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The impact of cognitive and emotional factors on user experience in HCI

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Abstract

This paper discusses how cognitive and emotional factors affect user experience (UX) in human-computer interaction (HCI). It examines how users' cognitive processes, including perception, attention, memory and decision-making, interact with emotional reactions, including satisfaction, trust and engagement, to shape the quality of interaction. Drawing on principles from cognitive psychology and affective computing, the study shows that effective HCI design extends beyond functionality and efficiency to include emotional appeal and user satisfaction. The paper emphasises that reducing cognitive load, maintaining interface consistency and using intuitive visual cues improve understanding and task performance. At the same time, integrating affective design principles, including aesthetic appeal, empathy and personalisation, contributes to greater emotional satisfaction and user motivation. It also assesses approaches for measuring UX, including usability testing, heuristic evaluation, affective feedback and physiological emotion monitoring, to capture the cognitive and emotional dimensions of interaction. The findings indicate that combining cognitive ergonomics and emotional intelligence in interface design can produce more adaptive, engaging and human-centred systems. By balancing mental efficiency with positive emotional experience, designers can create technologies that promote trust, empathy and long-term user engagement. Overall, this study supports the value of balancing rational and affective design to develop interactive systems that are useful, efficient, meaningful and emotionally satisfying.

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1. Introduction

The field of human-computer interaction (HCI) has developed considerably within the last few decades, moving beyond a sole concern with system usability and functional efficiency towards the human perspective: how users think, feel and interact with digital systems. With the growing use of technology in our lives, the quality of user interaction with computers has become a major determinant of the general satisfaction and success of the system. Modern HCI studies therefore extend beyond technical performance to include the significance of user experience (UX)–a holistic concept that includes both cognitive and emotional reactions of users

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during the interaction. Knowledge of these underlying psychological factors is crucial in creating systems that are not only usable but also engaging, enjoyable and appreciative of human needs [1, 2].

Cognitive factors determine how users perceive, process and react to information presented in an interface. These include attention, memory, mental workload, and problem-solving strategy, which influence users' efficiency in performing the tasks. Interaction is fluid and intuitive when the interfaces match the cognitive models of users and reduce the unwarranted complications. On the other hand, a design that places heavy cognitive load or does not conform to the expectations of the users may result in confusion and errors, as well as dissatisfaction. Therefore, awareness of cognitive processes gives useful information on how to make systems usable and how users can find their way in interfaces and learn them [1, 3].

The emotional factors, in turn, define the subjective experience of the user and their long-term interest in technology. Positive emotions such as satisfaction, trust, and enjoyment increase the perception of usability and create a feeling of connection to the system, whereas negative emotions such as frustration, anxiety, and boredom may discourage the use of the system. Emotional design seeks to elicit positive affective reactions with the help of aesthetics, feedback, and empathetic interaction patterns [4, 5]. Affective computing has also made further progress so that systems can detect and respond to the emotional state of the user to provide a more personalised and emotionally intelligent interfaces [6].

The interaction of cognitive and emotional factors determines the level and quality of user experience in HCI. Effective interface design requires striking a balance between mental and emotional appeals to make systems both cognitively efficient and emotionally engaging. This review explores the combination of cognitive and emotional determinants of user experience and offers implications that can be used to create more flexible, user-friendly, and psychologically sensitive systems. Incorporating the principles of cognitive science, psychology, and design, the research contributes to the emerging body of literature that helps to develop interactive technologies in accordance with human thought and emotion [7].

This paper makes three distinctive contributions to HCI literature:

1. Integrated synthesis: Unlike prior reviews that treat cognition and emotion separately, we synthesise their bidirectional interaction and show that cognitive efficiency and emotional satisfaction are complementary, not conflicting, dimensions of UX.
2. Conceptual framework (CEI): We propose the cognitive-emotional integration framework (Section 3, Figure 1) that models dynamic, reciprocal relationships between cognitive processes (attention, memory, load) and emotional responses (satisfaction, trust, frustration), linked to UX outcomes. This provides researchers and practitioners a visual tool for balanced design.
3. Actionable design implications with domain-specific examples: We translate the framework into concrete guidelines for education, healthcare, gaming, and adaptive systems, including ethical considerations for affective computing.

The paper is organised as follows: Section 2 reviews cognitive and emotional factors; Section 3 introduces the CEI framework and its interaction; Section 4 presents measurement approaches; Section 5 derives design implications; Section 6 provides case studies; Section 7 concludes with future directions.

2. Literature review

This paper is a narrative review of literature on the cognitive and emotional aspects of HCI. The review compiles previous and recent publications in related fields (cognitive psychology, affective computing, UX). The literature was retrieved by searching the following keywords in Google Scholar, ACM Digital Library and Scopus: cognitive load HCI, emotional design, affective computing, user experience measurement, and human-computer interaction psychology. Peer-reviewed journal articles, conference proceedings and books that were seminal between 2006 and 2025 were prioritised. The selection was intended to include major theories that have shaped the field (Cognitive Load Theory, Norman's Emotional Design Model) and recent empirical studies.

2.1. Review methodology

This paper is a narrative review synthesising cognitive and emotional aspects of HCI. To ensure transparency, we followed a structured search process. We searched Google Scholar, ACM Digital Library, and Scopus using the following keyword combinations: ("cognitive load" OR "attention" OR "memory" OR "mental model") AND ("HCI" OR "human-computer interaction"); ("emotional design" OR "affective computing" OR "user experience" OR "satisfaction" OR "trust") AND ("HCI" OR "UX"); ("measurement" OR "NASA-TLX" OR "SAM" OR "physiological") AND ("user experience").

Inclusion criteria: peer-reviewed journal articles, conference proceedings, and books published between 2006 and 2025, written in English. Exclusion criteria: non-peer-reviewed sources, editorials, and studies not directly addressing HCI/UX.

We prioritised seminal theoretical works (Cognitive Load Theory, Norman's Emotional Design) and recent empirical studies (2020-2025). After initial screening of 480 records, 85 sources were selected for full review based on relevance to cognitive-emotional interaction in HCI.

2.2. Cognitive factors in HCI

Cognitive factors involve the mental activities that shape how users perceive, understand, learn, and interact with computer systems. These factors play critical roles in HCI in terms of the degree to which an interface facilitates information processing and decision-making [8]. Users have varying cognitive capabilities, experiences, and expectations for their interaction, and the interface should be designed in a manner that accommodates these differences [9]. By applying cognitive principles, designers can create systems that are compatible with natural human thinking patterns, which lighten the mental load and increase usability [6]. On the other hand, ineffective systems may exceed users' cognitive abilities, causing confusion, frustration and erroneous information input in the performance of a task [10].

A critical cognitive consideration in HCI is attention, which is a limited and selective process enabling users to focus on a small number of elements in the interface at once [11]. The designers should ensure that necessary elements, including buttons, alerts, and navigation cues, are visually differentiated and prioritised in the context to attract and maintain user attention [12]. Closely related to attention, perception determines how users perceive visual and auditory information in an interface. Such factors as colour, contrast, typography, and spatial arrangement have a strong influence on perceptual clarity [13]. When perceptual design aligns with users' expectations, it becomes easier to locate, recognise and process relevant information [14].

Another important cognitive factor in HCI is memory. Users rely on both short-term and long-term memory in navigating the digital systems. Interfaces requiring memorisation of intricate sequences or instructions exert a cognitive load and deteriorate task performance [15]. Thus, systems must focus on recognition rather than recall by integrating prominent icons, tooltips, and menus to facilitate the easy retrieval of the information [16]. In HCI, cognitive processing is also based on the concept of mental models. A mental model is a user's personal understanding of how a system works [17]. Interactions become intuitive when interface design is congruent with these models; the incongruity makes the user have to invest more cognitive effort into learning and adapting [18].

Finally, a cognitive load, or the mental effort involved in the processing of information and task fulfilment, is to be considered. Too much cognitive load might lead to fatigue, mistakes and bad user experiences [19]. The cognitive load theory focuses on the balance between the intrinsic, extraneous and germane cognitive loads in the environment of interaction [20]. It includes reducing the amount of redundant information, making navigation simpler, and using progressive disclosure, which presents information progressively in HCI [21]. Such frameworks as GOMS (Goals, Operators, Methods, and Selection Rules) and their Seven Stages of Action offer systematic ways to comprehend how users think when performing a task and allow designers to foresee difficulties and to organise the workflow in the most efficient way [22].

The cognitive frameworks discussed above differ and can be used in various situations. The Cognitive Load Theory puts more emphasis on reducing cognitive load, whereas the GOMS model is concerned with task efficiency by decomposing the task into goals. Recent studies indicate that both of these approaches are complementary and not mutually exclusive: GOMS is a tool for understanding the structure of tasks, while CLT can support micro-level information presentation. But there is a lack of knowledge as to how these cognitive factors relate to the individual differences relating to the expertise of the user, and users' working memory capacity, which is a field of further empirical research.

Critical synthesis. Although the frameworks discussed (CLT, GOMS, information processing) provide robust tools for cognitive analysis, they share two limitations. First, they largely assume a homogeneous user, which ignores individual differences in working memory capacity, domain expertise, and age. Second, they treat cognition in isolation from emotion. Recent studies [21] show that even well-structured tasks can fail if the user feels anxious. A major research gap is how cognitive factors interact with emotional states over time, where most studies measure cognition post hoc rather than in real-time interaction with affect.

Finally, cognitive factors have a significant effect on the interaction and interpretation of digital systems by the users. Task efficiency, learning, and user satisfaction are all dependent on attention, perception, memory, and cognitive load [23]. Systems that integrate cognitive concepts into the interface design can be used to develop systems that complement the human ability to process information, easing the level of cognitive load and improving usability [24]. The fundamental knowledge of these cognitive processes is necessary to design interfaces that fit natural ways of thinking by users, which creates intuitive and productive human-computer interactions [25].

2.3. Emotional factors in HCI

Emotions significantly influence users' perceptions, motivation, and satisfaction of users in their interaction with digital systems. Although the original HCI studies focused on effectiveness and functionality, the current understanding points out the fact that emotions profoundly affect on the way users experience and evaluate technology [26]. Emotions affect attention, memory, learning, and decision-making, all of which are essential to user experience (UX) [27]. As a result, affective design has become an important area of interest for designers and researchers that is aimed at evoking positive emotions and reducing frustration or anxiety [28]. The emotional aspect of HCI highlights that usability is not enough; the interface should be interesting, pleasant, and should appeal to the emotions of the users to gain long-term satisfaction [29].

The user's affective state, which entails the mood, feelings, and attitudes, has a direct impact on how the user interacts with a system. Positive states (joy, curiosity, or trust), improve concentration and creativity, making it easier to perform the tasks [30]. On the other hand, negative emotions, such as irritation, confusion, or stress, may deter the decision-making process and lessen task persistence [31]. Emotional involvement is, therefore, an element of good design. Interfaces with aesthetically pleasing visuals,

Table 1: Summary of key cognitive and emotional factors in HCI.

Factor Category	Specific Factors	Key Theories/Frameworks	Measurement Approaches
Cognitive	Attention, Perception, Memory, Mental models, Cognitive load	Cognitive Load Theory (Sweller), GOMS (Kieras), Information Processing Model	NASA-TLX, Eye-tracking, Task completion time, Error rates
Emotional	Satisfaction, Trust, Engagement, Frustration, Anxiety	Emotional Design Model (Norman), Broaden-and-Build Theory (Fredrickson), Affective Computing (Picard)	SAM, PANAS, Physiological sensors (GSR, HRV), Facial expression analysis

meaningful feedback, as well as empathetic interactions lead to emotional attachments to technology [32]. The Emotional Design Model created by Donald Norman is an aid to thinking about emotional impact on three levels: visceral (sensory appeal), behavioural (usability and performance), and reflective (personal meaning and satisfaction) [33]. Together, these levels influence the level of emotional experience of a user.

Norman's three-level model (visceral, behavioural, reflective) can serve as a taxonomy, but empirical results are mixed. In the first study by Sonderegger & Sauer [34], the effect of aesthetic–usability was identified as being more pronounced during initial interaction with a product rather than during its use, indicating the importance of visceral factors might reduce over time. This finding highlights a gap in the literature, as few studies that investigate the changes in emotional reaction over time when systems are used for extended periods of time.

Aesthetic elements are important in creating emotional reactions. Visual design elements, including colour harmony, typography, and images can generate certain moods and appeal to or scare off users [35]. Studies suggest that more attractive interfaces can be perceived as usable in cases where their functionality does not differ, which is known as the aesthetic–usability effect [34]. Moreover, the feeling of empathy and responsiveness is promoted by feedback mechanisms (animations, sound effects, timely responses, and related states) [36]. These factors increase emotional satisfaction and at the same time lead to trust and loyalty to the system or brand [37]. Positive emotional design can be used to reduce anxiety in the user, improve motivation, and facilitate efficient interactions in emotionally sensitive areas, including healthcare or education [38].

Affective computing has made the emotional considerations of HCI even broader. Affective computing refers to the design of systems that identify, analyse, and react to users' emotional states based on physiological indicators, facial expressions or behaviours [39]. These adaptive interfaces may be used to dynamically change the content, tone, or difficulty to match the mood or stress level of a user [40]. For example, a learning platform may simplify the workflow after it notices that one is frustrated, or a chatbot can use empathetic wording in reaction to a negative mood [41]. These technologies are a step in the direction of the human-centred design of the system, as they not only cognitively understand the way human beings feel but are also sensitive to emotions [42].

In summary, emotional design is needed to create meaningful and satisfying user experiences. Emotions can define how we are perceived in terms of usability, engagement, and trust, and eventually how users appreciate technology [43]. Designers who combine emotional dynamics and cognitive principles can develop systems that appeal to the psychological needs of the users [44]. HCI can move beyond usefulness by integrating emotional intelligence into digital systems through beauty, empathetic feedback, and responsiveness to adapt by making interactions with devices and services more emotionally rich and, as a result, more functional and pleasurable [45].

Identified research gaps: (1) Limited longitudinal studies on emotion-cognition interaction over extended use; (2) Insufficient integration of individual differences (expertise, age, cultural background); (3) Need for validated combined measures of cognitive-emotional UX.

Critical synthesis. Norman's three-level model has been influential, but empirical evidence is mixed. Sonderegger & Sauer [34] found that the aesthetic–usability effect diminishes with prolonged use; visceral appeal matters most in first impressions. Moreover, most emotional design studies rely on self-report (SAM, PANAS), which suffers from recall bias and cannot capture moment-to-moment shifts. Physiological measures (GSR, heart rate) address this but cannot distinguish between similar arousal states (excitement vs. anxiety). A clear gap is the lack of validated combined measures that simultaneously capture cognitive load and emotional valence with high temporal resolution.

3. Interaction between cognitive and emotional factors

Based on the literature synthesis above, we propose the Cognitive-Emotional Integration (CEI) framework for HCI design. This framework conceptualises UX as emerging from dynamic, bidirectional interactions between cognitive processing and emotional responses.

3.1. The Cognitive-Emotional Integration (CEI) framework

The CEI framework (Figure 1) conceptualises UX as emerging from dynamic, bidirectional interactions between cognitive processing and emotional responses. Its three core propositions are:

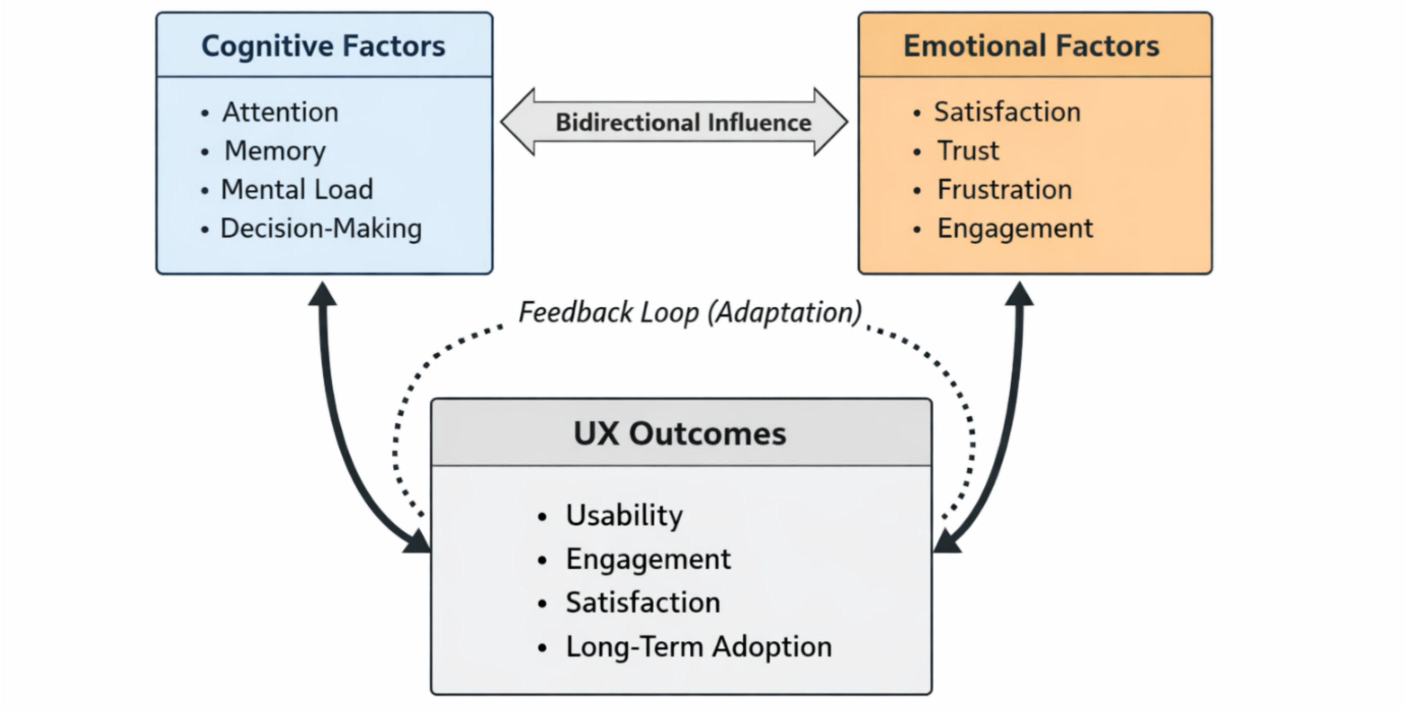

Figure 1: Cognitive-Emotional Integration Framework for HCI.

1. Cognitive factors directly facilitate task performance, but are contingent upon emotional state, e.g., positive emotions broaden attention, while negative emotions narrow it.
2. Emotional responses are elicited by cognitive evaluations: successful task completion triggers satisfaction; excessive cognitive load triggers frustration.
3. Optimal UX requires cognitive-emotional alignment: the cognitive load must match the user's ability and the resulting emotional reactions must be positive.

The framework differs from prior models (Norman's three levels) by explicitly modelling feedback loops: UX outcomes (disengagement) feedback to both cognitive and emotional states, creating adaptation over time. This framework is used throughout Sections 4-6 to organise measurement, design, and case study analysis.

The relationship between the cognitive factors (attention, memory, mental load, decision making) and the emotional factors (satisfaction, trust, frustration, engagement) is dynamic and bi-directional and is shown in a visual representation (Figure 1). Both sets of factors have an impact on UX outcomes (usability, engagement, satisfaction and long-term adoption), and they create a feedback loop that creates adaptations over time. The framework is based on three propositions:

1. Cognitive factors directly facilitate task performance, but are contingent upon emotional state.
2. The emotional responses are elicited by cognitive evaluations (such as successful task completion leads to satisfaction; too much cognitive load leads to frustration).
3. Optimal UX is achieved when the cognitive load is balanced with the user's ability, and any emotional reactions to the user experience are positively termed "cognitive-emotional alignment".

Cognitive and emotional aspects of HCI are interconnected and mutually dependent, which influence the user experience in general. Cognition is in control of the perception, processing, and taking of action on the information, and motivation, engagement, and satisfaction are motivated by emotional responses. Cognition and emotion are in continuous interaction to define UX, as opposed to functioning separately [46]. Cognitive performance can be either positively or negatively affected by emotions, and the same can be said about emotional states by cognitive load. This understanding of the interplay is crucial in the creation of systems that balance mental efficiency and emotional satisfaction, in that users will be able to complete tasks efficiently and will be able to enjoy the interaction.

One of the central features of this context is the power of emotions on cognition. Constructive emotions such as curiosity and joy broaden attention and promote exploration for better learning and creativity. On the other hand, negative affect such as frustration or anxiety can reduce cognitive flexibility and focus, and lead to more mistakes [47]. For example, when a user is pressured by the lack of feedback in the system, users are likely to have poorer memory recall or slower reaction times. The negative affect can be

Table 2: UX measurement approaches by dimension and method type.

Dimension	Subjective Measures	Objective Measures
Cognitive	NASA-TLX (workload), SUS (perceived usability), UEQ (perspicuity, efficiency)	Task completion time, Error rates, Eye-tracking (fixations, saccades), Navigation path analysis
Emotional	SAM (valence, arousal), PANAS (positive/negative affect), AttrakDiff (hedonic quality)	GSR (arousal), Heart rate variability, Facial expression analysis, Voice tone analysis
Combined	UEQ (attractiveness, stimulation), meCUE (integrated questionnaire)	Multimodal (physiological + behavioural + self-report)

tamed by emotion-supportive design features, including user-friendly navigation, positive feedback, and good looks, in line with the Broaden-and-Build Theory of positive emotions.

Emotional experiences in HCI are also influenced by cognitive factors. High cognitive load, unclear instructions, or poorly structured information may arouse negative emotions such as confusion or irritation. Emotional frustration leads to decreased satisfaction and motivation when users have difficulties in comprehending system behaviour. Interfaces that are easy to follow and reduce the cognitive load support a feeling of control and achievement to solidify positive emotional processes [21]. These states promote long-term involvement. The Cognitive-Affective Model of Learning with Media emphasises such a reciprocal interdependence where it is observed that emotional regulation improves cognitive performance and the other way round.

Employing both cognitive and emotional design principles is important for emotionally intelligent systems. Current adaptive interfaces employ real-time information, like interaction patterns, in tracking cognitive load and emotional state. For example, a smart tutor can modify the level of content when cognitive overload or lack of attention is detected. Healthcare or customer service affective interfaces can adjust tone or pacing to ensure that the user feels comfortable and on track. These systems become more personal and effective due to the consideration of cognitive and emotional aspects.

Synthesis and implications: The reciprocal relationship between cognition and emotion has important implications for design, that are not yet fully captured in commercial systems. In laboratory studies, reducing cognitive load results in emotional satisfaction being consistently improved; however, in real-world implementations, one dimension is often emphasised over the other [21]. For instance, most productivity applications are designed to focus on cognitive efficiency and ignore emotional engagement, which results in user disengagement over time. On the other hand, entertainment games might be designed to engage the user's emotions more than his or her intellect, leading to user frustration. The CEI framework suggests that when the system is designed in such a way that it adapts its mechanisms to the users' real-time cognitive and affective states, it is not necessary to compromise between cognitive efficiency and emotional satisfaction. This is still an active research domain, and current challenges are reliable detection of real-time affect and individual differences in cognitive-affective processing.

4. Measuring user experience

UX measurement requires instruments that capture both cognitive and emotional dimensions. Table 2 organises available measures by dimension (cognitive/emotional) and method type (subjective/objective).

4.1. Cognitive measures

Cognitive measurement in HCI assesses mental effort, efficiency in information processing and learning in order to identify how well interfaces can be used to facilitate cognition in a task.

Subjective measures: NASA-TLX (workload), SUS (perceived usability), UEQ perspicuity/efficiency subscales.

Objective measures: Task completion time, error rates, eye-tracking (fixations, saccades), navigation path analysis.

A widely used tool is the NASA Task Load Index (NASA-TLX), which assesses perceived workload in six dimensions, including mental demand, physical demand, temporal demand, performance, effort and frustration. A decrease in scores means increased cognitive correspondence between user and interface. Cognitive usability is also reflected in performance-based measures like task completion time, error rate, and efficiency of navigation. Eye-tracking research provides an understanding of visual attention, fixation, and information search behaviour to understand how users navigate the interface components [48]. Think-aloud protocols present real-time mental processes to research, which can deliver qualitative data about the mental models, confusion points, and decision-making. These steps determine points of cognitive load of interfaces or lack of support. A limitation of many cognitive measures is that they capture post hoc perceptions rather than real-time cognitive load. Eye-tracking and physiological measures partially address this, but remain resource-intensive for routine UX evaluation.

4.2. *Emotional measures of user experience*

Emotional measurement involves the measurement of affect in response to system interaction, such as satisfaction, frustration, or trust.

Subjective measures: SAM (valence, arousal), PANAS (positive/negative affect), AttrakDiff (hedonic quality).

Objective measures: Galvanic Skin Response (GSR), heart rate variability, facial expression analysis, voice tone analysis.

Self-report measures such as the Self-Assessment Manikin (SAM) and the Positive and Negative Affect Schedule (PANAS) can be used by users to describe feelings in terms of valence, arousal, and dominance, and provide quantitative data on the effects of design on mood. Affective responses are shown by behavioural responses such as facial expression and change of voice tone. Objective data on emotional arousal and stress is given by physiological sensors, including heart rate variability and Galvanic Skin Response (GSR) [48]. Such tools play a major role in affective computing, and through them we are able to create systems that are capable of detecting and reacting to emotional input in real time. Combining subjective and objective measures provides a clearer picture of emotional UX. Self-report measures of emotion suffer from recall bias and may be influenced by social desirability. Physiological measures provide real-time data but cannot distinguish between similar arousal states (e.g., excitement vs. anxiety).

4.3. *Combined user experience instruments*

The cognitive and emotional aspects are combined in standardised tools to achieve a complete assessment of UX. The User Experience Questionnaire (UEQ) is used to measure both the rational and affective sides of attractiveness, perspicuity, efficiency, dependability, stimulation, and novelty. System Usability Scale (SUS) provides a temporary evaluation of perceived usability, and the Affect Grid locates emotional reactions on the axes of pleasure and arousal. Multimodal theory incorporates usability measures, physiological measurements, and self-reports to measure subtle interactions with consideration of the interrelation between cognitive and emotional experiences.

Standardised tools that integrate both dimensions: UEQ (attractiveness, stimulation), meCUE (modular questionnaire) and multimodal approaches combining physiological, behavioural, and self-report data.

4.4. *Importance of comprehensive UX evaluation*

Comprehensive UX measurement ensures that both functional and emotional satisfaction are reflected. A concentration on cognitive efficiency and lack of affective engagement or vice versa can be counterproductive since placing an emphasis on emotional engagement at the expense of usability can negatively affect the performance of a task. Balanced assessment is used to direct design improvements in the iterative designs to determine the strengths and weaknesses in the two dimensions. Through the combination of cognitive workload measurement, emotional response measurement, as well as standardised measurements, designers will have a comprehensive perspective of how users think, feel, and behave, facilitating the development of efficient, trustworthy, and emotionally relevant human-oriented technologies.

Based on this review, we recommend that UX evaluations include:

1. at least one cognitive measure (NASA-TLX or eye-tracking);
2. at least one emotional measure (SAM or GSR);
3. a standardised combined instrument such as UEQ; and;
4. triangulation across subjective and objective data sources.

Single-measure evaluations risk missing critical UX dimensions and should be avoided.

5. Design implications

Cognitive and emotional insights in design practice is critical towards designing usable, intuitive, and interesting human-computer interfaces. The ability to comprehend the thoughts and emotions of the users enables the designers to go beyond the aspect of usability to the goals of satisfaction, trust, and long-term engagement [49]. Cognitive ergonomics is concerned with the cognitive requirements of the system interaction, whereas affective design principles are the ones that focus on the emotional reactions of the users [27]. The idea is to create interfaces that correspond to the human cognitive abilities and result in a positive emotional experience, making the systems functional and emotionally expressive [17].

5.1. *Cognitive design considerations*

Cognitive design aims to minimise cognitive load. Its research suggests presenting in a form that is easy to understand, logical and hierarchical to minimise the mental work that is required. Stable layouts, terminology and interaction patterns can help users build correct mental models, making navigation more predictable and intuitive [13]. Methods such as progressive disclosure are effective to avoid cognitive overload, indicating the information that is revealed as and when it is needed. Cognitive confidence can be supported by the use of features like error prevention and undo options, as well as contextual help, which helps to reduce frustration [50]. Such features of visual design as perceptual clarity through obvious cues, proper contrast, and simple typeface help the users to concentrate on the task-relevant information instead of focusing on the complexity of the interface.

5.2. Emotional design considerations

Emotional design research suggests creating a positive affect, empathy and involvement. Harmony of colours, spacing balance, and feedback of motion influence the mood of the users and impressions of the system [27]. A sense of responsiveness and emotional attachment are achieved through meaningful feedback, e.g., animations or success messages, which increases satisfaction. Personalization cues interactions according to personal preferences, which promotes further emotional connections [49]. In such sensitive areas as healthcare or education, the empathetic and trustful design minimises anxiety and promotes well-being and encourages openness and interaction of the users.

5.3. Integrating affective computing and adaptivity

Affective computing can enable emotion-aware interfaces that recognise and react to the emotional state of their user based on physiological measurements or behavioural indicators [40]. For example, an e-learning platform could make the content easier when it recognises an expression of frustration or can offer encouraging messages when the engagement falls. Emotional chatbots can provide a response of empathy and context-sensitivity. It is a combination of cognitive and emotional intelligence, where the adaptive system is used to initiate personalised interactions. It is important to implement it ethically and transparently to ensure the privacy and trust of users [51].

5.4. Holistic and culturally aware design practice

In holistic design, the main purpose is to consider both cognitive efficiency and emotional satisfaction using evaluative feedback, which involves usability testing combined with evaluating emotional reactions. Both dimensions are evaluated with the help of such tools as the User Experience Questionnaire (UEQ) and System Usability Scale (SUS) [50]. Cognitive and emotional reactions differ in different cultures, which affects the interpretations and emotional displays of the users [51]. Cultural knowledge has to be integrated into the design by designers to ensure that they come up with resonant systems. HCI practitioners create usable, meaningful, empathetic, and enjoyable technologies by combining cognitive clarity, predictability, and efficiency with emotions designed with intelligence to achieve the vision of a human-centred design [17].

5.5. Ethical considerations in emotion-aware design

Affective computing introduces ethical risks that designers must proactively address.

Privacy Emotion detection systems collect sensitive biometric data (facial expressions, voice patterns, GSR). Mitigations: (1) transparent data collection protocols; (2) local on-device processing where possible to avoid cloud storage; (3) clear retention and deletion policies (data deleted after session).

Informed consent Users must be explicitly informed what data is collected, how it is used, and who has access. Consent should be granular where users can opt into specific emotion-sensing features without agreeing to all. For vulnerable populations (children, patients), additional safeguards are required.

Bias and fairness Emotion recognition systems are known to perform unevenly across age, gender, and ethnicity [42]. Designers must test with diverse user samples and avoid using affective output as the sole basis for high-stakes decisions (hiring, mental health triage).

User autonomy Users should be able to disable emotion sensing without losing core system functionality. Affective features should augment, not replace, user agency.

Transparency Users should have access to their emotional data logs and receive explanations of how the system interpreted their state. This builds trust and allows users to correct misinterpretations.

These principles should be integrated from the design stage, not added as an afterthought. For further guidance, see the ACM Code of Ethics and recent CHI papers on affective computing ethics.

6. Case studies and applications

The integration of cognitive and emotional aspects in HCI has been demonstrated in different fields such as education, healthcare, gaming, and adaptive interface design. These cases show how the interpretation of human cognition and emotion can be used to improve usability, interaction and general user experience. Table 3 shows a few case studies and their implications for cognitive and emotional design in HCI [3, 5, 52, 53].

The three cases in Table 3 illustrate how cognitive-emotional integration operates across different HCI domains. Across all three domains, success depends not on prioritising cognition or emotion, but on designing for their interaction.

Table 3: Case studies and applications of cognitive and emotional factors in HCI.

Domain	System Example	Cognitive Factors	Emotional Factors	Concrete Example	Interpretation
Educational Systems	Intelligent Tutoring Systems (Carnegie Learning)	Cognitive load reduction via adaptive problem sequencing	Motivation enhancement through mastery-based feedback	System detects student struggling with algebra and offers simpler practice problems before advancing	The cognitive-emotional link is evident: reduced cognitive load (easier problems) prevents frustration, enabling a positive emotional state for learning
Healthcare	Telemedicine platforms (Amwell)	Simplified navigation, medication reminders	Anxiety reduction through empathetic interface design	Appointment confirmation includes reassuring visual cues and clear next steps	Trust emerges from both cognitive clarity (knowing what to do) and emotional reassurance (feeling cared for)
Gaming	Adaptive difficulty in games (Left 4 Dead's "AI Director")	Dynamic challenge adjustment based on player performance	Engagement maintenance through flow state preservation	Game increases enemy spawns when player performs well, reduces when struggling	

6.1. Case A: Intelligent tutoring system (Carnegie Learning)

Cognitive challenge Algebra students often experience high cognitive load when presented with multi-step problems beyond their current skill level.

Emotional response This leads to frustration, anxiety, and disengagement.

Design solution The system uses adaptive problem sequencing, which, if a student struggles, offers simpler practice problems before advancing.

Evaluated outcome Studies show reduced error rates (cognitive) and increased on-task persistence (emotional).

CEI interpretation Reducing cognitive load directly lowered frustration, enabling a positive emotional state conducive to learning.

6.2. Case B: Telemedicine platform (Amwell)

Cognitive challenge Older users often find appointment booking and medication reminders confusing due to poor navigation.

Emotional response Anxiety and mistrust.

Design solution Simplified interface with large buttons, visual confirmations, and empathetic language ("You're all set and we'll remind you").

Evaluated outcome Higher task completion rates and self-reported trust scores.

CEI interpretation Cognitive clarity (knowing what to do) and emotional reassurance (feeling cared for) jointly produced trust and satisfaction.

6.3. Case C: Adaptive difficulty in gaming (Left for dead's "AI director")

Cognitive challenge Players experience frustration when game difficulty is static which is too easy becomes boring, too hard becomes overwhelming.

Emotional response Boredom (low challenge) or anxiety/frustration (high challenge), both leading to disengagement.

Design solution The AI Director dynamically adjusts enemy spawns, item availability, and intensity based on player performance which increasing challenge when players succeed, reducing it when they struggle.

Evaluated outcome Maintains flow state, increases play session duration, and reduces quit rates.

CEI interpretation Cognitive demand (task difficulty) is continuously calibrated to match player skill, preventing both cognitive underload (boredom) and overload (anxiety), thereby sustaining positive emotional engagement.

Several patterns emerge from these case studies. First, successful implementations share a common characteristic: they treat cognitive and emotional factors as co-equal design priorities rather than trade-offs. Second, adaptive systems that respond to real-time user state (cognitive load, emotional valence) consistently outperform static designs. Third, domain-specific differences matter: healthcare applications prioritise anxiety reduction and trust, while gaming emphasises engagement and flow.

However, important limitations exist in the current evidence base. Most case studies report short-term outcomes (immediate satisfaction, task completion) rather than longitudinal measures of sustained engagement or learning retention. Additionally, few studies have examined how the cognitive-emotional balance varies across different user populations (older adults, users with cognitive disabilities, cross-cultural differences). Future research should address these gaps through longer-term, more diverse participant samples.

7. Conclusion

This paper makes three contributions. First, it provided an integrated synthesis showing that cognitive efficiency and emotional satisfaction are complementary, not conflicting, UX dimensions. Second, it proposed the Cognitive-Emotional Integration (CEI) framework (Section 3, Figure 1) with three testable propositions. Third, it translated these insights into design guidelines for education, healthcare, gaming, and adaptive systems, including ethical considerations for affective computing. The key message is that achieving cognitive-emotional alignment involves matching cognitive demands to user ability while generating positive affect, which is essential for successful HCI.

7.1. Future research directions

Based on the gaps identified in this review, we prioritise the following five research directions:

1. Longitudinal studies: Research question: How do cognitive-emotional dynamics change over weeks or months of system use? Method: Mixed-methods with repeated measures (monthly UX questionnaires + physiological sensors) over 6 months. Hypothesis: Initial aesthetic–usability effects diminish, while trust and cognitive load become more predictive of retention.
2. Individual differences: Examine how age, working memory capacity, cultural background, and prior expertise moderate the CEI framework. Method: Factorial design comparing younger vs. older adults, high vs. low digital literacy.
3. Validation of combined measures: Develop and psychometrically validate an instrument that simultaneously captures cognitive load and emotional valence in real time (a short scale administered during interaction).
4. Real-world affective computing: Deploy emotion-aware systems outside the lab (e.g., workplace or home settings) and evaluate ethical challenges (privacy, consent, bias) in practice.
5. Inclusive design: Empirical examination of cognitive-emotional UX across diverse populations, including users with cognitive disabilities, older adults, and cross-cultural contexts.

7.2. Final remarks

As HCI continues to evolve towards more human-centred and affect-aware systems, understanding the interplay between cognition and emotion becomes not merely academic, but essential for responsible design. The future of HCI lies in creating systems that are not only functional and efficient but also empathetic and emotionally rewarding, thereby bridging the gap between human psychology and technological innovation.

Data availability

Data will be made available upon reasonable request from the corresponding author.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this manuscript.

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