimehić, Häuslschmid, Hussmann, & schraefel, 2019). What is lacking is a review study that analyzes different approaches for designing technologies for ER training and their theoretical model. For the purposes of this thesis, a theoretical model in the context of ER training refers to a psychological or therapeutic model of cause and effect related to how individuals learn and practice self-regulation. In interactive technology based ER interventions, this model can be used as a mechanism to design the relationship and form of the system's input data, output representation, modality, timing, and the mapping between the input and output. Previous research identified the increasing need for literature reviews to evaluate not only what worked, but also the theory of why and how the intervention worked (Baxter et al., 2014).

To address this gap, this thesis presents a descriptive literature review on the topic of interactive technologies for ER training. Based on the findings of the literature review, we present a design framework on the topic. A design framework is a form of knowledge, involving concepts and their inter-relationships, that design researchers may find useful for informing the design of technologies in a certain area. There are two subsets of design frameworks. The first is an explanatory design framework that claims to explain how and why certain causes create their effect. The second is a descriptive design framework that is more exploratory and consists of a set of concepts, considerations and underexplored research areas that can inform future research (Antle & Wise, 2013). In this thesis I present a descriptive design framework since it fits the scope of a master’s thesis and it is motivated to reveal patterns in literature rather than explaining the relationship of how certain design features and their effect of ER processes.

1.4. Thesis Guide

This thesis presents a snap-shot of the field at this time, in order to steer future research and inform the design of interactive technologies for ER training. This descriptive literature review answers the following research questions:

1. What type of interactive technologies are used for ER training?
2. What type of users are interactive technologies for ER training designed for?

3. What are the theoretical models that underline interactive technologies for ER training?
4. What are the design opportunities created by interactive technologies for ER training?
5. What are the challenges faced when designing interactive technologies for ER training?

This thesis advances thinking in the field of interactive technologies for ER training. For designers, the descriptive framework provides a baseline of current research findings related to designing interactive technologies for ER training while emphasizing the design opportunities that can be leveraged and the challenges that still need to be explored. For researchers, the review provides a snapshot of what has been done in the field, what were the theoretical models that underline the design implementations, and what are the current research gaps.

Chapter 2.

Related Work

This section provides an overview on the leading psychological theory of ER followed by an overview of previous review papers in the field of Human-Computer Interaction (HCI) that drew attention to the quickly growing field of interactive technologies for ER training. This section presents the motivation and contributions of previous review papers and illustrates the need for a descriptive design framework for interactive technologies for ER training.

2.1. The Process Model of Emotion Regulation

One of the leading theories of ER is the Process Model of Emotion Regulation (Gross, 2015). In this model, Gross classified the process and strategies of ER by the stage the regulatory process occurred during the emotion-generation process. Gross defined this process by the following five strategies:

1. *Situation selection:* prior to exposure to an emotional situation, a person can select or avoid the situation in which he or she may be exposed to.
2. *Situation modification:* during deliberate exposure to an emotional situation a person can actively modify the emotional impact of such situation.
3. *Attentional deployment:* during exposure to an emotional situation a person directs his/her attention from the present situation, towards the goal of changing the emotional experience.
4. *Cognitive change:* during exposure to an emotional situation a person cognitively modifies the interpretation of the situation towards changing the emotional experience.
5. *Response modulation:* after the emotional response is well developed and is experienced as a behavior or a physiological change, a person actively acts towards changing the outcomes of the emotional experience, regardless its cause.

While there is empirical support for Gross's Process Model of ER, to this day, there is no empirical consensus on the cognitive and neurological process that underlines ER and the best strategies for ER training.

2.2. Previous Review Studies on Interactive Technologies for ER

Review methodologies are used in different fields when it is challenging for a single researcher to read, evaluate, and synthesize the state of a current field. Review papers contribute to the field by providing a snap-shot of the state of a current field, while analyzing different approaches to conduct research in that field, and they may draw attention to the need for future research in areas that are under explored (Dybå & Dingsøyr, 2008). The following section presents previous review papers in the quickly growing field of interactive technologies for ER training.

Sanches et al. (2019) conducted a literature review based on past ten years of Special Interest Group on Computer–Human Interaction (SIGCHI) publications on affective technologies in the context mental health. Their analysis focused on the validation process of these technologies and the ethical considerations that guided the research presented in this review. Their findings of their review raised the over emphasis of previous technologies on producing data, without considering how it is beneficial for user's wellbeing. They add that there is an under explored opportunity in involving people with mental health disorders in the design process of future technologies (Sanches, Höök, Sas, Janson, et al., 2019). Howell et al. (2018) performed a critical analysis of both commercialized and academic-based emotional biosensing technologies. Their analysis leveraged standards from various fields to serve as a conceptual lens to unpack the design space of emotional biosensing technologies. For example, from the field of biopolitics, authority was leveraged as a conceptual lens to question the tendency of biosensing technologies to play out their authority and promise insights and unrealistic positive emotional outcomes. Their analysis emphasized the tendency to design emotional biosensing technologies in a way that promotes particular normative vision of a 'good life' and the constant striving for a 'better life' (Howell, Chuang, De Kosnik, Niemeyer, & Ryokai, 2018). Sanches et al. (2019) and Howell et al. (2018) contributed to the field of HCI by drawing attention to issues in the design space of affective and emotional biosensing technologies. They raised ethical and social-technical questions that should guide future research and design of technologies in the field. However, they did not claim to provide researchers and designers with concrete design guidelines for designing future technologies in the field (Howell et al., 2018; Sanches, Höök, Sas, Janson, et al., 2019).

Other review papers focused on a certain types of technological methods for ER training. Vasiljevic and Miranda (2019) conducted a systematic literature review on electroencephalogram (EEG) brain-computer interfaces (BCI) in the context video game based ER training. Their findings emphasized the opportunities of using consumer-grade EEG devices in the context of gaming for ER training. However, they noted that most of the research in the field focused on quantitative aspects of the BCI system such as accuracy and performance. The authors concluded by emphasizing gaps and open topics in the field that should be further explored. They raised the need for future research in the field to shed light on usability aspects such as quality of interaction and user satisfaction when interacting with such technologies (Vasiljevic & Miranda, 2020). Jerčić and Sundstedt (2019) conducted a systematic review of technologies for ER training in the context of serious games. Serious games in biofeedback-based ER training involve an interactive medium that is coupled with physiological sensors that are used to monitor the users' emotional state during gameplay. During the training session the game mechanics are changing towards target behaviors and mental states. The authors provided an overview of previous published research in terms of the type of users, the experimental design, and the outcomes of studies using serious games and biofeedback to provide opportunities for ER training. While their findings call for future research to carefully consider the standardization and methodological process, such as integrating sham-biofeedback condition, their findings emphasized the potential of practicing ER skills in the context of games (Jerčić & Sundstedt, 2019). Vasiljevic and Miranda (2019) and Jerčić and Sundstedt (2019) provided a detailed review of the field of ER training. However, their scope focused on the specific context of video games and serious games and they did not provide design guidelines and recommendations on how to design future technologies in this context.

Other review papers focused on different types of activities that can be associated with ER training. For example, mindfulness has been the focus of three previous review studies. Sliwinski et al. (2017) presented a review on interactive tools as support for mindfulness meditation. Their review is mostly based on commercialized apps. Their findings raised opportunities including the use of gamification to support mindfulness; enhance social interaction to facilitate feeling of oneness and community; use meaningful narratives to encourage prosocial qualities of mindfulness. The also promoted the use of Virtual Reality (VR) and affordable-biofeedback for self-transcendence experiences

(Sliwinski et al., 2017). Terzimehić et al. (2019), conducted a structured literature search based on mindfulness. They provided broad definitions and concepts of mindfulness and analyzed 38 peer-reviewed papers that were published in the Associate for Computing Machinery (ACM) database. Based on this body of literature, they synthesize six lines of research in current technologies for mindfulness: meditation practice, therapy, reflection and knowledge gain, mindfulness in daily life, mindfulness in interaction, and performance enhancement (Terzimehić et al., 2019). While Sliwinski et al. (2017) and Terzimehić et al. (2019) presented concrete design guidelines for future technologies in the field, they were informed solely on one type of activity (i.e. mindfulness meditation) that may be associated with ER. In another review paper focused on technologies that used breathing awareness as a physiological process that is associated with ER, Prpa et al. (2020) analyzed 31 breath-based interactive systems. They provided a theoretical framework and design strategies for designing future technological systems for breath awareness and emphasized the need for a more conscious design practice that is informed by theoretical framing. While this paper contributes the field by informing researchers and designers on how to approach the process of designing technologies for breathing awareness, it only includes interactive technologies designed to support respiratory input

To the best of our knowledge, only one paper previously presented a literature review on technologies for ER training with the explicit goal of developing a design framework. Yoon et al. (2019) analyzed 36 publications and provided 17 strategies for ER training based theories of ER strategies (Yoon, Li, Hao, & Kim, 2019). While the motivation of this paper is similar to the motivation of the current thesis, they did not provide design guidance, exemplars of themes, or highlighted underexplored research areas, as this thesis does.

Chapter 3.

Methodology

The following section presents the systematic process of a descriptive literature review on the topic of interactive technologies for ER training. The process included searching papers in relevant data bases, filtering them according to a criterion of exclusion, and analyzing them based on the research questions above.

3.1. Search Criteria

The search was conducted in May 2019 and again in June 25^{th} 2020 to add any recent published papers. We searched for papers that were published between 2009 and the day of the search and included the key terms 'interactive technology' and 'emotion regulation' or 'self-regulation'. A second search included the key terms 'interactive technology' and 'stress' or 'stress regulation'. Both of the searches looked for the key words in title, abstract, and author keywords. We searched for papers that were published in two data bases: Institute of Electrical and Electronics Engineers (IEEE) and Associate for Computing Machinery (ACM). We chose these data bases as together they have a comprehensive collection of articles in the field of HCI. This search resulted in a total of 5,076 papers.

3.2. Filtering Process

We manually filtered all the papers while keeping in mind their relevance to the research questions mentioned above. The first author and a senior researcher with years of experience in ER technologies reviewed papers identified by keywords to determine suitability. During this process, a set of exclusion criteria were developed and applied (see Table 1).

The first pass of filtering included a manual scan of the paper titles. I excluded non-English paper and duplications. The second pass of filtering included manual scan of key terms, excluding papers that did not address human self-regulation (e.g. "A Supply-Insensitive Self-Regulating CMOS Ring Oscillator"), papers that did not include technology (e.g. “A Survey into the Teacher's Perception of Self-Regulated Learning”), papers that included a technology that is being used for medical purposes (e.g. “Bioelectromagnetic and Subtle Energy Medicine”) and non-primary papers (i.e. review papers). Review papers that were found to be relevant were described in the Related Work section. After the first two passes, I excluded 4,718 papers, keeping 295 papers that were further filtered. The third pass of filtering included reading abstracts and scanning full texts. The purpose of this pass was to evaluate the nature of the technological intervention. During this pass we excluded papers that presented technologies that did not have an interactive nature with the user. For example, papers that measured physiological data to shed light on certain self-regulatory processes (e.g. “Expanding the Scope of Learning Analytics Data: Preliminary Findings on Attention and Self-Regulation using Wearable Technology”). The fourth pass of filtering included a review of the publication details. I excluded non-peer reviewed papers, thesis papers, papers that were published in non-international publications, and short-papers that were not published in one of the leading venues in HCI (e.g. Conference on Human Factors in Computing Systems, Designing Interactive Systems). In cases of multiple publications of the same research project, the most recent and comprehensive paper was kept. The fifth pass of filtering included a review of the methodology that was used. I excluded papers that did not include a user study. After passes three, four, and five, I excluded 179 papers, keeping 116 papers.

The sixth pass of filtering included an analysis of the theoretical model. In HCI there different approaches to derive design guidance. One is through designing certain prototypes and evaluating their effect. An example for this process is research through design. Through this process researchers and designers can generate knowledge on what works. However, there is no promise for a theoretical understanding of why or how certain

Pass	Method	Exclusion criteria
1	Manual scan of titles	Non-English papers and duplications
2	Scan of key terms	Review papers, clinical trials and technologies that do not include human ER
3	Reading abstracts and scanning full texts	Technologies that do not have an interactive aspect with the user
4	Publication quality	Non-peer reviewed papers, non-international publications
5	Methodology	Proposal of technologies with no user study
6	Theoretical model	Papers with no theoretical model

Table 1: Exclusion Criteria

design features works. Another approach that is influenced by a pragmatic world view, uses a more scientific logic of cause and effect. A theoretical model defines the relationship of cause and effect between the design features of a system and the intended outcome. It is usually described as a left to right flow of *"if...then"* approach to describe the chain of reasoning on how the intervention leads to a certain outcome, such as a behavior change around learning or practicing ER (Baxter et al., 2014). We decided to exclude papers that did not explicitly define a theoretical model. We acknowledge that this pass might have excluded exploratory papers that might have contributed to the analysis. However, previous research raised the need of systematic reviews to evaluate not only what works, but also the theory of why and how an intervention works (Baxter et al., 2014). At the end of the filtering process, 54 papers were found to be relevant for the purpose of this review.

3.3. Data Coding and Analysis Process

We coded and analyzed the papers in 5 passes, based on the research questions: (1) type of technology, (2) type of users (3) theoretical model, (4) opportunities and (5) challenges.

We analyzed the type of technology based on the technological platform, the input that was used to indicate upon an emotional state, and the output that was provided to the user. The second research question addressed the type of users the technology was designed for. We analyzed the type of users based on their demographics and health condition. The next three research questions addressed the theoretical model, opportunities, and challenges of the technological interventions. We defined opportunities as contributions of the technological intervention and the different design facets that contributed for promoting ER training. We found that opportunities were usually identified by authors in the Discussion section. We defined challenges as conceptual, usability, or technical limitations of the technological intervention. We did not include methodological limitations as the purpose of the analysis was to conceptualize the different design features of interactive technologies for ER rather than their evaluation process. We defined theoretical model as a theory of change that was used to put in place the technological intervention towards supporting ER training (Baxter et al., 2014; Frechtling, 2007). We identified theoretical model in the Introduction, Related Work, or Design section as flow chart or a verbal description of the theory of change.

Both coders (Ofir Sadka and Professor Antle) fully read the papers and raised codes based on the research questions. The coding process was done in rounds of 3-4 papers. After each round, the coders met, compared their codes, and discussed. The codes of the first two research questions (type of technology and type of users) were similar between the two coders, as they were usually explicitly mentioned in the papers. The codes that concerned the theoretical model, opportunities, and challenges required several meetings until agreement was reached between the coders. After analyzing and discussing the codes that were raised based on the analysis of the first 13 papers, the codes of the last three research questions matched between the coders. Based on the process of generating the codes of the first 13 papers, the first author coded the remaining 41 papers while keeping the codes in mind and being open to new codes. To ensure reliability, after all papers were coded by first author, we randomly chose 5 papers and they were also coded by the second author. Following the data coding, both coders individually read all the codes, clustered them into themes and proposed general themes. We chose an exploratory thematic analysis rather than confirmatory thematic analysis (Guest, MacQueen, & Namey, 2012). We chose an inductive method because we wanted to generate knowledge based on the data rather than being informed by previous review studies. The coders compared the themes, keeping themes that reached consensus, and discussed until disagreements were reconciled.

3.4. Methodological Limitations

We acknowledge that a different set of papers and a different methodological approach could raise different themes of theoretical model, types of technologies, and opportunities and challenges. We excluded papers that were published in databases other than ACM and IEEE, such as mental health and psychological publications. Our motivation was to provide the HCI community better understanding of the field from a design perspective. However, for broader understanding of the field, we encourage HCI researchers to refer to publications from other fields such as medical and mental health literature. In addition, papers that did not include the key words that were presented under the search criteria sections were excluded. We are certain that some of the papers that were excluded might have provided interesting insights, for example, early stage technologies that did not include a user study. As a result of these methodological limitations, our analysis may not be considered comprehensive. In terms of biases, I analyzed, made the decisions, and asked questions. These could have caused confirmation biases in the way I chose, coded, and arrange the papers in themes based on my worldview, previous experience, beliefs, and culture.

Chapter 4.

Results

Towards the development of a descriptive design framework, this section presents the findings of a descriptive literature review on the topic of interactive technologies for ER training (See Appendix for papers analysis). We chose to present the frequencies of the themes in each category to illustrate the distribution of the themes within a category; and to provide quantitative evidence about the magnitude of themes, which may indicate trends, well-researched areas, and/or underexplored research areas in the field of HCI. The findings in this section are presented from the most frequent theme to the least frequent theme.

4.1. RQ 1: What Types of Technologies are Used for ER Training?

We analyzed the type of technology in terms of the platform that was used, the type of activity it was designed for, the input that was used to indicate upon an emotional state, the modality of the output that was used to deliver the feedback, the level of abstraction of the feedback, and the timing of the feedback.

4.1.1. Technological Platform

The review indicated that screen-based platforms such as PC (e.g. (Crepaldi, Colombo, Baldassini, Mottura, & Antonietti, 2017)), tablets (e.g. (Antle et al., 2019)), and mobile phones (e.g. (Bakker & Rickard, 2018)) were used in 64% of the papers. Wearable platforms such as smartwatches (e.g. (Pina et al., 2014)) were used in 18% of the papers. Tangibles such as fidgets (Cottrell, Grow, & Isbister, 2018) and interactive dolls (Slovák et al., 2018) were used in 9% of the papers. Smart home (e.g. (Snyder et al., 2015)) and cars (e.g. (Balters, Mauriello, Park, Landay, & Paredes, 2020)) were used in 5% of the papers and VR (e.g. (Cavazza et al., 2014)) was used in 4% of the papers (see Figure 1).

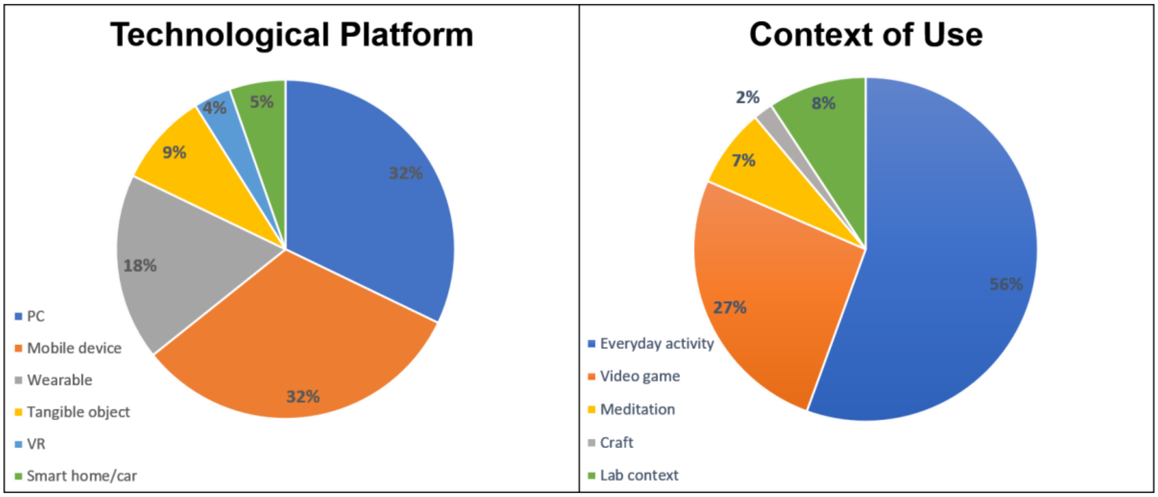

Figure 1: Pie charts with the technological platforms and contexts of use

4.1.2. Context of Use

The ER training were framed around 5 contexts of use: 56% of the technologies were designed for everyday activity such as everyday activity in a classroom (e.g. (Fage et al., 2019)) and everyday PC related activities (Moraveji, Adiseshan, & Hagiwara, 2012), 27% of the technologies were designed for video games such as multiplayer video games (Khong, Jiangnan, Thomas, & Vinod, 2014) and car racing games (Z. Wang, Parnandi, & Gutierrez-Osuna, 2018). 8% of the technologies were designed for lab contexts (e.g.(Wells, Outhred, Heathers, Quintana, & Kemp, 2012)), 7% of the technologies were designed for meditation sessions (e.g.(Shamekhi & Bickmore, 2018)), and 2% of the technologies were designed for craft activities (e.g. (Lee & Hong, 2017) (see Figure 1).

4.1.3. Emotion-based Input

The review showed that 66% of the technologies used physiological data (both biological and neurological) to indicate users' emotion regulatory state. 54% used biological data such as respiration (e.g. (Pisa, Chernyshov, Nassou, & Kunze, 2017)), heart-rate variability (e.g. (Lobel et al., 2016)), and skin conductance (e.g. (Parnandi & Gutierrez-Osuna, 2017)). 12% of the papers used neurological input such as EEG (e.g. (Cavazza et al., 2014)). Self-report (e.g. (Springer, Hollis, & Whittaker, 2018)) was used as input in 15% of the technologies. Behavioral input, such as interactional behaviors during video play (e.g.(Lloyd, Brett, & Wesnes, 2010)) or tangible interaction during interaction with a fidget (Cottrell et al., 2018) were each used as input in 5% of the papers. Data about physical location was also used for input in 5% of the papers (e.g. (Huang, Tang, & Wang, 2015)) and body movement was used in 4% of the papers (e.g. (de Rooij & Jones, 2015)) (see Figure 2).

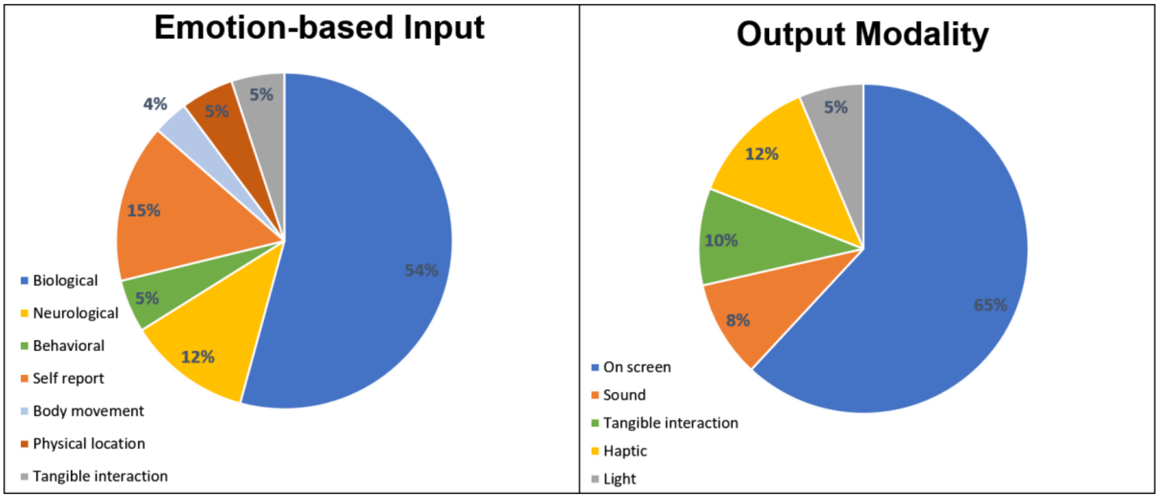

Figure 2: Pie charts with the emotion-based inputs and output modalities

4.1.4. Output Modality

The output modality refers to the sensory channels through which the output is perceived by the user. While many technologies used multimodal feedback (i.e. audio and visual displays in a video game), we included in this analysis only output modalities that were modified based on the emotion-based input. 65% of the technologies used on-screen visual modality as an output, such as PC's (e.g. (Reinschluessel & Mandryk, 2016)), tablets (e.g. (Slovák et al., 2016)), and mobile phones (e.g. (Carlier, Van der Paelt, Ongenae, De Backere, & De Turck, 2019). 12% of the technologies used haptic modality in the form of vibrations (e.g. (Choi & Ishii, 2020)). 10% used tangible interaction with a physical object (Stangl, Weidler-Lewis, Lauff, Price, & Fauble, 2017), 8% of the technologies used audio (Ghandeharioun & Picard, 2017), and 5% used light not from a screen source (e.g. (Liang, Yu, Xue, Hu, & Feijs, 2018; Yu et al., 2018)) (see Figure 2).

4.1.5. Output Level of Abstraction

Technological interventions varied in terms of the level of abstraction of the output that was used to convey an emotional state or an emotion regulatory process (see Figure 6). 44% of the technologies provided concrete feedback. Using concrete representation can support the interpretation of symbolic representations of abstract processes (Alissa Nicole Antle & Wise, 2013). We found that designers used concrete representations such

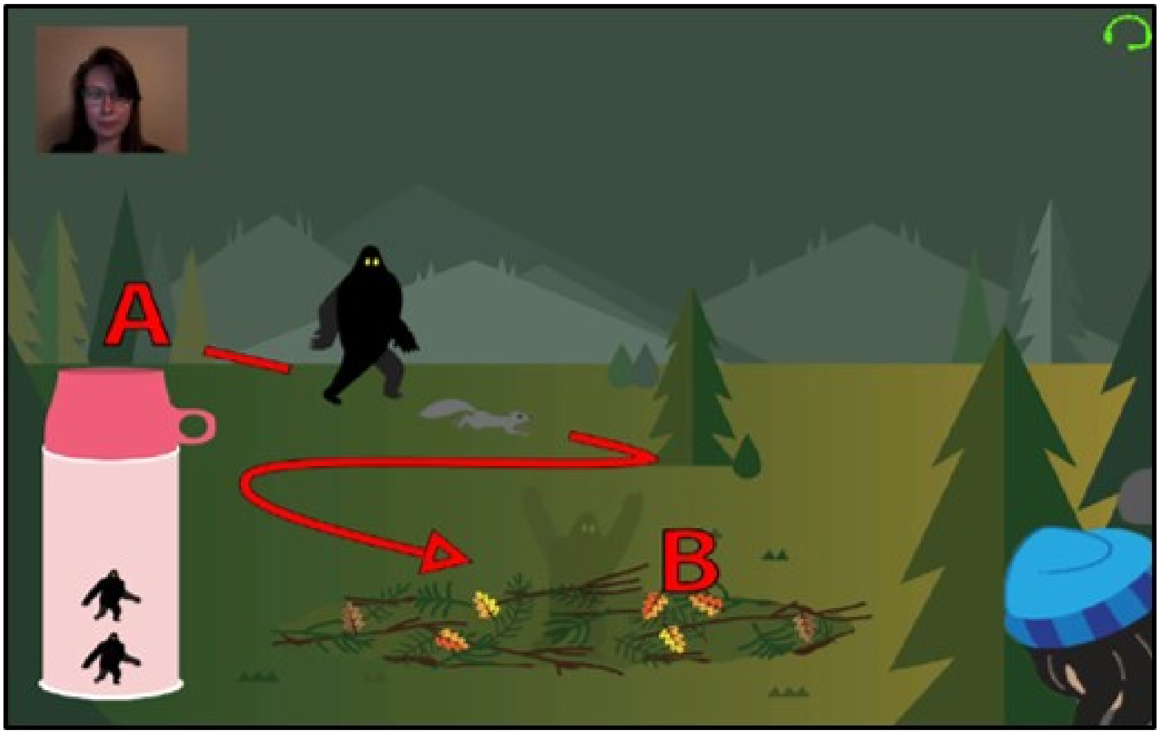

Figure 3: Example of concrete representation: the user collects monsters in the jar when sustaining relaxation. Copyright- Antle et al., 2019

as explicit behavioral suggestions (e.g. (Fage et al., 2019)), numbers and graphs (e.g. (Kocielnik, Sidorova, Maggi, Ouwerkerk, & Westerink, 2013)), and explicit cues during a video game in the form of penalty or reward points (see Figure 3).

37% of the technologies used metaphors to indicate the efficiency and progress of an emotion regulatory process (e.g. (Sas & Chopra, 2015)). Metaphoric representation are used to convey abstract concepts through unconscious metaphorical elaboration (Alissa Nicole Antle & Wise, 2013). Designers used metaphoric representations such as increasing speed of a race car during a video game (i.e., the faster the car goes the better the emotion regulatory process) (Khong et al., 2014), the use of colors to convey an emotional state (Snyder et al., 2015) (see Figure 4), upwards and downward movement in a VR environment (Prpa et al., 2018), vertical vibration patters to indicate a respiration rate (Balters et al., 2020), and metaphors from the natural words such as rain, flowers, fire (Bermúdez i Badia et al., 2019), and growth patterns of trees (Yu, Funk, Hu, & Feijs, 2017). 13% of the technologies used analogies to indicate the emotional state or the emotion regulatory process. Analogical representation are based on similarity between elements of the abstract concept and their representation. This type of representation was used in various ways such clearing overlay texture during a video game that resembles the

Figure 4: On the top: metaphorical representation, blue for decreasing arousal and red for increasing arousal. Copyright- Snyder et al., 2015. On the Bottom: Analogical representation, where more texture overlay on the screen indicate lack of focus. Copyright- Mandryk et al., 2013

abstract process of focusing (Mandryk et al., 2013) and slow vibration patterns on the skin that resemble physiological signs such as heart rate (e.g. (Choi & Ishii, 2020)) and respirations (e.g. (Frey, Grabli, Slyper, & Cauchard, 2018)). The rest of the technologies (6%) used abstract representations that required the user to explicitly make sense of the emotion regulatory process or the emotional state (Alissa Nicole Antle & Wise, 2013) such as reflecting on shapes of clay (Lee & Hong, 2017) and amorphous, abstract shapes and colors (e.g. (Sanches, Höök, Sas, & Ståhl, 2019)) (see Figure 5).

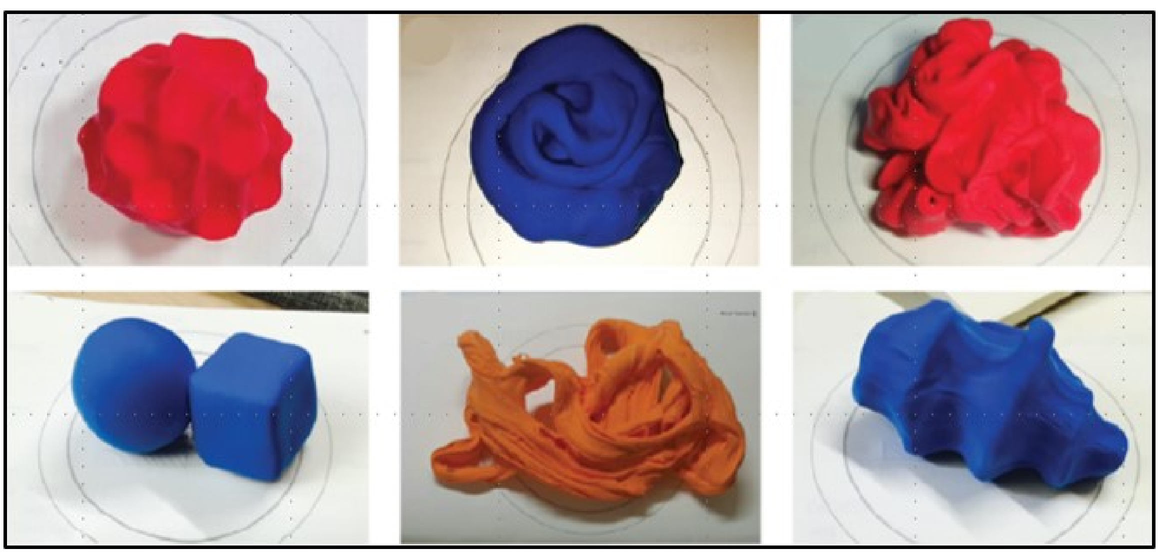

Figure 5: Abstract representation, different shapes of clay represent various emotional experiences. Copyright- Lee & Hong, 2017

4.1.6. Output Timing

The timing of the emotional output varied between technologies. 81% of the technologies provided immediate feedback to the users based on their input (e.g. (Smyth & Heron, 2016)). 7% of the technologies provided longitudinal emotional output (e.g. (Sanches, Höök, Sas, & Ståhl, 2019)). 8% of the technologies provided the users both immediate and longitudinal output (e.g. (Díaz-Escudero, Torrado, Gomez, & Montoro, 2018)). 4% of the technologies provided random (Oehler & Psouni, 2019) and partial output (Parnandi & Gutierrez-Osuna, 2018).

4.2. RQ 2: What Type of Users are Technologies for ER Designed for?

We analyzed the type of users in two levels: age and health condition. We chose these levels since different developmental stages and health conditions require different type of support for ER training. Our analysis revealed that 78% of the technologies were designed for adults (e.g., (Semertzidis et al., 2020)) and 22% were designed for children (e.g., (Crepaldi et al., 2017)) and adolescents (e.g., (Scholten, Malmberg, Lobel, Engels, & Granic, 2016)). When analyzing the health condition withing each age group we found that only 2.6% of the technologies that were designed for adults were designed for non-healthy adults (e.g. highly stressed adults). In contrast, 82% of the technologies that were designed for adolescents and children were designed for non-healthy adolescents and children (e.g. ADHA, autism spectrum disorders, fetal alcohol spectrum disorders, anxiety) (see Figure 6).

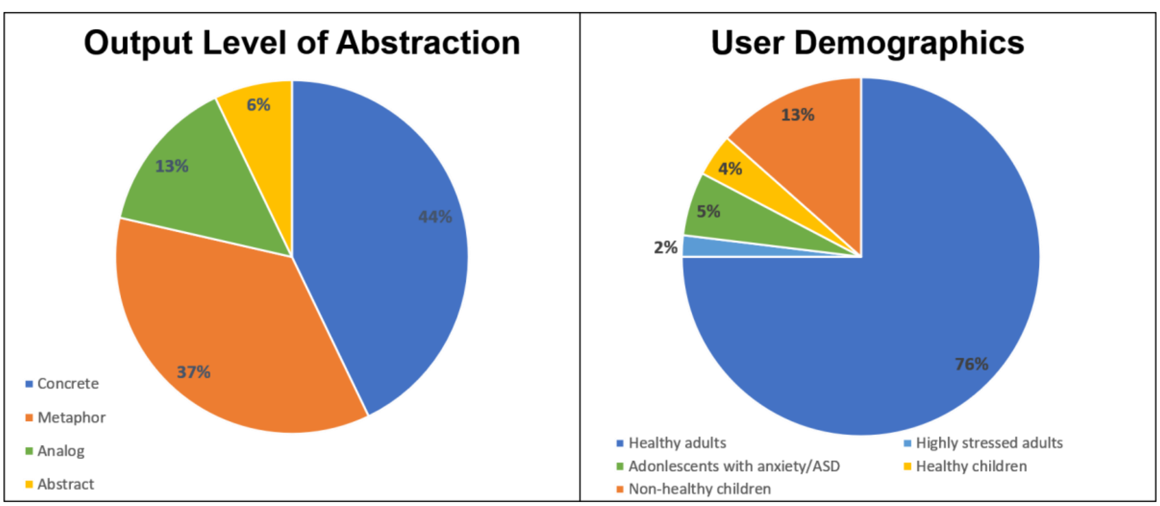

Figure 6: Pie charts with the output level of abstraction and user demographics

4.3. RQ 3: What are the Theoretical Models that Underline Interactive Technologies for ER Training?

To answer this RQ, our analysis focused on identifying the theory of behavior change related to ER used to structure the design components that were foundational to the intervention (Frechtling, 2007). Identifying a theoretical model during coding was a challenging task. Many of the authors did not detail how the technological system was grounded in a psychological or therapeutic model, or how their systems supported learning and/or skill development around ER. As such, papers that did not include a description of a theoretical model, or where a theoretical model was implied or assumed (but not explicitly described or provided with references), were excluded in the sixth pass of the filtering process. Our analysis of the remaining papers revealed four categories of theoretical models. The categories are non-exclusive, some technological interventions were designed based on more than one of the theoretical models that we found in our analysis (see Figure 7).

4.3.1. Biofeedback and Neurofeedback

57% of the technological interventions built upon biological or neurological state as an indicator for an emotional state. Our analysis revealed two strategies that were used in designing technologies under this theoretical model. 67% of the technologies under this theoretical model encouraged users to reach a target physiological state based on positive or negative feedback (e.g. (Parnandi & Gutierrez-Osuna, 2018)). These technologies were designed based on the assumption that users should regulate their emotions towards reaching a certain physiological target. This strategy is informed by operant conditioning. In this strategy, specific biological or neurological states are rewarded, either continuously or intermittently, with some sort of feedback. The rest of the technologies under this theoretical model (33%) were designed to raise user's awareness of their current physiological signs that are associated with ER through feedback (e.g. (Sanches, Höök, Sas, & Ståhl, 2019)). They assumed that through raising awareness to changing physiological signs, users can modify their emotional experience.

4.3.2. Psychological Models

29% of the technologies were based on psychological models. These technologies are informed by evidence-based strategies that are usually used in the context of psychological therapy and psychological informed workshops. Under this theoretical model, 75% of the papers are based on Cognitive Behavioral Therapy (CBT) (e.g. (Pina et al., 2014)). CBT is grounded on the relationship between how we feel, think, and behave (Beck, 1997). The core aspects of CBT is built upon the notion of supporting patients to think about their thinking and identifying patterns that have a negative impact on their emotions and behaviors. After being aware to negative thoughts, patients are encouraged to actively change their thoughts and behaviors (Beck, 1997). The rest of the papers under this theoretical model (25%) are designed based on the dual pathway model (Crepaldi et al., 2017), emotion-focused therapy (Jingar & Lindgren, 2019), attachment-theory (Oehler & Psouni, 2019), and positive psychology (Paredes et al., 2014) .

4.3.3. Cueing

9% of the technologies provided users feedback that was based on target-beneficial emotion regulatory state. Unlike other interventions, technological interventions under this theoretical model did not represent user's emotional state, but rather provided users with a feedback that represented desired emotional state. This process builds on the notion of interpersonal touch (Gallace & Spence, 2010), empathy (Fukushima, Terasawa, & Umeda, 2011), increase of conformity (Dong, Dai, & Wyer Jr., 2015), and physiologic al synchronization (Keller, Novembre, & Hove, 2014). Costa et al. (2019), presented BoostMeUp, a smartwatch intervention that was designed to "override user's self-perception of their heart rate" by providing a slower haptic feedback (Costa, Guimbretière, Jung, & Choudhury, 2019). Similarly, Iishi et al presented a wrist-worn mobile heart regulator that through tactile stimulus mimics the feeling of a heartbeat pule (Choi & Ishii, 2020). Frey et al., (2018) showed how users "modified their respiration" to match the haptic feedback that was formed by a necklace (Frey et al., 2018). Slovák et al. (2018) presented a smart plush-toy that was designed to support children's self-soothing behaviors through vibration feedback that mimicked the toy's heart rate (Slovák et al., 2018).

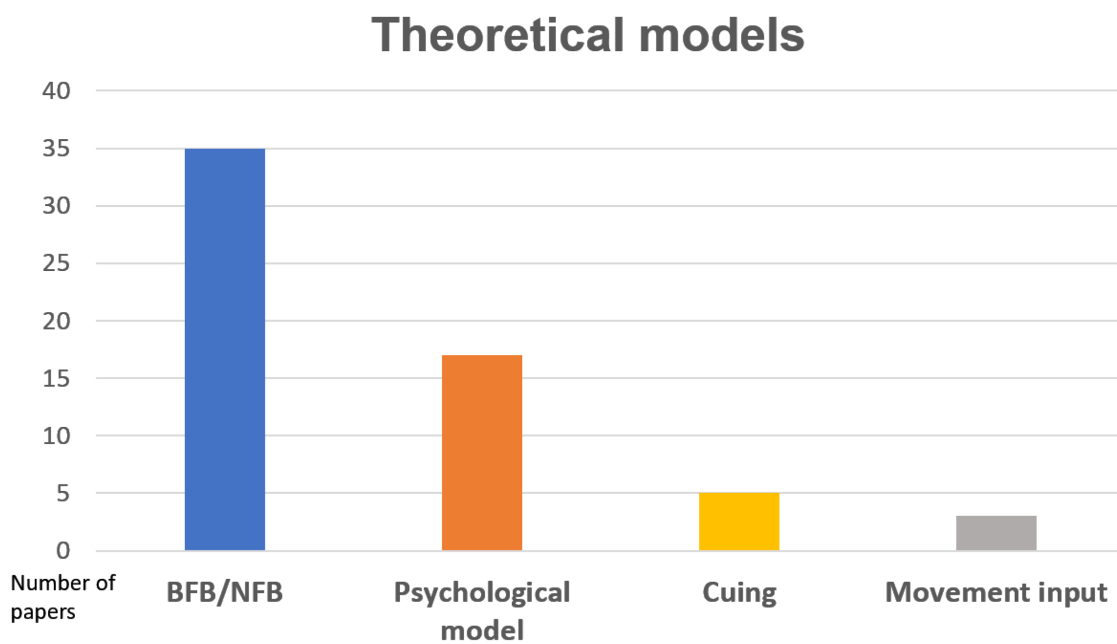

Figure 7: Bar chart with the theoretical models

4.3.4. Motor-based Input for Emotion

Previous research associated the sensory-motor system as an elementary core of emotional processing (Leventhal, 1984). Motor expressions are the physical aspect that are associated with emotions (de Rooij & Jones, 2015). This association is considered innate as it is noticeable in newborns' ability to express and interpret emotions. It is assumed that when a motor expression matches the emotional experience, the intensity of the emotion is increased rather than changes (Leventhal, 1984). Only 5% of the papers built upon this model and integrated appropriate design features in the technological intervention. Two of the papers presented technologies used body movement as an input for emotion regulatory processes. Niksirat et al. (2019) designed a mobile app that tracked user's repetitive body movement as an input for their level of attention during a mindfulness training session (Niksirat, Silpasuwanchai, Cheng, & Ren, 2019). Their technology was designed based on the Relaxation Response Theory that enhances slow and repetitive movements to elicit relaxation (Benson, Beary, & Carol, 1974). Rooij and Jones (2015) presented a system that helped augment human creativity through approach and avoid arm gestures (de Rooij & Jones, 2015). Another type of technology used physical interaction with tangible modality to express emotions. Lee and Hong (2017) presented an approach for representing and expressing emotions through tangible interaction with a plasticine clay. They mentioned that “tangible modality afforded users an opportunity to embody their emotions in a variety of forms” (Lee & Hong, 2017).

4.4. RQ 4: What are the Design Opportunities Created by Interactive Technologies for ER Training?

The thematic analysis revealed 14 opportunities that were subsequently arranged into 4 high-level themes (see Table 2).

Table 2: Opportunities themes

High-level theme	Opportunities
Access	Emotional training during everyday activity
	Using prevalent devices
Embeddedness	Gamifying ER training
	Structuring ER training as storytelling
	Providing external motivation
	Social emotional sharing and support
	Multimodal feedback
Feedback for awareness	Feedback that is easy to interpret and understand
	Feedback that provides space for interpretation
	Longitudinal feedback
	Opportunities for reflection
Personalization	Enable user customization
	Using ML to learn and predict an emotional state
	Coupling subjective and objective emotional experience

4.4.1. Access

The review showed that technologies that were designed for use during everyday activity may offer “constructive in-the-moment support” during everyday stressful situations (Slovák et al., 2018). Huang et al. (2015) emphasized location and contextual situations in real-life as important triggers for emotion (Huang et al., 2015). Oehler and Psouni (2019) added that mobile technologies offered opportunities to influence human behavior as they can be integrated in daily life within different locations (Oehler & Psouni, 2019). Moreover, integrating systems for ER training within everyday PC related activities can enable multiple opportunities for ER training throughout different activities (Lobel et al., 2016). As such, there is an opportunity in prevalent devices such as wearables (e.g.(Costa et al., 2019)), tangibles (e.g. (Cottrell et al., 2018)), and mobile devices (e.g.(Niksirat et al., 2019)) that can sense in a non-invasive way behaviors or physiological processes that are associated with ER.

4.4.2. Embeddedness

The review indicated that there are diverse approaches to embed users with ER training. Gamification was a prevalent method that increased user's engagement through positive (e.g. (Parnandi & Gutierrez-Osuna, 2017)) or negative reinforcement (e.g. (Mandryk et al., 2013)). Reinschluessel and Madryk (2016) showed that positive reinforcement was more effective in encouraging players to keep their brain activity regulated when playing neurofeedback games (Reinschluessel & Mandryk, 2016). Another method was storytelling. Slovák et al. (2016) designed a digital storytelling system that was framed around a "grumpy Pirate Harrdy searching for his treasure". The narrative motivated children to "re-live their feelings" in a safe environment with their caregiver (Slovák et al., 2016). Díaz–Escudero et al. (2018) presented a mobile technology that was based on external authority. Their technology provided users with Autism Spectrum Disorders (ASD) "step-by-step coaching methods of emotional self-regulation" (Díaz-Escudero et al., 2018). Multimodal representation such as visual and audio representations of an emotional experience were used to embed users during the interaction with the technology towards supporting emotional self-awareness and fostering "more effective emotional regulation strategies" (Bermúdez i Badia et al., 2019). While most technologies for ER training were designed for an individual user, some were designed for sharing emotional experiences and providing social-emotional sharing and support. Snyder et al. (2015) presented an interactive ambient lighting system that responds to biosensor input related to an individual's current level of arousal. Their findings showed that implementing such a technology in a social context enabled users to validate and acknowledge the feelings of others and "adjust themselves to try to optimize their shared experience" (Snyder et al., 2015). Slovák et al. (2016) designed a digital storytelling system that was designed to "promote the parental involvement and support" for children's ER skills. Through the storyline, they "set the scene for a more direct parent-child interaction" (Slovák et al., 2016). Designing technologies that enable sharing emotional experience and moments for social-emotional support can be beneficial when trying to induce behavioral change. Karapanos (2015) emphasized that “social relationships may be more effective in inducing behavior change than human-technology ones” (Karapanos, 2015).

4.4.3. Feedback for Awareness

The review revealed that cumulative feedback was often used to represent an emotional experience. Cumulative feedback has a clear mapping that makes it easy to interpret and understand what a desired mental state is (i.e. ‘higher’ numbers that indicated a good regulatory mental state). Yang et al. (2019) quantified real-time brain functionalities through colored graphs that elevated when users successfully enhanced mental states that are associated with ER (Yang et al., 2018). In contrast, some technologies provided feedback that provides space for interpretation. Sanches et al. (2019) designed a mobile application that represents user’s levels of skin-conductance in a way that “evokes multiple interpretations in an on-going process of co-constructive making of meaning” (Sanches, Höök, Sas, & Ståhl, 2019). Other technologies used tangible ways to represent an emotional experience. Lee and Hong (2017) presented an approach for representing and tracking emotion through tangible interaction with plasticine clay and a diary. They mentioned that the abstraction of emotions through different shapes of clay represented a “nuance of emotion with a shape that was not accurately defined” that gave participants opportunities to reflect upon their emotions and encouraged self-awareness.” (Lee & Hong, 2017). Finally, some technologies provided longitudinal emotional representation. Bakker and Rickard (2018) described a mobile app that presented emotional data over time, based on daily-mood surveys (Bakker & Rickard, 2018).

4.4.4. Personalization

Technologies that enabled user customization are scarce. Antle et al. (2019) integrated a customization feature to a neurofeedback game for children. This feature enabled the intervention to meet the changing needs of individuals in real time and increased motivation by setting achievable goals (Antle et al., 2019). Miri et al. (2020), emphasized the importance of personalizing vibrotactile interventions for ER. They raise the importance of personalizing emotional feedback not as a one-time procedure, but as a continuous process that can capture the dynamic influences of the both inward and outward processes on an emotional state (Miri et al., 2020). Other ways to personalize ER training used machine-learning to analyze and predict emotional state and coupling subjective and objective data of an emotional experience. Paredes et al. (2014) used a machine-learning based intervention that provided personalized stress reduction strategies based on self-report and sensory features that were collected through mobile phone usage, such as GPS location and calendar record (Paredes et al., 2014). While many of the technologies use physiological data to infer upon an emotional state, only few coupled subjective forms of data and objective measurements to enable personalized emotional feedback that is sensitive to current emotional and contextual environment (e.g. (Kocielnik et al., 2013)).

4.5. RQ 4: What are the Challenges Faced when Designing Interactive Technologies for ER Training?

The thematic analysis revealed 8 challenges that were subsequently arranged into 3 high-level themes (see Table 3).

Table 3: Challenges themes

High-level theme	Challenges
From emotional data to emotional representation	Providing appropriate emotional feedback
	Mapping emotional state
	Lack of context of emotional data
Feedback for awareness	Awareness vs. attention
	Enable transfer and maintenance
	Interaction flow
Ethics	Raise self-judgment
	Ensure privacy

4.5.1. From Emotional Data to Emotional Representation

While there has been significant investment in deterministic and diagnostic methods to detect and infer emotional state, little is known on how to provide appropriate emotional feedback that is beneficial for ER training. Technologies that provided concrete feedback that infers ‘good’ and ‘bad’ emotional state or an emotion regulatory process often overlook the contextual environment and situational emotional state of the user (e.g. (Díaz-Escudero et al., 2018)). On the other hand, providing abstract and ambiguous emotional representation is often hard to interpret and understand (e.g. (Yu et al., 2017)). Technologies that expose user's stressful emotional representation, ponder on what is the right amount of stress that triggers a healthy emotion regulatory process (Lobel et al., 2016). Another challenge noted in Huang et al. (2015) was the use of a set of discrete categories to map an emotional state. Participants complained that the 16 emotions that were designed to choose from to represent an emotional state "were not sufficient to express their emotional experience" (Huang et al., 2015). Similarly, technologies that use single physiological sensors to infer an emotional experience map an emotional experience through a threshold that indicates stress or calmness. Howell et al. (2018) raised the concern that emotional biosensing technologies "flatten the messiness" and that current technologies do not acknowledge the "complexity of affect, feeling and emotion" (Howell et al., 2018).

4.5.2. Moments of Reflection

The review revealed that there is a challenge in providing emotional representation that both engages users during the interaction with the technology and encourages users to reflect upon their emotional state and emotional regulatory skills. Kolb (2014) emphasized the crucial role of reflection in the formation of abstract concepts related to social-emotional learning. He added that moments of reflection enable users to understand both the conscious and the unconscious components (Kolb, 2014). Deep understanding of the components can enable to transfer and maintain the emotional learning skills throughout different contexts and times. However, most technologies were designed to create an engaging experience by drawing user's attention to a certain task or activity that represented a behavior or physiological state that is associated with ER. For example, Zafar et al. (2017) presented a respiration-based biofeedback game that created a "more engaging alternative to traditional stress therapies" (Zafar, Ahmed, & Gutierrez-Osuna, 2017). While they created an engaging experience, they did not provide opportunities for the user to actively reflect upon the emotional experience and the self-regulatory skills that were applied. Moments of reflection are hard to design since they often harm the flow of the interaction with the technological intervention. Slovák et al., 2016 described this challenge by enabling users to 'stop & learn' from emotional experiences by implementing reflective skills (Slovák et al., 2016).

4.5.3. Ethical Issues

The review indicated that there are ethical issues when designing interactive technologies for ER training. Leveraging social support has the potential to be beneficial for ER training. As such, some technologies provided opportunities to share emotional data. However, sharing digital emotional data raises privacy ethical issues. There is growing technological development and ability of prevalent devices such as wearables and mobile devices to sense physiological data that can be associated with an emotional experience. For example, this raises an ethical challenge of autonomy when designing assistive technologies for vulnerable populations. Díaz-Escudero et al. (2018) presented a smart-watch that sensed heart rate of children with ASD. The physiological data from children's everyday activity was sent to the caregiver's smart-phone (Díaz-Escudero et al., 2018). While this ethical concern is always relevant when storing personal data on digital devices, it is especially relevant when emotional data is stored and shared. Another ethical issue is the potential negative impacts of emotional representation. Niksirat et al. (2019) discussed the importance of using forms of emotion representation that avoid raising user's self-judgement about their experience or their inability to regulate their emotions (Niksirat et al., 2019). Technologies that provided cumulative feedback that frame an emotional experience or an emotion regulation skill as 'good' or 'bad' can raise user's self-judgment and result in unintended negative consequences on mental health.

Chapter 5.

Design Framework

Building on the understanding of the various ways technologies for ER training are designed and implemented in HCI literature, we present a descriptive design framework for designing technologies in this context. We present five key concepts that were generated from the literature review: theoretical space, level of contextual embeddedness, users, emotion-based input, and emotional representation. For each concept we present key considerations in the form of questions. We derived these questions based our interpretation of the thematic review findings combined with important design features cited across papers in order to highlight important considerations. Research and designers should ask themselves these questions throughout the iterative process of designing technologies. Where relevant, we highlight research gaps, or underexplored areas where researchers and designers might want to further explore. Our motivation is to make these concepts accessible and actionable for researchers and designers during the iterative process of designing interactive technologies for ER training.

5.1. Theoretical Model

We emphasize the importance of recognizing in early stages of the design process how theoretical models work and what is their chain of reasoning. In our analysis we identified four theoretical models that were used in previous technologies for ER training (bio/neurofeedback, psychological models, cueing, and motor-based input). Each theoretical model can be used to lead to different (but not distinct) design features. We acknowledge that a different set of papers, analysis method, and coders could have resulted in different theoretical models. We do not claim that researchers and designers should choose from the theoretical models that were raised in our analysis, but rather consider the opportunities offered by each theoretical model in early stages of the design process. We encourage researchers and designers to consider the following questions:

What is the chain of reasoning on how the technological intervention will lead to ER training?

What are the intended outcomes of the technological intervention and how do they relate to the chain of reasoning?

Can the technological intervention leverage opportunities from multiple theoretical models?

In our findings, we presented theoretical model themes that were used in previous publications. Here, we synthesize the theoretical model themes in light of the opportunities and challenges that were raised in the findings of the review. We emphasize an underexplored opportunity of providing users with multiple perspective and approaches for ER training within a single technological intervention. Knox et al (2011), provided users with CBT psychoeducational content coupled with opportunities for biofeedback assisted relaxation training. This approach enabled children to cognitively understand the process of how stress arises and how relaxation behaviors can prevent stress based on psychological models of CBT, followed by experiential learning where children executed the previously learnt relaxation skills during game-based biofeedback sessions (Knox, Michele et al., 2011). Another example for a technology that leveraged opportunities from more than one theoretical model was proposed by Paredes et al. (2014). They raised the motivation of previous technologies to the design 'the best intervention' based on a single theoretical model. To contradict this approach, they developed a smart-phone application that provided behavioral suggestions based on a machine-learning recommender system. The behavioral suggestions were chosen from diverse psychological theoretical models such as positive-psychology, CBT, and meta-cognitive. Each behavioral suggestion from the varied theoretical models was provided based on user's personal traits and contextual data (Paredes et al., 2014).

5.2. Level of Contextual Embeddedness

In our findings we raised the growing use of prevalent technologies and their opportunities in facilitating moments of ER training during everyday activity. Our review indicated that some technological interventions for ER training defined the context of the activity. These technologies were embedding ER training within a certain context of use (i.e. meditation (Sas & Chopra, 2015) and video games (Z. Wang et al., 2018)). Other technological interventions were designed to be embedded during other everyday activities. Recent technological development in mobile platforms such as mobile phones and tablets, wearables, and tangibles can enable to facilitate ER training throughout different physical locations. Providing opportunities for ER training during everyday activity and 'in-the-moment' emotional support can enhance transfer and maintenance of the ER skills throughout time and space. This raises the challenge of designing technologies that can fit various contexts throughout everyday activities. Technologies that were designed for ER training often required user's attention when interacting with the technological intervention, either by providing an emotion-based input (e.g., self-report (Fage et al., 2019)) or when receiving the emotional representation (e.g., behavioral suggestion (Carlier et al., 2019)). This type of interaction can result in disengagement from the environment and the social context. We encourage researchers and designers to consider the following questions:

Does the interaction with the technological intervention define the activity, or is it being embedded during other activities?

Does the form of interaction fit with the context of technology use?

What is the interplay between the context of the activity and the interaction with the technological intervention?

The results of the review showed that 56% of the technologies were designed for everyday context and 59% of the technologies were designed based on prevalent devices as platforms. With the growing development of mobile devices, we expect that there will be a growing need to embed future technologies for ER training in the changing context of everyday activity. While there are great opportunities in this direction such as providing access to such intervention, there are also challenges such as lack of context and how to preserve the flow of activity in changing context. We highlight three approaches in which researchers and designers can ensure that technologies that are designed to be embedded in everyday activity do not disengage users from their environment. The first is based on technologies that can sense contextual data and provide appropriate opportunities for ER training. This can be achieved by active data collection such as user's self-report (e.g. (Y. Wang, Fischer, & Bry, 2019)), or by passive data collection such as location (e.g. (Huang et al., 2015)) and activity by synching to the user's calendar, (Kocielnik et al., 2013). The second approach is based on the notion of designing two parallel interactions with the technological intervention. One that requires user's full attention and engagement when interacting with the technology and the second, when the user is not actively engaged with the technology. Pina et al. (2014) designed a mobile app that provided parents of children with ADHD in-situ behavioral support. The app was designed to support parents in two contexts. In times when the parent was fully engaged with the app, s/her received written behavioral strategies on how to facilitate moments of duress. In times when parents were not engaged with the app, during 'hot moments' with the child, a peripheral glanceable display that was previously associated with the behavioral suggestion was presented (Pina et al., 2014). The third approach involves inviting users to interact with the technological intervention, rather than forcing an interaction. Sanches et al. (2019) designed a skin-conductance bio-feedback system that provided an emotional representation that was abstract and ambiguous. This emotional representation invited users to actively reflect upon their emotional experience rather than 'being forced' to participate in the meaning-making. An invitation for such an interaction and designing features that are evocative and mysterious rather than didactic and explicit can enable the user to decide on when to interact with the technological intervention, in times that fit the context (Sanches, Höök, Sas, & Ståhl, 2019).

5.3. Users

Users vary in their ability to regulate emotions and their need for support by interactive technologies. The findings of the review showed that previous technologies were designed to support a wide range of users in terms of age and mental health challenges and/or disorders. As such, we encourage researchers and designers to follow a user-centered design process (Abras, Maloney-krichmar, & Preece, 2004) by considering the target users and accordingly, the type of emotion regulatory skills that should guide the focus of the technologies design.

Who are the target users of the intervention?

What is the emotion regulatory challenge of these users?

Is the motivation to teach children ER skills? Is the motivation to help populations with pathologies to practice ER skills? Is the motivation to provide healthy populations opportunities to practice their ER skills?

In the context of children, their ability to regulate emotions depends on their developmental stage. Similarly, different mental health challenges/ disorders challenge users with different stages of ER (i.e. ADHD and ASD). We emphasize an underexplored opportunity in integrating users in the design process of the technology. Fage et al., 2019 used a participatory design approach when designing a mobile application designed to guide children with ASD with self-regulation towards integration in mainstream classes. The paper demonstrated how involving school staff, children with ASD, and children's caregivers to identify user requirements, usage scenarios, and design principles

In terms of target users, the findings from the literature review showed that most technologies that were designed for children, were designed for non-healthy children. In contrast, most technologies that were designed for adults, were designed for healthy adults. We highlight the gap in technologies that are designed for healthy children and non-healthy adults. Preventative interventions for healthy children in the context of ER have the opportunity to develop protective factors against different pathologies. The gap in technologies for ER training for adults with pathologies can be explained by the methodological challenge of running a research with this population.

5.4. Emotion-based Input

Next, researchers and designers should consider the different methods to sense data that is associated with an emotional experience. This decision should be derived by previous choices of the theoretical model, context of activity, and the type of users. The review showed that there are various methods for sensing an emotional experience (bio-sensing, neuro-sensing, behavioral measurements, self-report, body movement, physical location, and tangible interaction with an object). When interactive technologies for ER training are being implemented in a lab setting, they have the potential to differentiate between emotional states under a controlled environment, i.e. attention vs. lack of attention (e.g. (Antle et al., 2019)) and stress vs. relaxation (e.g. (Lobel et al., 2016)). As of today, even in a lab setting, the ability of to infer upon an emotional experience is limited. However, with recent development of sensing capabilities in prevalent devices, technologies that claim to infer upon an emotional experience are implemented outside lab context, 'in-the-wild'. While this holds a great opportunity as these devices can provide accessibly opportunities for ER training during everyday activities, we encourage researchers and designers to ask themselves the following questions:

What does the data tell us about the emotional experience?

What is the level of determinism of the input? Does the input sense data that can differentiate between different emotional states, or infer upon an emotional experience?

Does the data consider contextual and situational factors that can influence the emotional experience?

The assumptions and capabilities of sensing technologies in the lab context, in a controlled setting, are fundamentally different outside the lab context as the nature of an emotional experience 'in the wild' is ambiguous, dynamic, and complex. When designing technologies for ER training outside the lab context, we encourage researchers and designers to use multiple sources of input that can contextualize the data within the everyday activity (i.e., self report and behavioral measurements). While coupling various forms of data can shed light on the nature of an emotional experience, multiple inputs can create a heavy-handed experience and be challenging to implement in way that is not bulky. As such, researchers and designers should strive to find the sweet-spot between designing technologies that can *determine* on a situational emotional experience by multiple inputs, and designing technologies that are based on a single input that is only *associated* with an emotional experience.

5.5. Emotional Representation

Finally, researchers and designers should decide upon the emotional representation that will be provided to the user. Little is known about how to provide emotional representation that is beneficial for ER training. The review showed that the methods of providing an emotional representations varied in terms of their modalities, level of abstraction, and timing. We encourage researchers and designers to consider the following questions:

Is the emotional representation in-line with the level of determination that is provided by the input?

Is the emotional representation motivated to encourage users to interact with the technological intervention?

Does the emotional representation encourage users to reflect upon their emotional experience?

We encourage researchers and designers to design an emotional representation that is in-line with the level of determinism that can be provided from the emotion-based input. When using emotion-based input that can only infer upon an emotional experience, we encourage researchers and designers to provide an emotional representation that is ambiguous and open-ended. However, while open-ended feedback can invite users to make meaning out of their emotional experience (e.g. (Niksirat et al., 2019), without concrete tools and support, there is no promise that the user will self-reflect upon his/her emotional experience. Reflection upon an emotional experience is crucial for learning an implementing ER skills. Even when technologies were designed to provide an open-ended and ambient emotional representation, users tended to “give more credit to the system than to themselves in terms of knowing how they were feeling in the moment” (Snyder et al., 2015). In addition, we highlight the challenge of designing experiences that encourage users to ‘stop & reflect’. In this context, there is an under-explored opportunity in designing technologies that encourage and facilitate social-emotional communication between users (Slovák et al., 2016), and technologies that raise social-awareness to the emotional state of users (Snyder et al., 2015). Other technological interventions were designed to encourage users to practice ER training while playing video games and during meditations sessions. In these cases, there is an opportunity in creating an experience that is engaging, towards extending the duration of the ER training and lowering the threshold for ER training. This can be achieved by providing multimodal feedback (e.g. (Prpa et al., 2018)), an appealing narrative for a video game (e.g. (Khong et al., 2014)), or in the form of concrete representations where certain behaviors and mental efforts are rewarded (e.g. (Antle et al., 2019)).

Chapter 6.

Conclusion

This paper has two main contributions. First, we intend to guide researchers and designers interested in technologies for ER training to quickly understand the field, find relevant previous work, and to better position their own research within the field. Second, we present a design framework that synthesizes the main concepts and key considerations for designing future technologies in the context of ER training. We presented the key considerations in the form of questions. Rather than providing answers to our questions, our goal is to encourage researchers and designers to ponder these questions during early stages of the design process. By presenting the theoretical models that were previously used, we encourage researchers and designers to leverage the opportunities and examine underexplored areas. Previous review studies reviewed certain methods, such as BCI (Vasiljevic & Miranda, 2020) and certain contexts of activity such as mindfulness (Terzimehić et al., 2019). Together with the work of Yoon et al. (2019), this work is positioned among previous review paper in the field by analyzed technologies across methods, approaches, and activities. In addition to the design framework presented by Yoon et al. (2019), this thesis provided design guidance, with exemplars of themes, and highlighted underexplored research areas.

Future work should continue to explore the quickly growing field of interactive technologies for ER training. The design framework that was generated in this thesis was based on an inductive process of analyzing previous technologies. In future research, this design framework can be used as an analytical lens to evaluate existing technologies. This thesis presents a first attempt to describe the current state of research and design of interactive technologies for ER training. As such, we present a descriptive design framework. We encourage future research to consider more details of the coding process. Future design framework in the field should aim to present an explanatory design framework by drawing relationships of cause and effect between certain design features and their outcomes and view such relationships in light of other review studies in the field.

Designing technologies for this sensitive context requires an ethical standpoint that is reflective and transparent. We hope that future designs would provide more space for user’s contextual and social interpretation of their emotional state rather than absolute reliance of the emotional representation that is provided from technology. We emphasize the need for a constant responsive and situational ethical stance, that is constantly reflective throughout the different stages of the design and evaluation stages.

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Appendix- paper analysis

Paper	Users	Theoretical model	Technological platform	Context of use	Emotional-based input	Output modality	Output level of abstraction	Output timing
Antle et al., 2019	Children with anxiety	Neurofeedback	Tablet	Video game	Neurological	On screen	Concrete Metaphor	Real time
Badia et al., 2018	Healthy adults	Biofeedback	VR	Lab context	Biological	On screen Sound	Metaphor	Real time
Bakker & Rickard, 2018	Healthy adults	Psychological model	Mobile phone	Everyday activity	Self-report	On screen	Concrete	Longitudinal
Balters et al., 2020	Healthy adults	Cueing	Car	Everyday activity	None	Haptic	Metaphor	Real time
Carlier et al., 2019	Children (6-10) with ASD	Psychological model	Mobile phone	Video game	Behavioral	On screen	Concrete	Real time
Cavazza et al., 2014	Healthy adults	Neurofeedback	PC	Lab context	Neurological	On screen	Metaphor	Real time
Choi & Ishii, 2020	Healthy adults	Biofeedback	Wearable	Everyday activity	Biological	Haptic	Analog	Real time
Costa et al., 2019	Healthy adults	Cueing	Wearable	Everyday activity	None	Haptic	Analog	Real time
Crepaldi et al., 2017	Children with acute ADHD (8-10)	Psychological model	PC	Video game	Behavioral	On screen	Concrete	Immediate
de Rooij & Jones, 2015	Healthy adults	Movement input	Wearable	Everyday activity	Body movement	Tangible interaction	Concrete	Immediate
Díaz-Escudero et al., 2018	Children with ASD	Psychological model Biofeedback	Wearable	Everyday activity	Biological	On screen	Concrete	Real time + longitudinal

Paper	Users	Theoretical model	Technological platform	Context of use	Emotional-based input	Output modality	Output level of abstraction	Output timing
Fage et al., 2019	Adolescents with ASD	Psychological model	Tablet	Everyday activity	Self-report	On screen	Concrete	Immediate
Frey et al., 2018	Healthy adults	Cueing	Wearable	Everyday activity	None	Haptic	Analog	Real time
Ghandeharioun & Picard, 2017	Healthy adults	Biofeedback	Wearable and PC	Everyday activity	Biological	On screen Haptic Sound	Analog	Real time
Huang et al., 2015	Healthy adults	Psychological model	Mobile phone	Everyday activity	Self-report	On screen	Concrete	Real time + longitudinal
Jingar & Lindgren, 2019	Healthy adults	Psychological model	Tangible Mobile phone	Everyday activity	Tangible interaction	On screen	Concrete	Real time
Khong et al., 2014	Healthy adults	Neurofeedback	PC	Video game	Neurological	On screen	Metaphor	Immediate
Knox et al., 2011	Children with anxiety Adolescents with anxiety	Psychological model Biofeedback	PC	Video game	Biological	On screen	Metaphor	Real time
Kocielnik et al., 2013	Healthy adults	Biofeedback	Wearable Mobile device	Everyday activity	Biological, Behavioral Self-report	On screen	Concrete	Longitudinal
Lee & Hong, 2017	Healthy adults	Movement input	Tangible	Craft	Tangible interaction	Tangible interaction	Abstract	Real time + longitudinal

Paper	Users	Theoretical model	Technological platform	Context of use	Emotional-based input	Output modality	Output level of abstraction	Output timing
Liang et al., 2018	Healthy adults	Biofeedback	Tangible	Everyday activity	Biological	Tangible interaction Light	Metaphor	Real time
Lloyd et al., 2010	Children (9-13) with ADHD	Psychological model Biofeedback	PC	Video game	Biological	On screen	Metaphor	Real time
Lobel et al., 2016	Healthy adults	Biofeedback	PC	Video game	Biological	On screen	Metaphor	Real time
Mandryk et al., 2013	Children with FASD	Neurofeedback	PC	Video game	Neurological	On screen	Analog	Real time
Miri et al., 2020	Healthy adults	Cueing	Wearable	Everyday activity	Biological	Haptic	Analog	Real time
Moraveji et al., 2012	Healthy adults	Biofeedback	PC	Everyday activity	Biological	On screen	Concrete Metaphor	Real time
Niksirat et al., 2019	Healthy adults	Movement input	Mobile phone	Meditation	Body movement	On screen Sound	Abstract	Real time
Oehler, M., & Psouni, 2019	Healthy adults	Psychological model	Mobile phone	Everyday activity	None	On screen	Concrete	Random
Paredes et al., 2014	Healthy adults	Psychological model	Mobile phone	Everyday activities	Behavioral	On screen	Concrete	Real time
Parnandi & Gutierrez-Osuna, 2015	Healthy adults	Biofeedback	PC	Video game	Biological	On screen	Concrete	Real time

Paper	Users	Theoretical model	Technological platform	Context of use	Emotional-based input	Output modality	Output level of abstraction	Output timing
Parnandi & Gutierrez-Osuna, 2018	Healthy adults	Biofeedback	Mobile phone	Video game	Biological	On screen	Concrete	random
Pina et al., 2017	Parents of children with ADHD	Biofeedback Psychological model	Mobile device Wearable	Everyday activity	Biological Self-report	On screen	Concrete	Real time
Prpa et al., 2018	Healthy adults	Biofeedback	VR	Meditation	Biological	On screen Sound	Metaphor	Real time
Reinschluessel & Mandryk, 2016	Healthy adults	Neurofeedback	PC	Video game	Neurological	On screen	Concrete	Real time
Sanches et al., 2019	Healthy adults	Biofeedback	Mobile device Wearable	Everyday activity	Physical location Biological	On screen	Abstract	Real time + Longitudinal
Sas & Chopra, 2015	Adult mindfulness meditation practitioners	Neurofeedback	PC	Meditation	Neurological	Sound	Metaphor	Real time
Scholten et al., 2016	Adolescents at risk for anxiety	Psychological model Biofeedback	PC	Video game	Biological	On screen	Concrete Metaphor	Immediate
Semertzidis et al., 2020	Healthy adults	Biofeedback	VR	Everyday activity	Neurological	On screen	Abstract	Real time
Shamekhi & Bickmorz, 2018	Healthy adults	Biofeedback	PC	Meditation	Biological	On screen	Concrete	Immediate
Slovák et al., 2016	Healthy children (5-8)	Psychological model	Tablet	Everyday activity	None	On screen	Metaphor	Real time

Paper	Users	Theoretical model	Technological platform	Context of use	Emotional-based input	Output modality	Output level of abstraction	Output timing
Slovák et al., 2018	Healthy children	Cueing	Tangible	Everyday activity	Tangible interaction	Haptic	Analog	Real time
Smyth & Heron, 2016	Highly stressed adults	Psychological model	Mobile phone	Everyday activity	Self-report	On screen	Concrete	Real time
Snyder et al., 2015	Healthy adults	Biofeedback	Smart home	Everyday activity	Biological	Light	Metaphor	Real time
Springer et al., 2018	Healthy adults	Psychological model	Mobile phone	Everyday activity	Self-report and Behavioral	On screen	Concrete	Longitudinal
Stangl et al., 2017	Healthy children (3-6)	Psychological model	Tangible	Everyday activity	Self-report	Tangible interaction	Metaphor	Real time
Wang et al., 2018	Healthy adults	Biofeedback	PC	Video game	Biological	On screen	Concrete	Real time
Wang et al., 2019	Healthy adults	Biofeedback	Mobile phone Wearable	Everyday activity	Self-report Biological	On screen	Metaphor Concrete	Longitudinal
Wells et al., 2012	Healthy adults	Biofeedback	PC	Lab context	Biological	On screen	Concrete	Real time
Yang et al., 2018	Healthy adults	Neurofeedback	PC	Lab context	Neurological	On screen	Concrete	Real time
Yu et al., 2017	Healthy adults	Biofeedback	Mobile device	Everyday activity	Biological	On screen	Metaphor	Real time
Yu et al., 2018	Healthy adults	Biofeedback	Smart home	Everyday activity	Biological	Light	Metaphor	Real time
Zafar et al., 2017	Healthy adults	Biofeedback	PC	Video game	Biological	On screen	Concrete	Real time
Zhou et al., 2020	Healthy adults	Cueing	Tangible	Everyday activity	Biological	Haptic	Analog	Real time