The Psychology of User Frustration

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ABSTRACT

User frustration can be characterised as the emotional response elicited when users perceive they are impeded in their performance of a computing task. This impedance is most often due to issues with the software or device in use, either because of functional errors or because of poorly designed interactions. User frustration can result in psychological and physiological stress, and can have implications for the user both in terms of their future interactions with the system and with their general mood and psychological well-being.

This paper examines the ways in which user frustration can be understood, focusing on psychological perspectives from cognitive, neurological, and behavioural paradigms. The physiological changes that occur during frustration are discussed, as are the longer-lasting effects that frustration can have on users' conceptualisations of the technology and of their ability to use it. Additionally, the multiple roles of frustration in evolutionary theory are discussed, and suggest that while frustration is usually best avoided, it can sometimes lead to a positive outcome. If properly understood and harnessed it may even present itself as a useful tool in interaction design.

Author Keywords

Frustration, stress, HCI, physiology, biopsychology, behaviourism, learned helplessness.

INTRODUCTION

The demarcation and understanding of emotions has had a chequered history within scientific psychology. The behavioural paradigm, which was particularly prevalent in the early-to-mid twentieth century, held that emotions and other unobservable phenomena should be disregarded when studying behaviour, and instead focused on observable and measurable actions. Bessière, Newhagen, Robinson, & Shneiderman (2006) note that despite the 20th century popularity of behaviourism, the conceptualisation of frustration is traceable to Freud's psychoanalytic work in the 1920s, while Scheirer, Fernandez, Klein, & Picard (2002) describe how frustration (and, more broadly, psychological stress) has long been capable of being analysed through the use of physiological measures including galvanic skin response (GSR), blood pressure, differential neural activation, and changes in muscle tension. It would seem that psychology has acknowledged and accepted the multiple roles that emotional states can play, and the interaction between emotion, perception, cognition, and action.

Against this background it is somewhat puzzling that, compared to other aspects of HCI, relatively little basic research has been conducted on the psychological effects and physiological correlates of computer user frustration. HCI tacitly focuses on the reduction of frustration while ignoring the study of frustration for its own sake. Some research does exist, but is fragmented and often subject to methodological oversights. Accordingly, it is necessary to look broadly and beyond the HCI literature, particularly towards psychology. Cognitive scientists, evolutionary psychologists, psychological physiologists, and neuroscientists have conducted numerous and varied studies into how stress impacts cognitive performance, and these findings can be examined and integrated into the HCI literature to present a more complete account of frustration and the stress that is associated with it. This paper will discuss a variety of psychological perspectives on frustration. While these models and perspectives are yet to form a coherent picture that can adequately explain frustration and stress, we will synthesise the psychological theories and models with relevant HCI literature, concepts, and examples to form a more complete perspective of computer user frustration.

PHYSIOLOGICAL CORRELATES

Frustration and stress share a number of common physiological markers (Scheirer et al., 2002). During a frustrating or stressful experience, humans tend to respond in similar ways. While individuals may be conscious that they are feeling frustration, or may be conscious of the physiological changes associated with frustration, many of these correlates are controlled through the autonomic nervous system and are therefore not subject to conscious control or manipulation. Accordingly, simply being aware of being frustrated does not reduce or eliminate the frustration itself.

As with most emotional states, it is not possible for an external party to directly observe or be aware of an individual's frustration. However, since there are a number of common physiological signs that have been found to be correlated with feelings of frustration, it is possible to make an estimation of an individual's degree of frustration based on the direct or indirect observation of these signs.

Scheirer et al. (2002) describe two common physical signs that indicate stress and frustration. The galvanic skin response (GSR) is based on analysing the conductivity of the skin, which changes markedly during periods of acute stress. This is usually measured through the placement of electrodes at suitable locations on the body, and is one primary component of the so-called 'lie detector test'. The blood volume pressure (BVP) of an individual also provides an indication as to their levels of frustration and stress, with higher blood pressure indicating higher levels of stress. Both of these signs can be measured through the use of digital sensors placed in appropriate places on a user's body, and can be useful tools to gauge a user's frustration level during a particular task.

Hazlett (2003) notes that facial expressions are often correlated with internal stress or frustration, and that humans tend to use facial expressions when gauging the mood of others. It is possible to quantitatively analyse human facial expressions through the use of electromyography (EMG), which measures muscular activity through the placement of sensors on particular parts of a user's face. Hazlett (2003) used this technique with users of a computer system and found that changes in specific facial muscles were significantly correlated with user frustration. However, this type of technique has the main disadvantage that it requires sensors to be placed in precise locations on a user's face, and this is unlikely to be comfortable for any period of time. While it is also possible to indirectly measure facial expressions through the use of computer vision, such techniques are much less accurate and have a greater degree of variability than measuring the muscles directly.

Puri, Olson, Pavlidis, Levine, & Starren (2005) also describe the use of facial information to judge user frustration, but instead focus on thermal imaging; when individuals perceive frustration and stress, they are likely to become flushed and the temperature of their face will increase. Such changes were detected by thermal cameras, and the validity of the measure was established by correlating the thermal imaging results with another accepted measure of frustration–that of energy expenditure (EE), which analyses the amount of oxygen that an individual is inhaling and is predicated on the assumption that respiration increases (and additional oxygen is used) in higher-stress situations. The thermal imaging results were significantly correlated with the EE results, indicating that the measure is psychometrically valid. Thermal imaging presents an advantage in that it is a completely non-invasive measurement technique; unlike many other measures it does not require any sensors to be placed on or inside a person's body. However, it does require a thermal camera, which is prohibitively expensive for most usage scenarios, and also requires considerable computing power and image processing for the results to be interpreted. As such, this type of technology has largely been confined to the research lab, and researchers such as Puri et al. (2005) have had to perform post-hoc analyses of the thermal scans, making this type of data particularly difficult and time-consuming to collect and interpret.

Additional measures are also thought to be correlated with stress, but are harder to interpret–and are particularly difficult to use in an HCI context. For example, electroencephalography (EEG) measures overall brain activity, and while it is possible to retrospectively differentiate brain activity patterns during periods of stress from baseline periods, this is very hard to draw any meaning from. Likewise, it is possible to measure the levels of the hormones cortisol and adrenalin (epinephrine) through analysis of saliva, but this is difficult to do inside most HCI experimental paradigms. Finally, Murray & Arnott (1993) discuss the findings that vocal speech differs depending on an individual's emotional state, and suggest that this may be analysed to determine whether a user is stressed. However, this type of analysis is not yet reliable enough to be used to determine any arbitrary individual's stress or frustration levels.

CORRELATING PHYSIOLOGY WITH HCI

HCI presents interesting challenges and requires suitable experimental paradigms when studying frustrating experiences. Scheirer et al. (2002), for example, discuss the creation of a game that intentionally frustrates its users by appearing to 'lock up' at random intervals. Their paradigm, in which they correlate the user's behaviour with measures of physiological arousal and stress, can be adapted to a range of other experimental research into this area. However, to date, there have been limited studies that attempt to do so.

While some studies (e.g. Puri et al., 2005; Scheirer et al., 2002) have successfully measured frustration using one or a combination of the physiological measure described above, it is unlikely that any of these measures will be in widespread use in the foreseeable future. Human physiology and psychology is extremely complex, and at any given point in time a particular individual will have a large number of factors influencing their mood and stress levels. Gilleade & Dix (2004) note the difficulty in obtaining a reliable baseline of frustration levels for a user in order to compare later stress levels: a number of factors (general wellbeing, exercise levels, physiological and sexual arousal, etc) will alter some or all of the signs that can be used to determine stress levels, and it is not currently possible to isolate individual factors that contribute to each of these levels.

With this caveat notwithstanding, a number of researchers have attempted to find suitable physiological measures for conducting laboratory-based HCI experiments. Unlike ethnographic and real-world studies, laboratory experiments present an opportunity to control (to some degree, at least) the external factors that a user may be experiencing. They also have the advantage of allowing baseline data to be captured before an experimental condition begins. It has been demonstrated (e.g. by Scheirer et al. (2002)) that some physiological measures can be calculated while users undergo usability tests, and that these measures can then be correlated with user behaviour and system functionality to find particularly frustrating, annoying, and stressful components of an interaction.

Ideally, this type of analysis should be possible beyond the research lab and into real-world environments. Systems should be able to determine when a user is frustrated or stressed and adapt their behaviour accordingly. This adaptation could take the form of silently redirecting the user to another function or part of an interface if the user is repeatedly experiencing frustration at a particular element, or it may result in the software detecting the user's stress levels and allowing them to focus on a task without interruption. While this type of adaptation is conceivable, as previously noted it is difficult to conclusively determine a user's stress levels and make appropriate judgments. Additionally, the monetary cost of the technology to measure these factors is currently prohibitive, and many of the sensors are intrusive and unlikely to be adopted on a mass scale. Even camera-based systems have the disadvantage of requiring users to stay within the camera's field of vision–and, depending on the analysis, may require the user to stay in the same position to allow the system to make appropriate comparisons.

In an effort to work around some of these constraints, some researchers have incorporated physiological sensors into a computer mouse (described in Wensveen, Overbeeke, & Djajadiningrat, 2000); others have suggested analysing indirect measures such as the pressure with which a user presses buttons on a keyboard or keypad (e.g. Gilleade & Dix, 2004). While both of these techniques are relatively non-intrusive, they are less used than others and are also less accurate. However, research in this area is ongoing, and a growing number of researchers believe that these types of non-invasive measures (and others, such as cameras) may be increasingly useful for determining a user's psychological state as the technology improves.

Another useful, and slightly less ambitious, application of this technology might be to collect data from a user that indicates various physiological precursors and subtle factors that may occur before a user starts to consciously feel frustrated. This could provide useful research information both on the software interaction and on the nature of the physiology of frustration; ultimately, it may be possible for a system to detect a user beginning to exhibit unconscious signs of frustration and allow the system to deal with this silently, pre-empting any psychological stress before it occurs.

THE ROLES OF FRUSTRATION

Until this point, and in most emotion and HCI literature, frustration has generally been understood as a negative emotional state and one to be avoided if at all possible. However, psychologists are increasingly coming to understand that frustration is both necessary and useful for a variety of reasons. By understanding the roles of frustration it may be possible to not only appreciate its evolutionary role, but also to use it appropriately for practical and applied purposes.

In order to understand the evolutionary role of frustration it is important to appreciate the role of emotion in general. Bessière et al. (2006) discuss the perspective that emotion can be regarded as providing prototypical reactions; emotional schemas suggest appropriate actions for a given situation. This means that organisms experience automatic and innate emotional reactions to situations, and that these emotions provide guidance on useful actions to perform. For example, in response to another person physically harming you, you would likely feel anger towards the person; this anger would implicitly suggest that an appropriate response (from an evolutionary perspective) is to behave violently towards the perpetrator. Through processes of social conditioning we are retrained to avoid reacting instinctively and to instead consider socially and morally appropriate responses to situations. However, emotion provides an unconscious and efficient heuristic to indicate what should occur and (to a lesser extent) why. As such, emotion is an adaptive mechanism that can assist an organism during processes of natural selection.

Bessière et al. (2006) also discuss the function of emotion from an information processing perspective. The information processing model in cognitive psychology suggests that the mind is optimised to receive information, to process it in various ways, and to make appropriate output responses. This model includes the idea that the mind is also subject to a number of constraints, and that a variety of filtering mechanisms determine what the mind will process; these filters are collectively known as 'attention'. Attentional filters (a term initially coined by Broadbent, 1958) can include contextual expectations, results of previous perceptions, and cues from internal and external sources. Bessière et al. (2006) argue that emotion is another type of attentional filter, and that during particular types of emotion–including frustration–attention is filtered to ensure that only information that is relevant to the task at hand is processed. As noted above, this type of filtering could be mirrored by software that is capable of adapting to users' stress levels; unnecessary or distracting components of an interaction could be removed while a user is under stress.

Most psychologists now accept that frustration and stress are emotions that are correlated with physiological and psychological arousal (Bessière et al., 2006). In times of stress, an individual's cognitive performance can increase, its attentional patterns adapt, and the brain prepares the body for action. In many situations this type of arousal is advantageous, and from an evolutionary perspective would present a clear survival advantage. However, this type of arousal is only useful to a point (Hebb, 1955). There is a level at which arousal begins to decrease cognitive performance and presents a disadvantage. Beyond this level, it becomes harder for an organism to function. Therefore, any physical or psychological factors which are intended to affect arousal must be carefully constructed to optimise arousal while minimising cognitive performance deficits. In the case of HCI, this leads to the idea that a moderate amount of stress during a user interaction may present clear and transient advantages, but if this stress is too great, lasts too long, or is apparently irresolvable it may rapidly begin to cause performance deficits which become increasingly difficult to manage–and may, in fact, lead to a feedback loop that causes a user to feel increasingly frustrated and yet become less able to resolve the situation.

Based on this, it is not entirely surprising that a number of studies (as discussed in Bessière et al., 2006) have indicated that the neural substrates involving the evaluation of an experience tend towards a more complex model than simply a 'good' or 'bad' evaluation of emotional valence (quality). According to these studies, the brain includes separate positive and negative evaluation centres, both of which can be activated by the same stimulus simultaneously; in other words, an experience can both be positive and negative at the same time. While this increases the complexity of modelling the experiential aspect of a stimulus or an interaction, it also allows us to account for the fact that a frustrating experience can, at least at times, be ultimately rewarding. Gilleade & Dix (2004) argue that games use different types of frustration at different times and for different players, and that the outcome of this frustration is often exhilarating. Research in this area is ongoing, and is far from conclusive, but is beginning to indicate how complex and multifaceted even a seemingly straightforward emotional response such as frustration can be.

BEHAVIOURISM

The idea that the removal or resolution of a frustrating event causes exhilaration (Bessière et al., 2006) should be of no great surprise to behaviourists. Behaviourism was popularised in the 20th century but has since largely been superseded by cognitive science as the dominant paradigm within scientific psychology. As its name suggests, behaviourism is solely concerned with the actions of organisms and has little to say about thought, emotion, and other seemingly abstract concepts. By purely focusing on the behaviour of an organism and the ways in which this behaviour can be manipulated, behaviourists found and popularised a great number of laws and constructs which can be used to explain, interpret, and predict behaviour. One major topic within behaviourism, operant conditioning, is based on the premise that a behaviour which is followed by reinforcement (i.e. reward) will be more likely to occur in similar conditions in the future, while a behaviour that is punished will be less likely to occur. One type of reinforcement is negative reinforcement–the removal of an already-present aversive stimulus–which can, when combined with behaviour, increase the probability that the behaviour will occur again.

As stated above and as noted by Bessière et al. (2006), it has been observed by physiological psychologists and others that the removal of a frustrating event often causes exhilaration. When combined with the behaviourist idea of negative reinforcement this begins to form a more coherent and unified picture. Reinforcement causes neurological changes (for example, the release of endogenous opiates, or endorphins) which condition an organism to perform that behaviour again. Another consequence of this neurological change is the exhilaration that is experienced by the organism–such as a user who has recently resolved a computer issue or has completed a difficult level of a game.

Behavioural psychology is not limited to the study of reinforcement; another behavioural construct is useful when considering computer user behaviour. Bessière et al. (2006) conducted research into the types of situational and dispositional factors that predispose users to feeling frustrated, and note that "...we have seen an otherwise smart and productive individual...simply turn away from the challenge and opportunity this new technology has to offer and say 'I am not a computer person'". These findings could be considered evidence of learned helplessness. Learned helplessness occurs when an individual or organism is exposed repeatedly to irresolvable situations. After a certain number of trials (the number depends on a variety of experimental and individual factors), the organism's performance in similar future situations is often severely inhibited, even when those situations are in fact resolvable.

The seminal work on learned helplessness was conducted by Seligman (1975). When he exposed a group of dogs to uncontrollable electric shocks, the dogs initially tried to escape the shocks, although their attempts to do so were thwarted by the experimenters. After several trials, the dogs were placed in a different apparatus and were given shocks that they could actually avoid by jumping over a small wall. However, the dogs hardly attempted to escape, instead simply lying down and whining while the shocks were given. A control group of dogs was given the opportunity to avoid the shocks throughout the whole experiment and they did not exhibit this learned helplessness behaviour.

Learned helplessness has since been demonstrated in a variety of situations and with a number of animal species. While ethical rules would certainly not permit Seligman's experiment to be repeated, it is possible to replicate the underlying findings using humans. Dor-Shav & Mikulincer (1990) conducted a study using the Raven puzzle task paradigm, in which incomplete visual puzzles are presented and the participant is asked to select a puzzle piece to complete the puzzle. The researchers generally found that individuals–irrespective of their measured tolerance levels for frustration–became increasingly convinced they were not able to complete puzzles that were actually solvable if they had been previously presented with impossible (and, therefore, highly frustrating) puzzles. They also found that the degree to which subjects were inhibited was a function of the number of impossible puzzles they had been presented with.

Other studies with both humans and animals have found similar results on a variety of tasks, suggesting that the phenomenon of learned helplessness has severe implications for situations in which individuals must cope with complex and cognitively demanding tasks. It is easy to see that computer use can be viewed as an extension of this phenomenon: if a user is repeatedly frustrated in their attempts to complete a task, behavioural theory suggests that they will ultimately become convinced that their efforts are fruitless and will stop trying. This is consistent with the findings of Bessière et al. (2006).

SUMMARY AND FUTURE WORK

Frustration is an important, and generally undesirable, aspect of human-computer interaction. While the topic has been largely neglected in the HCI literature, it is possible to integrate information from various aspects of psychological research. Psychologists have a variety of paradigms and tools to understand emotions such as frustration and the psychological and physiological stress that accompanies it: physiological psychologists have identified a range of physical markers that indicate an individual is stressed; cognitive and evolutionary psychologists have begun to explore the functional purpose of emotions such as frustration and the various effects it can have; and behavioural psychologists have traditionally focused on the ways in which frustration can affect an organism's behavioural patterns. Other branches of psychology also have perspectives on how emotion and frustration should be researched and understood.

This paper has integrated frustration research from a variety of psychological paradigms, with a focus on how these findings can be interpreted and used in the context of human-computer interaction. HCI has traditionally focused on the reduction, and ultimately the elimination, of frustration in computer interfaces. By understanding behavioural concepts such as reinforcement and learned helplessness, HCI researchers and practitioners can develop an appreciation for the types of processes that human psychology incorporates–and why frustration is such a powerful emotion. By incorporating physiological information into usability tests, and by continuing to explore ways to measure users' emotion through sensors and imaging technology, those with an interest in HCI can take advantage of the wealth of psychological knowledge about stress and frustration and can use this to ensure their software and systems are useful and pleasant to use. Research into improving physiological sensors and making them easier to use in everyday situations is an important and ongoing area, and will have significant implications for both psychology and HCI. Finally, by understanding the evolutionary roles and functions of frustration, it is hoped that HCI researchers will appreciate the complexity of human emotion and will begin to explore the as-yet untapped potential of using frustration and stress to a user's advantage in the design of computer systems.

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