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Forgiveness in human-machine interaction

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Forgiveness has been extensively studied across various academic fields, but not in relation to Human-Machine Interaction (HMI). The work presented in this article aims to answer two interrelated questions: what is forgiveness in HMI, and how do we forgive an erring technology? Relying on a literature review of both forgiveness and HMI studies, the article offers a holistic definition of the concept, according to which forgiveness in HMI is a shift in the users' feelings, from negative to positive, that prevents the users from abandoning the erring technology and allows them to keep using it without resentment. Based on a pioneering focus groups study with a convenience sample of 27 young adults, four forgiveness mechanisms are illustrated: (1) evaluating the cost of the error against the benefits of using the technology; (2) transferring responsibility for technology errors to humans (either those "behind the technology" or the users); (3) communicating with or about the technology; and (4) accepting the technology's faults. The results suggest that users undergo complex cognitive and emotional processes when faced with a technological error. As forgiveness is one of the most critical aspects of every relationship, the conceptualization and preliminary study presented here may serve as a starting point for a new area of research and as a springboard for an essential scholarly discussion.

KEYWORDS

communication, error, forgiveness, technology, focus groups

Introduction

Technology is an integral part of our everyday lives. It is ubiquitous and affects us on cognitive, emotional, and behavioral levels (Carr, 2008). Ever-evolving technology presents new functionalities and experiences through advancing possibilities like artificial intelligence (AI) and machine learning, which are implemented and integrated into devices and routines. Human-Machine Interaction (HMI) theories, such as Media Equation (Reeves and Nass, 1996) and Computers Are Social Actors (CASA, Nass and Moon, 2000), have shown that despite knowing they face technology, users apply communication and behavior patterns similar to those used with fellow humans (Dehnert and Leach, 2021). This kind of interaction is bound to get more complicated because the relationship between humans and technology is becoming more complex and intimate (Cheok et al., 2017).

One of the most important aspects of every relationship is forgiveness. Forgiveness involves shifting from negative to positive feelings (McCullough et al., 2000). It holds tremendous power to influence the entire relationship, while a lack of forgiveness might lead to a termination of the relationship (Antony and Sheldon, 2019; McCullough and Witvliet, 2002). The multifaceted nature of forgiveness, with diverse approaches and levels, has been extensively studied across academic fields, including sociology, psychology, health, and culture. However, forgiveness in HMI has yet to be explored.

The work presented in this article aims to serve as a basis for a scholarly discussion and future research on forgiveness in HMI. Accordingly, its first part is focused on conceptualization. Relying on a literature review of forgiveness and HMI studies, it offers a

holistic approach to the concept. The second part presents findings from a pioneering study that explored what users value when technology errs and their forgiveness schemes. Hence, two primary questions – *what* forgiveness in HMI is and *how* we forgive technology – are answered.

Part I: what is forgiveness in HMI?

Forgiveness

Despite its ancient roots across monotheistic faiths (McCullough et al., 2005), the concept of forgiveness remains highly relevant today. While numerous definitions of forgiveness exist, they commonly involve relinquishing negative emotions and adopting a more positive orientation (McCullough et al., 2000). An example of such a definition is "an inner process, central to psychotherapy, where the injured person, without the request of the other, releases those negative feelings and no longer seeks to return hurt" (Denton and Martin, 1998, p. 288).

Forgiveness is central to the three Abrahamic faiths - Christianity, Judaism, and Islam. In Christianity, forgiveness is seen as a critical, unconditional act (Ely, 2004), exemplified in the Lord's Prayer (Matthew 6:12–15, The New Testament). Judaism also emphasizes God's mercy and the importance of repentance and forgiving others, for example, in Yom Kippur (Dratch, 2003). Similarly, Islam views God as forgiving and merciful, as referenced multiple times in the Quran (Warsah, 2020). Despite a few differences, the shared emphasis on divine mercy and interpersonal forgiveness across these three monotheistic religions illustrates forgiveness's ancient and revered nature as a virtue.

Forgiveness has also occupied philosophers' minds since ancient times, with influential thinkers espousing diverse perspectives. For example, Aristotle approved of overlooking wrongs, while Plato, Socrates, and Epicurus saw forgiveness as unfit for the "perfect person" (Griswold, 2007). Nietzsche associated forgiveness with weakness and the inability to seek revenge (Griswold, 2007). Kant argued true forgiveness was impossible, as sins require punishment, not exoneration (Kant, 1797/1991, in North, 1987). In contrast, modern philosophers highlight the positive effects of forgiveness. Arendt linked forgiveness to love and the capacity to free oneself from past wrongs. She argued that forgiveness has power for both religious and secular people (Arendt, 1958). Similarly, Derrida considered forgiveness a potentially "gracious gift" (Derrida, 2000, p. 44), inextricably tied to concepts of mercy and grace.

Forgiveness is a complex human experience with diverse types, such as conditional forgiveness, artificial forgiveness, and pseudo-forgiveness (Antony and Sheldon, 2019), occurring in varied contexts from the interpersonal to theological (Denton and Martin, 1998). It is also seen as a multi-step *process*. Hargrave (1994) suggests that the process of forgiveness is composed of exonerating, which comprises insight and understanding, and forgiveness, which must include giving opportunities for compensation. Based on the foundations of Kohlberg's (1976) perceptions, Enright et al. (1989) saw the process as developmental and consisting of six stages, and Worthington (1998) suggested a five-step pyramid model composed of both cognitive aspects and emotional conditions.

Because forgiveness is such a meaningful force, it is studied broadly. Research showed that forgiveness is associated with older age (McCullough et al., 2000) and is more common among women (Antony and Sheldon, 2019). Forgiveness also correlates with personality traits: agreeableness relates positively to forgiveness (Ashton et al., 1998), and "forgiving people are less ruminative, narcissistic, exploitative, and more empathic" (McCullough and Witvliet, 2002, p. 449). Beyond personal traits, the willingness to forgive relates to situational factors like relationship commitment and offense context, including intention, consequences, and amends made (McCullough and Witvliet, 2002).

Finally, forgiveness was found to impact the physical and mental health of the forgiver. Forgiveness has been shown to reduce stress levels (Newberg et al., 2000), and it correlates with greater life satisfaction (Toussaint et al., 2001). In their review, Van Dyke and Elias (2007) noted that "research to date has revealed a range of psychological, emotional, and physical benefits that have been repeatedly associated with the healthy integration of forgiveness" (p. 410). Overall, it is clear that forgiveness holds power as an ancient virtue with modern relevance and that forgiving can impact human health and happiness in multiple interrelated dimensions.

Human-machine interaction (HMI)

Whereas classic models consider communication a process between two or more humans (Narula, 2006), mass media led to a shift in the way communication is perceived. Still, the media were regarded as mediators in human communication processes (Guzman, 2018). HMI represents an additional change to viewing technology as an active communicator in the process of "creation of meaning among humans and machines" (Guzman, 2018, p. 3), where they both have a mutual, nearly equal contribution (De Visser et al., 2018). Although "machine" may refer to any technology or device that performs work or a function, whether mechanical, electrical, or digital, the HMI discussed in this article mainly considers Information and Communications Technology (ICT), namely, devices designed to process, store, or communicate information using digital or electronic technology (Sadiku et al., 2024).

Like forgiveness, HMI can be seen as a process. Some even emphasized the communication process rather than its elements (Guzman, 2018). For example, Oberquelle et al. (1983) presented levels of communication development with machines (e.g., passive, active, interactive) and identified similarities and differences between human-human and human-computer communication across six characteristics like *intention, comparable premise of understanding, and partner expectations*. Norman (1984) also highlighted communicators' intentions and proposed a four-stage process: *intention, selection, execution*, and *evaluation*, noting that errors can occur at each stage and complicate the interaction. Communication with technology can also be viewed as placed on a scale of an automatic process: from a computer assisting a human who makes all decisions to a fully autonomous machine ignoring the human (Parasuraman et al., 2000).

CASA is one of the most influential theories in the field of HMI. The theory claims that people mindlessly apply the same social rules and norms while facing a computer (Gambino et al., 2020; Nass and Moon, 2000; Reeves and Nass, 1996). Multiple studies conducted

over the years, with thousands of participants, have shown that even though people claim computers should not be treated or understood as humans, they apply behavior toward machines that is similar to their behavior toward humans. For example, people often use social constructs like gender, reciprocity, and team membership when interacting with computers, especially as systems become more interactive, human-like, and textual (Nass and Moon, 2000).

While the CASA paradigm was well established, it required updates for modern technologies, leading to the Media Are Social Actors (MASA) theory. MASA not only expands CASA to modern technology but also elaborates additional social cues that can cause users to perceive media as social entities, including personality, reliability, and social context (Lombard and Xu, 2021). Another extension proposes that people have developed "specialized, more nuanced scripts for interactions with media agents" (Gambino et al., 2020, p. 78) over time as both media and humans evolve. Its reasons are partly shaped by media ownership, computer use, new affordances, personalization, and prolonged use (Gambino et al., 2020).

Human-machine cooperation is an evolving emphasis in HMI. Rafaeli (1988) noted that interactive conditions may increase cooperation, a claim still relevant today due to technology's inherent interactivity. Hoc (2000) mentioned that failures like loss of expertise, complacency, trust, and adaptability threaten the foundation of cooperation. Based on human cooperation principles, he also claimed that designing cooperative machines with shared goals has advantages (Hoc, 2001). Similarly, Pacaux-Lemoine and Trentesaux (2019) argued that knowing how to cooperate is key to maximizing machine benefits.

As interactions increasingly resemble human ones, relationships become more complex (Young et al., 2008). Boundaries between humans and machines blur as we constantly surround ourselves with, use, wear, and even implant technology (Guzman, 2020). Recent developments in social robots elicit this complexity. Literature shows positive associations between trust and quality evaluations of robots (Zafrani et al., 2023). Interacting with a polite robot can also lead to enjoyment and satisfaction (Kumar et al., 2022). However, among older adults using robots, tensions arise along with feelings of disrespect, privacy concerns, and fears of harm or reduced autonomy (Zafrani and Nimrod, 2019). Negative emotions like technophobia and inconvenience may be stronger predictors than trust regarding robots (Zafrani et al., 2023). Nevertheless, profound positive feelings also emerge. Claims exist about duplicating complex psychological factors like psychological attachment and love (Cheok et al., 2017; Sullins, 2012). Levy (2007) even suggested humans could prefer a robotic lover to a human one due to the potential for perfect love.

These shifting perceptions carry broad social implications: machines are now not just tools or free agents that are active communicators, especially as AI advances, but "have the potential to be… equivalent agents in communication processes as both social and functional actors according to the same criteria of agency" (Banks and de Graaf, 2020, p. 29).

Forgiveness toward erring technology – conceptualization

Mistakes and errors are an integral part of our lives. They can be divided into three categories: human errors, instrumentation and technological errors, and fundamental methodological factors in the field in question (Dror and Charlton, 2006). The one mistaken can be a human, animal, or even a machine (Cheney-Lippold, 2017). However, it is more acceptable to think of technology and machines as "erring" rather than mistaken because a mistake is an "incorrect judgment in the real world" (Funder, 1987, p. 76), while error has to do with a technical terminology: "condition… ignorant or imprudent deviation from a code of behavior" (Merriam-Webster Dictionary, 2023).

The results of technological errors can range from minor inconveniences to significant failures with severe real-world consequences. For example, the autonomous cars and the legal system represent fields in which an erring technology can affect the lives of the users or their surroundings (Cunneen et al., 2020; Freeman, 2016; Winkelman et al., 2019; Završnik, 2020). Some minor scale errors include shutting down, failing to upload a page, not saving changes, and directing a driver to an obstructed road. When those errors occur, the user needs to decide how to act next: operationally, emotionally, and cognitively. Ultimately, one must choose whether to forgive or not to forgive.

This work suggests a new kind of forgiveness: forgiveness toward technology. Building on forgiveness and HMI studies, forgiveness toward technology is defined here as:

> A shift in the users' feelings, from negative to positive, that prevents the users from abandoning the erring technology and allows them to keep using it without resentment.

The justification for the definition is derived from both fields. The first part is based on most definitions of forgiveness, which acknowledge the importance of shifting feelings as integral to forgiveness (McCullough and Witvliet, 2002). The second part of the definition relies on the importance of maintaining use because the taxonomy in the HMI field refers to "adoption or abandonment" (Dyb et al., 2021, p. 8).

As technologies evolve and become more complex, so are user-technology relationships, and it appears they will only get more tangled (Cheok et al., 2017; Young et al., 2008). With the feelings of humans toward machines becoming increasingly more profound, the risk of disruption grows (Hald et al., 2021). There are links between errors and trust, and a connection between trust and acceptance (Fortunati and Edwards, 2021). Trust is also connected to reliance and overall performance (Lewis et al., 2018). If users do not think highly of the technology in question and do not trust it to perform correctly, they will not want to use it.

Furthermore, the concept of empathy for machines shows that profound relationships exist between the user and the machine (Ho and Ho, 2025). While forgiveness toward machines focuses on a concrete and specific task, rather than the overall psychology of the users and their cultural settings, the two concepts may be tied, and empathy could be a factor that promotes forgiveness. Therefore, understanding how people act when an error occurs and how they forgive technology is essential to theory and practice alike.

Applying the CASA theory extension by Gambino et al. (2020), this understanding may lead to developing specific scripts in case of an error. Exploring if and how new designs can encourage forgiveness and whether forgiving technology promotes better cooperation between humans and machines may improve the daily use of technology, enhance user experience, and even benefit marginalized groups. Cracking the "black box" of the process of forgiveness might thus have far-reaching implications.

Part II: how do we forgive technology?

The pioneer, exploratory research presented here aimed to serve as a starting point for understanding the mechanisms that facilitate the process of forgiving technology. Since studying forgiveness toward technology is unprecedented, we applied a qualitative approach to enable in-depth conversation and allow people to share their opinions, beliefs, experiences, and emotions. Since the topic is relatively neutral, we performed focus groups with ICT users. The guided discussion encouraged participants to "reflect upon aspects of their daily life that are usually taken for granted" (Acocella, 2012, p. 1126) while sharing different points of view.

Participants and sample description

The sample in this study was a convenience sample of young adults, most of whom were graduate students and young professionals. Overall, 27 participants were recruited by personal invitations and snowball sampling. The focus group participants were randomly divided into four separate groups to ensure that they could express themselves most effectively and comfortably. Thirteen participants were women and 14 were men. The age of most participants ranged between 28 and 34 (only three were over 40), and the majority (21 individuals) had an academic degree. All participants reported high intensity of mobile phone (average of 4.9 out of 5) and laptop (average of 4.4 out of five) use and low tablet computer use (average of 1.5 out of 5). Participants' demographic information and reported ICT use are presented in Appendix A.

Data collection

Before the focus group meeting, participants signed a consent form and filled in a demographic questionnaire, which also included a table probing their frequency of use of various digital devices. All four groups were held online via Zoom for maximum participants' convenience and were recorded. The meetings lasted 60–90 min, and a semi-structured guideline was used to encourage free-flowing discussion. At the first stage of the group meetings, participants were requested to share memories of times or situations in which technology acted contrary to expectations, causing negative feelings, while attempting to understand general feelings ("How did you feel?") and thoughts ("What did you think?"). The second stage explored forgiveness processes in the cases presented and more generally ("Do you think that there are constant mechanisms or conditions that can help us forgive an erring technology?," "If forgiveness is a process, could you elaborate on the stages?"). Topics spontaneously raised by the participants, such as the trust between humans and machines, were also discussed thoroughly.

Data analysis

The groups' recordings were transcribed verbatim, and an inductive, thematic approach was used to analyze the data. The analysis included six stages: comprehensive transcript review, coding and categorizing, developing initial themes, reviewing them, defining them, and producing a report that unites the raw data into meaningful units (Braun and Clarke, 2006; Marciano, 2022). This method was chosen due to the possibility of a thorough understanding of data across all six stages. Team meetings were held throughout the process, and extensive memo writing was used to document the discussions. To protect the participants' privacy, pseudonyms are used in this report.

Results

Study participants discussed various technologies, mainly focusing on ICT: mobile phones, portable and stationary computers, internet use, different software and applications, and so on. Other technologies (e.g., microwaves and vacuum cleaners) were also mentioned briefly. The types of errors mentioned were classified into two main categories: *hardware*, which concerns the physical device, and *software*, which moves along a broad axis of problems related to the operating systems and interfaces. Examples of the first kind are laptops that overheat and display an error message and mobile devices that physically break down. Examples of the latter include files that close unexpectedly without saving the work done and navigation applications that mislead users along the way. There was a shared understanding among participants that when the malfunction involved hardware, there was a greater necessity to deal with the issue pragmatically, leaving less room for emotional responses such as anger, thus making them prone to forgiveness.

The reported relationships between users and erring technologies were complex, moving along different emotional axes of negative feelings and feelings of dependence. Anthropomorphism and tone represented emotionally charged relationships, and emotions such as disappointment, anger, and frustration were frequently mentioned, sometimes leading to violent expressions, demonstrated in a high emotionality and passion for the subject. The analysis revealed four forgiveness mechanisms, as described below.

Evaluating the cost of the error against the benefits of using the technology

One of the prominent mechanisms reported as part of the forgiveness process may be described as cost–benefit evaluation. The users tried to assess "loss" versus "profit" factors. The factors of loss were related to prices that the user had to pay and the "damage" that they absorbed in the event of a technological error. The profit factors were the benefits derived from using technology, which often served as a justification for absorbing the damage. Yaron, 30, a worker in the aerospace industry, explained:

> It is a game of cost-effectiveness. If it is easy for me to deal with those flaws, this technology is better for me because I 'pay less money,' so to speak, in [terms of] time when I use this technology effectively. Then, some kind of scheme is built. The simpler this scheme is and the more effective it is on a certain level, the more I benefit from this technology.

The factors mentioned as "losses" or "costs" included an assessment concerning the *characteristics of the mistake itself*: the magnitude of the error ("a minor problem that does not really take too many resources or time or aggression"), its timing ("let us say the problem happens suddenly and it comes to you as a surprise"), the time it takes to fix it ("if it's something that suddenly interrupts your day for two hours, or

prevents you from doing things, then there's a greater chance that you'll want to replace it"), the frequency of the error's appearance ("if it happens once a year, you can be happy and move on with your life, but if it happened to you once a week, I think it would have been more difficult to be indifferent to it or to move on"). Accordingly, significant errors that appear at problematic timing, require a long time to fix, and occur frequently are experienced as having high costs.

Another aspect of the assessment of the error concerns personal and social harms. Sometimes, the error only affects one user ("I talked to my trainer to see if I was the only one with the crashing application, or if it happened to everyone else as well, and it was just me"). Still, in other cases, it affected multiple people at once. In one of the cases, Zofia, 27, who works in marketing, mentioned an error that could have created "a bad reputation… cause damage on a business level and not solely on a personal level – [making it] much harder to forgive."

The economic cost of a technology error is another factor in the assessment. The economic aspect can be measured primarily from a financial point of view: how much money is spent on buying the technology, replacing it, or fixing the error. It also refers to time spent on the error itself or trying to fix it. The higher the amount of money spent, or the more "invested" people were in fixing it, the less forgiving they were.

Another cost that emerged in the focus groups related to negative feelings, including anger, disappointment, and frustration. Participants shared: "It creates frustration." (Noam); "It is just annoying, maddening" (Yaniv); "It was really frustrating and made me angry and sad" (Zoe). Those feelings may affect the well-being of the users and, in extreme cases, even provoke violent impulses, such as a desire to break the faulty devices.

In addition to the varied costs presented, the participants also spoke of different benefits. They evaluated the use of technology in general and recognized its functionality. In the workplace context, technology was described as having important advantages, including a tendency to make fewer mistakes than humans. In that context, Coral, 27, a medicine student, shared: "I try to go through those thinking processes of 'yes, but it would take longer if I had done it [instead of a machine], I would lose data or information.'"

Technology was also regarded as having many benefits in users' private lives, including their leisure activities and inner worlds. Zofia, for example, discussed the pleasure and expanded horizons she could draw from an online post she lost: "It could have been funny, or educational, or relevant for me, and that's it, it's gone." Some people even mentioned an emotional value. For example, Ora, 27, a kindergarten teacher, described a navigation application as taking away "the helplessness of not knowing how to navigate on the roads" and giving her "certainty and tranquility." She added, "That's also why I still forgive it when it errs and gets me in a traffic jam."

As shown, the cost–benefit evaluation is composed of multiple emotional and conditional factors, thus complicating the ability to determine whether or not forgiveness toward technology may occur and essentially making it not binary. It can follow a hierarchical structure, shaped by factors such as the type of machine involved, the user's emotional or cognitive state, the nature of the error, and the context in which it occurs.

To sum up, this first mechanism focuses on users' cognitive calculations as they weigh the possible costs of the technology and its errors against its benefits. In some cases, this is a mirror image: the magnitude of the personal or collective harm was compared with private and social benefits, and the negative feelings with the positive ones. Assessment in which the benefits exceed the losses typically results in a faster and more efficient forgiveness process.

Transferring responsibility for technology errors to humans

Whereas some study participants thought the technology was to be blamed for its error, most participants emphasized human responsibility. The first type of "responsibility holder" was the user. Whether the users felt that they only contributed to the error through suboptimal operation ("I always somehow mess it up"), or that all the blame laid on them ("I cannot get along with it… the blame is on me"), users who perceived themselves as responsible for technological errors tended to be more forgiving. The second type of "responsibility holder" was the designer or programmer. Herzel, a 30-year-old physician, stated: "I always find myself looking for the person behind the machine, thinking about where the IT guy is sitting." For Yaniv, a 29-year-old sales manager, the one to blame "will always be the one who created the technology." Some users suggested a divided responsibility among different factors, and the assigned responsibility for the error seemed to play a significant role in the forgiveness process.

The degree of user affinity with the ICT industry and their occupation appeared to be related to transferring responsibility to a human factor other than themselves. The users who classified themselves as "technophiles" and those with technology-oriented occupations forgave more easily due to their understanding of the systems. Ran, 29, a programmer, shared, "I can understand that it is a huge project, and maybe the developing environment is still experimental." Similarly, Ariel, 29, an application engineer, noted, "I am aware of how many 'bugs' can be in the software even if it is really good… This side of really getting to know the other side leads to [thinking] 'Well, okay, the solution was easy, simple, not interesting.'"

For most technophiles, transferring responsibility for the mistake to the programmer or technology manufacturer is easier because they understand it is a human error. It should be noted, however, that one participant, Rick, 49, a business owner, said the opposite: "The higher the level of knowledge and understanding, the higher the frustration will be." In contrast, the "technophobes" typically took responsibility for technical errors. They forgave the technology because the mistake was perceived as one they caused. Still, this mechanism was limited to "minor" faults. When the failures were significant and required complex solutions, technophobes tended to postpone further use as much as possible or avoid use altogether.

Overall, it was evident that transferring responsibility to a human agent plays an essential role in the forgiveness process. It can also be claimed that there is a connection between the transferring responsibility mechanism and users' characteristics, including their familiarity and comfort with the technology and field of occupation.

Communicating with or about the technology

The process of transmitting messages via technology is becoming more common and reciprocal. The participants of the focus groups emphasized two significant aspects of communication in the process

of forgiveness: transparency, which occurs when the technology initiates the dialog, and response, which happens when the user starts the conversation.

To begin with, even though participants accepted that errors were part of technology use, there is an expectation that the technology companies will also acknowledge the random errors and be transparent about them in both leisure and work contexts. Whether it is a screen that acknowledges the error itself, an explanation at different levels of detail, or possible solutions for the error, owning the error can make the user more forgiving, as Noam, 30, lawyer, stated:

> An explanation can often help [me] to understand why, not on the super technological level, but to understand that they are not trying to lead you astray. to understand the source of the error, why it happened, how they are trying to resolve it, not just say it will be fixed in two hours, and then it takes two days… some kind of transparency.

Another meaningful aspect of this communication mechanism concerned transmitting messages in the opposite direction – from the user to the technology companies and, as most participants mentioned, the people "behind the scenes."

The different ways and reasons participants were trying to reach out to human factors behind the technology ranged from the desire to resolve a specific problem rapidly to the desire to receive a human response over a technological one. Not having an option for such communication could result in ceasing to use the technology. This was the case of Michal, 40, research support coordinator, who quit using one music app and switched to another:

> There is no option for feedback as well. I remember when I wanted to write something extremely angry on their website, and I did not find any place where I could do that. No, there is no [such option]. I could not find where to do it [give feedback], so I just let it go.

The ability to transmit messages to those behind the technology when an error occurs might benefit the users not solely by fixing the error but also by sharing their thoughts, feelings, or impressions. That is why a claim can be made about the inherent connection the users make between technology and those behind it and the desire to implement human-human communication patterns even within technology contexts.

Accepting the technology faults

The last mechanism identified in the focus groups relates to how participants perceive and accept the current technological environment. The participants outlined a comprehensive image of technological dependence as individuals and as society, as they observed, appreciated, and accepted the technological reality around them. This acceptance played an important role in their ability to forgive an erring technology.

Initially, the study participants noted their tangible need to use technology constantly ("We simply cannot be without them [technological devices]"). The understanding of technology's integral place in the individual's life and the desire to live with it peacefully led to prompt forgiveness ("We are always with technology. I cannot stop using [it], so obviously, I forgive it for all sorts of things"). Technology's role in the social fabric was also part of the acceptance of technology. Yaniv stated, "If it does not work, then there is also a social issue," making technology an inseparable part of users' social lives. Accordingly, it is evident that when a widespread malfunction occurs, it impacts the individual user's feelings ("There is less to get angry about. You feel that you are in the same boat as other people.").

The obligation to use technology was also described as a central component of one's work. Most study participants mentioned using technology in their work. Despite occasional dissatisfaction, they acknowledged the absolute obligation imposed on them to continue using the same technology, leading some participants to feel like they "have no choice but to forgive because it's part of my work." Some users mentioned having to adapt to technology that did not function properly, for example, by adding preventative actions like copying work to another program to avoid losing information. Therefore, the ability to forgive is sometimes associated with the user's surroundings. The fact that technology is present in various social and occupational contexts may lead the user to accept and adapt to a reality that includes technological errors and to continue using the same flawed technology, sometimes in different ways.

Furthermore, the acceptance mechanism includes an additional layer of recognizing the various options and alternatives available to users when they are dissatisfied with the technology. While replacing an erring technology cannot be considered forgiveness, *evaluating alternatives* is a significant factor in a person's ability to accept and forgive an erring technology. The focus groups revealed three ways in which evaluating alternatives promotes forgiveness. First, by accepting there is no alternative or better alternative ("I will be much more forgiving to technology that I know I do not have an alternative for"). Second, the user may forgive the erring technology by deciding the alternative is too economically costly ("We do not buy hardware every day… and we have no choice but to forgive it for the recurring errors and glitches"). Third, forgiveness can result from the effort involved in examining other alternatives ("The search itself is sometimes more frustrating than dealing with a minor malfunction").

Acceptance is also affected by the user's expectations regarding the technology. If expectations were met (for example, "I did not expect Android to work" or "iPhone is crap"), it was easier for users to forgive. However, if expectations were not met, the high degree of incongruity made forgiving difficult. Dalia, a teacher, demonstrated it regarding her new computer: "I'm not on this computer anymore because I do not forgive it… 'damn it, you are new, you should do your job.'" The users' early expectations regarding the technology, including the operating systems, possibilities, and the company behind the technology, might affect the response to the erroneous technology. These expectations are another component of the reality acceptance as part of the forgiveness process, as well as in the decision not to forgive.

Discussion and conclusion

This article offered a conceptualization and initial understanding of forgiveness toward technology, a terra incognita highly relevant to daily life in the 21st century. The study explored the notion of technology users' shifting emotions from negative to positive that

follow the occurrence of a technological error. By so doing, it revealed four forgiveness mechanisms users utilize, separately or simultaneously, when the technology's performance does not align with their expectations: (1) evaluating costs and benefits, (2) transferring responsibility to a human factor, (3) communication, and (4) acceptance. The results suggest that users undergo complex cognitive and emotional processes when faced with a technological error.

The first mechanism involves numerous considerations users weigh when assessing the costs of the technological error compared to the benefits of use. The cost–benefit analysis originated in the economic thought process (Jiang and Marggraf, 2021) and is a mechanism broadly used across multiple life domains. It assists humans in decision-making (Drèze and Stern, 1987). Thus, it is unsurprising that people apply it in their decisions regarding an erring technology. Yet, this decision is not purely rational but also emotional, as expected, given the role of emotions in forgiveness (McCullough et al., 2000).

The users' gains of pleasurable leisure time and emotional advantages, on the one hand, and the negative emotions that errors brought upon them, on the other hand, can be seen as part of the impairment of any relationships, as suggested by the social exchange theory that views any relationship as created through a process of cost–benefit analysis (Lawler and Thye, 2006). In addition, the fact that study participants emphasized harms and benefits not only to themselves but also in connection to a group of people fits the multi-party obligations, namely, the mutual responsibility group members feel, described by the social exchange theory (Cropanzano and Mitchell, 2005; Ekeh, 1974).

The cost–benefit mechanism also aligns with the HMI scholarship. Carroll (1997), for example, discussed the role of the cost–benefit process among the engineer, developer, and user, in which the overall aspiration is to "optimize cost–benefit" (p. 68). Factors like user performance and usability can be taken into consideration when trying to understand the best cost–benefit scheme; however, the ever-evolving field of HMI also suggests multiple approaches and developments that may not fit the cost–benefit thinking process (Carroll, 1997), as evident in the other three mechanisms revealed in this study.

The focus of the second mechanism—transferring responsibility for technology errors to humans—is who or what the users hold accountable for the error and its implications in their forgiveness scheme. Different attributes of the error and the user's personality led to various forgiveness schemes. Understanding that behind the technology, there is a person who created it and is responsible for the way it functions aligns with an overall human-centric approach that places humans as the "primary objects" (Deibert, 2018, p. 412), while other factors like technology are secondary, only serving to assist humans.

According to the study participants, the human factor remains extremely important throughout the entire lifecycle of the technology: from creating it to operating the system to maintaining appropriate use. This perception is consistent with the claim that "technology failures resulted in only a small proportion of the incidents" (Foord and Gulland, 2006, p. 172), while human malfunctions are varied and include design, implementation, operation, and maintenance errors (Foord and Gulland, 2006). The approach that focuses on the human side of technology goes both ways – both successes and failures are attributed to them (El-Deeb, 2022).

Multiple forgiveness studies align with the second mechanism. Viewing forgiveness as contextual (e.g., who is the offender) was also suggested by Darby and Schlenker (1982), Boon and Sulsky (1997), and others. Furthermore, forgiveness studies suggest a relation to personality traits (Ashton et al., 1998; McCullough and Hoyt, 1999). Those connections to context and personality were evident in the present study.

In the focus groups, both willingness to forgive and wish to interact with the erring technology were evident and partly depended on the level of the participant's understanding of technology. Those who identified as technology lovers and worked in the high-tech field seemed to forgive the erring technology more easily. Contextual forgiveness was apparent in the participants' differentiation between the error types. For example, those who claimed they were not techno-enthusiasts were more forgiving toward minor errors and much less forgiving when it came to more significant errors.

The third mechanism, communication, was bi-directional: from the users to the people behind the technology and vice versa. While the former aligns with existing literature and adds to it, the latter contradicts it. Acknowledgment of the wrongdoing was described as important in forgiveness literature (Darby and Schlenker, 1982) but not in HMI research, according to which providing an explanation or acknowledging the error does not benefit the users or make them more trusting of the erring technology (Hald et al., 2021).

Still, reaching out to share thoughts, opinions, and criticism relates to interactivity – one of the main characteristics of new media. Interactivity has been described as improving satisfaction, effectiveness, efficiency, and overall attitudes in websites' context (Schejter and Tirosh, 2016). New possibilities such as machine learning, AI, and virtual reality allow new levels of interactivity and conversation-making (Zue and Glass, 2000). With ubiquitous advanced technologies enabling constant, complex, and diverse conversation, it can be an outlet for users' negative feelings. The interactivity argument was thus described as important in the process of forgiveness toward technology.

Acceptance, the last mechanism, invites us to look at society through the lens of forgiveness toward technology. Understanding that it is almost impossible to be a member of modern society without technology is an axiomatic truth of our everyday lives. While multiple studies foresee a more techno-oriented future, the study participants were highly aware of the techno-oriented present and accepted it. The described acceptance mechanism also involves the search for alternatives and the users' pre-existing expectations; both are a testament to modern society, living in an era of information, choice, and being accustomed to goods.

The expectations and their effect on the forgiveness process fit and extend the existing theories about forgiveness. Studies show that unmet expectations in a relationship may harden the process of forgiveness since ego and trust are damaged (Siassi, 2007). This principle seems to apply even when the relationship is between humans and technology. The users' unmet expectations regarding their devices are closely linked with their level of trust and willingness to forgive. In contrast, fulfilled expectations (good or bad) lead to a rapid forgiveness process. Hence, the findings regarding the acceptance of reality vis-à-vis expectation from technology align with existing forgiveness literature and demonstrate similar patterns to HMI.

In summary, this research sheds light on a new concept in HMI literature. The findings presented four mechanisms users apply when

facing an erroneous technology. The implications of this research may range from additional theoretical knowledge to actual implementation within the high-tech industry. The ability to improve the users' experience and foster the acceptance of erring technology, rather than abandoning it, might be closely connected to the forgiveness scheme of the user.

Limitations and future research

Like any other exploratory pioneer research, the present study had several limitations that should be acknowledged, the first being the small, non-representative convenience sample of highly educated young adults. Those attributes may skew toward familiarity with technology, which may influence their forgiveness schemes and limit the generalization of the findings. Another limitation is the use of the online Zoom platform to accommodate the participants' busy schedules. Using a technological system when conducting a study about technology limited participation to technology-oriented individuals. Moreover, while using Zoom, a couple of online errors occurred. These "live demonstrations" of the topic at hand led to higher levels of emotion and involvement that may have influenced participants' reports.

Further studies should continue exploring the concept of forgiveness toward technology and the implications of the process for users. To build a meaningful body of knowledge, be able to generalize assumptions, make forgiveness classifications, examine the concept of forgiveness for machines versus empathy for machines and even build a hierarchy of forgiveness, studies should examine diverse audiences, including marginalized groups, and apply a variety of qualitative and quantitative methods, such as surveys, experiments, and co-design sessions. Insights arising from these studies may have multiple implications for implementing conclusions within the technology industry. They may benefit users' overall experience in using technology and result in far-reaching changes and improvements.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the Ethics committee, Department of Communication Studies, Ben Gurion University of the Negev. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

IH: Formal analysis, Methodology, Data curation, Writing – original draft, Conceptualization, Investigation. GN: Validation, Methodology, Supervision, Conceptualization, Writing – review & editing.

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The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The authors declare that no Gen AI was used in the creation of this manuscript.

Publisher's note

Supplementary material

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