

It's all in the Face: Studies on Monitoring Users' Experience

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Abstract

We propose to observe users' spontaneous facial expressions as a method to identify adverse-event occurrences at the user interface level. We discuss an experiment designed to investigate the association between incidents during a word processing task and users' facial expressions monitored using electromyogram sensor devices. The results suggest that an increase of task difficulty is related to an increase in specific facial muscle activity. A second study is presented where an application offers assistance based on the users' facial expressions. This study evaluates a social agent that reacts to the users' spontaneous display of emotions, in an attempt to reduce the frustration caused by usability problems. The results indicate that for highly frustrated users the agent often increased their frustration, while those experiencing a moderate level of frustration stated that it somewhat reduced their frustrations.

Categories and Subject Descriptors (according to ACM CCS): H5.2. [Information interfaces and presentation]: User Interfaces --- Evaluation/methodology

1. Introduction

Consider the following scenario: “You are running short on time, the software does not seem to share your urgency: you need to insert a few pictures aligned vertically next to the column of text and you still need to review everything before submitting the final version. The text layout keeps shifting all over the page as you insert the pictures and resize them. You grim, you start to get agitated, it is obvious that the stress is taking over you.”

If we were observing that moment, we would most likely be able to recognize the tension in our user, maybe through the agitated movements, maybe through changes in our user's facial expressions. Noticeably the computer would neither. The nonverbal behavior, and in particular the grim face, would be important clues to understand the emotional distress and very much indicative of an incident with the interaction. In this paper, we present the recognition of facial expressions as a method to identify adverse-event occurrences at the user interface level. We discuss the results of two studies designed to investigate the association between adverse-event occurrences and users' facial expressions. The first study investigates facial expressions as a function of the difficulty the user experiences working with a word processing application. The second study analyses the users' perception of an anthropomorphic interface that reacts to their facial expressions.

2. Non-verbal communication

In human social interactions non-verbal behavior is a central part of the communication process. Beyond the message that is being verbal communicated, we focus our attention on gestures, posture, and the face. We learn to interpret the other subtle clues that might signal comprehension, agreement, or disagreement. Most multimodal interactive systems already integrate users' speech and gestural input, while other modalities, such as haptics and eye gaze, are also being researched. Those interaction channels, together with the traditional keyboard and mouse input, allow the user to control and express commands towards the system. They fail though to provide a means by which the computer can observe the users' reaction to the interaction. Studies on the user reactions to computers emphasize the importance of observing users attitudes towards them: two thirds of computer users shout, swear or are violent towards their PC when problems occur [MOR02].

Building on the importance of innate non-verbal behavior that characterizes human communication, we aim to understand to what extent computers can observe and eventually assist the user in response to their behavior.

2.1. The Relevance of the Face

The face is the most visible and expressive of all the channels for communication of emotions and therefore assumes an importance of its own in non-verbal communication. From the

early childhood, the face is one of the first links of communication between the mother and the infant. From the thousands of possible different facial expressions, we learn to observe in others surprise, happiness, love, sadness, approval or disapproval, ranging from subtle to more expressive facial expression.

For a long time though, facial expressions were interpreted as a product of the social environment; for example there are reports of some cultures that smile when in grief. Eventually those assumptions were challenged; a series of studies by Ekman demonstrated that when facial expressions are observed in isolation, outside a social situation, they consistently convey the individual evaluation of the stimuli [EKM72]. Ekman identifies six major families of facial expressions associated with distinctive emotional reactions: fear, anger, sadness, happiness, disgust and surprise. Other researchers have challenged the notion of a discrete number of facial expressions and have proposed other models, e.g. [KW01], nevertheless both theories share the common principle that components, or patterns of the expression, can characterize the individual reaction.

2.2. Face in HCI

The perspective of monitoring and recognizing users' facial expressions opens a new channel of communication between the user and the computer that so far has been neglected. Within the usability field, we are investigating how facial expressions of distress would be helpful to identify problematic features of the interaction. The development of this methodology could lead to new technologies to complement traditional usability lab setups: For example the participants' recordings from a usability study could be indexed by the amount of negative expressions to quickly find the most problematic incidents. We can also imagine this approach being extended beyond the lab to a real-world environment, where the users' frustrating expressions would be recognized and the incident recorded. The logs collected over a large pool of users would constitute a remote collection of incidents associated to tasks in real-world scenarios. Those examples however, raise a set of research questions that need to be addressed to comprehend the feasibility of such approach. We discuss next some of the previous work in this area, followed by a discussion of our studies and their significance.

3. Previous work

A first and fundamental question is to what extent facial expressions are at all relevant to measure computer related task difficulty? Work with physiological sensors has explored a relation between usability problems and physiological signals, using measures such as skin conductance and heart rate [WMCJ01]. But the work with facial expressions has not been investigated to a great extent, probably due to the difficulties in measuring it. Two processes are available to record facial expressions: electromyogram (EMG) sensors that measure muscular activity, and visual observation. The latter can be based on protocols such as the Facial Action Encoding System [EFH02], and requires either a manual, time-consuming

process or alternatively an automatic computer system, which are yet not fully mature. Electromyogram sensors can be placed over key facial muscles to detect certain expressions. This approach has been taken by a variety of work, studying facial expressions of emotions and constitutes a validated measure. Hazlett [HAZ03] describes how facial EMG sensors were used to assess the usability of websites. In that study, an index based on the overall activity of the corrugators muscle (muscle responsible for frowning) positively correlated with the websites lack of usability.

Video-based computer systems are less intrusive in the sense they do not require contact with the user, but remain difficult to implement for all the users and all the different appearances, as well as tend to require high processing time to yield good results. There have been a number of researchers working on the problem of detecting emotions based on the video image of facial expressions. Essa and Pentland [EP97] developed a system capable of recognizing six different posed facial expressions (anger, disgust, happiness, surprise, eyebrow raise and neutral). Still, the recognition of spontaneously occurring facial expressions, in opposition to posed emotional expressions, is an open research area. Nevertheless, the current research focuses on systems for detailed analysis of facial expressions [TKC01].

4. Study Case #1: EMG Monitoring of Induced Frustration in Word Processing

This study investigates the association between task difficulty and occurrence of facial expressions. It differs from previous work that associates facial responses to *overall* usability assessment [HAZ03], as we study the dynamics of facial expressions on a *task-by-task* basis. This allows us to assess the validity of the face in identifying particular problematic events when they occur, in opposition to just use it to establish an overall usability index, thus introducing a higher degree of granularity to the usability evaluation process.

The experiment was conducted with a group of 16 volunteers, 11 female and 5 male, recruited through a volunteer mailing list from the Motion Analysis Laboratory, Harvard Medical School. The subjects were required to have at least minimal experience with the Microsoft® Word application. The task consisted of formatting one page of text that was previously typed. The subjects were given a printed page illustrating how the final result should appear (figure 1). If they could not complete a particular component of a task they were asked to skip it and move on. They worked until they finished all required steps, or felt they had completed as much as they could. The tasks involved, encompassed a range of difficulty levels requiring different skills and levels of proficiency. Text alignment, indentation of paragraphs, picture placement, image editing, inserting special characters, and inserting *WordArt* were among the tasks.

Though our ultimate goal is to employ video monitoring to detect facial expressions, we initially used EMG sensors to create a data baseline, and validate our future findings with video systems. EMG sensors have been established as a valid method to study muscular activity. Three pairs of EMG sensors were placed symmetrically on both sides of the subject's face, recording the activity of three muscle groups: corrugator,

frontalis, and zygomatic. The corrugator pulls the inner half of each eyebrow downward. The frontalis brings the eyebrows upward. The zygomatic muscles control movements of the mouth and produce expressions like smiles.



Figure 1: Word processing task.

The EMG signal was collected at 1000 Hz. A video camera recorded the subjects' faces, and the screen was video captured during the period the subjects worked on this activity. In the design of the experiment, among the employable methods to gain insight into the subjects' assessment of the task, the "think-aloud" approach was set aside since the subjects' conversation would have interfered with the EMG data collection.



Figure 2. Example of a facial expression portrayed by the participants.

During the design of the experiment it was unclear how difficult the subjects would find the required tasks. To ensure that at least one relevant adverse event would occur, a font required in the instructions was removed from the system, creating a difficult/unsolvable task for all users.

Following the experiment, the subjects were debriefed and filled out a questionnaire. In this questionnaire, they rated their level of experience with Microsoft® Word (average of 3.8 out of 5) and identified which tasks they experienced problems executing.

4.1. Data Analysis and Results

The screen-captured video was inspected and all the subject actions were scored in a scale ranging from 1 to 6 according to the difficulty experienced executing them. The following examples illustrate how this scale was applied: When a subject took slightly longer than expected to locate an option in the menu (e.g. inserting a *WordArt*), that would be scored (2); During a task such as inserting an *Autoshape*, where the subject experienced several missteps placing and aligning it, that would be assigned a (4); The score (6) was reserved for tasks that after some effort, the subject was not able to complete, e.g. searching for the font which was not present and eventually giving up.

This EMG signal was processed to identify muscle excitability, by detecting an increase of 3 standard deviations over the mean, with duration of at least 1s. For each subject, the action in the log file corresponding to that signal segment, was coded as 0 or 1, depending on whether a peak was detected or not.

To determine whether there is any correlation between muscle activity and task difficulty, we aggregated the data for all the subjects and analyzed the frequency of tasks with and without muscle activity. Table 1 shows the contingency table for the corrugator and zygomatic muscles. Recurring problems with the frontalis sensors did not allow us to factor that muscle in.

Corrugator						
	1	2	3	4	5	6
A	168 338.0	110 100.2	58 45.6	76 44.3	122 63.0	185 127.9
~	884 714.0	202 211.8	84 96.4	62 93.7	74 133.0	213 210.1
Zygomatic						
	1	2	3	4	5	6
A	244 486.5	174 144.3	82 65.7	109 63.8	162 90.6	264 184.1
~	808 565.5	138 167.7	60 76.3	29 74.2	34 105.4	134 213.9

Table 1. Contingency table for muscle activity (A) versus no muscle activity (~A) for each task difficulty level.

The details on the data analysis are discussed in [BFEB05]. A chi-square analysis showed statistical significant correlation between task difficulty and corrugator muscle activity ($p < 0.001$) and also between task difficulty and zygomatic muscle activity ($p < 0.001$). These results lead us to conclude there is a relationship between the muscle activity and task difficulty.

At first analysis, the association of task difficulty with zygomatic activity seems to contradict the fact that this muscle is associated with positive stimuli (smile). Nevertheless, this phenomenon has been previously observed multiple times in computer-game settings where increased zygomatic activity was reported in negative or obstructive events [REE00].

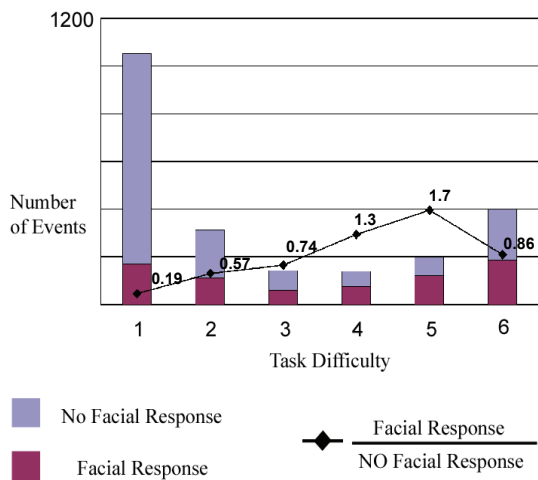


Figure 3. Proportion of tasks with associated corrugator muscle activity.

Figures 3 and 4 show the distribution of tasks with and without associated muscle activity, as well as their ratio, for each task difficulty level.

It is evident from the graphs that, in general, the proportion of tasks with muscle activity increases with the increase on the task difficulty.

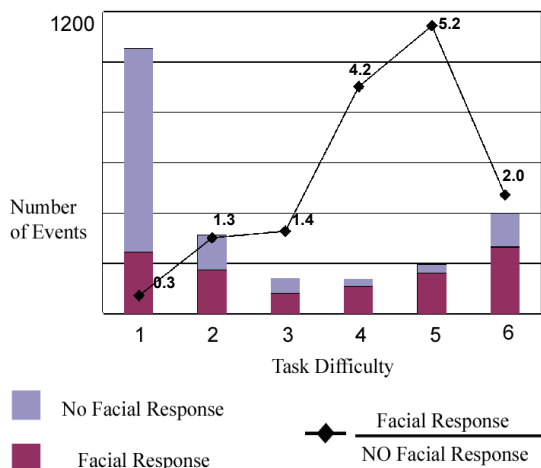


Figure 4. Proportion of tasks with associated zygomatic muscle activity.

Notably, for tasks scored as (6), there's a decrease in the muscle activity. Though we have not yet scientifically studied and evaluated this phenomenon, we have anecdotal evidence that this behavior represents the subjects' resignation, as those events correspond to tasks the subjects were not able to complete and gave up on.

4.2. Discussion

The above study suggests that an increase in the difficulty of the user's experience with an interface is associated with an increase in the EMG signal. This is a first step in verifying the relevance of facial expressions as a method of identifying

occurrences of user-perceived difficulties interacting with software. This result is promising but its application relies on the ability to identify facial expressions with less obtrusive sensor technologies. Video-based facial expression analysis is less intrusive, in the sense it does not require contact with the user, but remain difficult to implement. Nevertheless, the increasing presence of web cameras in desktop computing environments, and the emergence of commercial software capable of facial expression analysis, [NEV06] makes this the most promising approach.

5. Study Case #2: Camera-based Monitoring of User Facial-Response to Virtual Assistant

The experiment previously described addressed the relation between task difficulty and users' facial expressions. One of the possible applications for monitoring facial expressions is to offer user assistance based on their expressions. In the previous word processing application, there is the risk that approach can quickly become an obstruction to the user, therefore we explored that scenario within the context of an activity that is social in nature, and where is, thus, less likely to disrupt the user. We chose a shopping website, featuring a social agent that reacts to the users' spontaneous display of emotions. From the previous study, we know users were most likely to exhibit facial expressions when experience difficulties with the task. Therefore, the goal in this study is to address the users' frustration, and prevent further aggravation. We present the study and discuss the results in the following sections.

We have created an online furniture shopping website based on the "Kliving" e-commerce demonstrated from SAP Research. The site contains a humanlike sales assistant (social agent) capable of speech output and subtle facial expressions (See Figure 5). While the presence of social agents in an application is not always appropriate, they have been shown to work well in motivating and engaging users in some computer activities that are social in nature, such as training, presentation and sales [DOY99].

The female character was created using Haptik Inc.'s People Putty [HAP05]. The social agent speaks about the items in a similar manner to an actual shopping assistant. Although much of the product information is available as text, she offers supplementary information and occasionally makes suggestions.

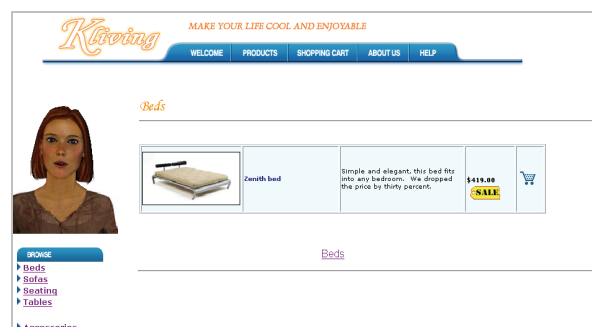


Figure 5. Furniture shopping website.

In this study we replaced EMG sensors with a video-based facial expression analysis system, and evaluated users' reactions to this monitoring modality. The automated facial expressions analysis system was in fact simulated, without the participants' knowledge, using the "Wizard-Of-Oz" technique [WR98]. The investigators, who were remotely monitoring the participant's screen over the network, and face via a web cam, controlled the animated character by triggering prerecorded phrases in response to their facial expressions. There were a total of five responses to negative facial expressions, for example: "*I apologize if you are having troubles. Please be patient as we continue to improve our site*", "*Sorry if you're having troubles. I suggest writing the problem in the feedback form and moving on*", and two responses to positive facial expressions: "*I hope you're having a good time!*" and "*Looks like you're enjoying the shopping!*".

To assess the users' appreciation of the social agent when it responded to the users' expressions of difficulty, it was necessary to introduce problems in the website that would resemble real-life usability problems. Two different versions of the website were used. In the first, high frustrating version, some of the products could not be purchased and several links were broken or led to the incorrect page. The second version, which was used after the first twelve users, eliminated some of the issues and was left with a purchasing problem in one product category and with one broken link. Although the website is fairly easy to navigate, some of the product pages contain small graphics of poor quality, and often very terse descriptions. Originally, there was also an unexpected shopping cart error that we later found to be exclusive to the Internet Explorer browser, which caused all of the purchased items to disappear randomly from the cart, and all subsequent purchases to never appear in it. This unpredictable shopping cart behavior was initially an unintended problem, which we, however, decided to keep for the first version of the website because it provoked frustration in our users and it represents a real-life scenario that causes annoyance and inconvenience to the customer.

5.1. Study Design

Thirty users (18 females and 12 males) with at least a basic knowledge of computers, such as experience with email and Internet browsing, were recruited to represent users with different ranges of experience with online shopping. More than half of the users were recruited through an electronic posting on Brown University's graduate student bulletin, while the rest responded to a web posting on Craig's list for Providence, RI (<http://providence.craigslist.org>), a community electronic bulletin board. The announcement was posted in the volunteers section of this website. Since both recruiting methods involve an online posting, the participant pool is guaranteed to be comprised of those who use computers and the Internet.

The users interacted with the faulty website containing the virtual shopping assistant. The study was conducted as a two-condition experiment, where the participants were assigned randomly to each condition. In the control condition, the virtual assistant was programmed to speak solely based on the website page and user clicks. Most of these comments were

related to the products. In the experimental condition, the assistant also spoke in reaction to the participant's spontaneous facial expressions as described in the previous section. The participants were informed that their face would be monitored with a camera and that in case they were randomly chosen to be in the experimental group, the social agent may respond to their facial expressions.

After hearing the navigation instructions from the social agent, users could begin shopping and were expected to purchase a minimum of ten items, at least one from each of the seven categories. As they shopped, they encountered the obstacles previously described. When finished, users filled out surveys that collected qualitative data about their experience with the application and the virtual sales assistant. At the end of the session, the subjects were debriefed and informed whether they participated in the control or experimental condition. Several participants offered comments and suggestions, which often provided additional meaning to survey results. The results are discussed next for each of the versions, comparing the control and experimental groups.

5.2. Results

As mentioned above, we ran two versions of the experiment. The first version, with the more frustrating website, had 6 users in the control and 6 users in the experimental condition. Of the 18 participants in the second version (less frustrating), two scores were not used due to technical difficulties that may have influenced their ratings. As a result, there were 8 users in the control and 8 users in the experimental condition.

Participants were asked to report the highest level of frustration that they experienced during their interaction with the application. The following scale was used: (1) Not frustrated, (2) Slightly frustrated, (3) Somewhat frustrated, (4) Frustrated, (5) Very frustrated. As expected participants using the first version of the website reported being more frustrated (3.8) than the second version, which was designed to be less frustrating (2.6). An independent samples t-test showed this to be a significant difference, with $p=0.02$.

Next, to assess if the users' preferred the assistant that reacted to their expressions, we asked participants to rate the influence of the assistant's behavior on their mood during the frustrating times of the interaction. The following scale was used: (1) Reduced frustration, (2) Slightly reduced frustration, (3) Did not have an influence on mood, (4) Slightly added to the frustration, (5) Added to the frustration. We expected the users in the experimental condition to report a more significant reduction in their frustration.

In the first version of the website (more frustrating), participants had an average score of 3.5, which is between "neutral" and "slightly added to frustration", there was no significance difference in the effect of the social agent whether it reacted to users' facial expressions or not.

In the second version, the control group users reported that the agent had "no influence on mood" (3.1) but the experimental group reported the agent to slightly reduce the frustration (1.7). A Mann-Whitney U test for significance (unlike the t-test, the Mann-Whitney test does not assume

normally distributed answers for the two independent groups) indicated a significant difference between the average ratings of the two conditions in the second version, with $p=0.011$.

The results from the second version indicate that when users experience moderate frustration, the social agent intervention to the users' facial expressions seem to help lower the frustration the user experienced. To assert this hypothesis we correlated the number of responses that each user received in reaction to negative facial expressions with how much the social agent influenced their mood. For users in the control condition, this number was always 0; the number varied between 1 and 4 for the experimental condition. The result of this correlation yields a statistically significant positive correlation (0.73) between the number of interventions of the social agent and the effect that it had on reducing frustration.

Regarding the participants' acceptance of video-based monitoring, they were asked "How would you feel about having your facial expression monitored by the computer during use of an application for the purpose of detecting and addressing possible frustrations?". 50% of the users did not mind, 39% answered that it should be fine in some situations, and 11% opposed the idea.

5.3. Discussion

In the first version of the website, most users reported being frustrated or very frustrated. For these users the intervention of the social agent seemed to further aggravate their frustration: slight trends indicated that those in the experimental group assessed the agent more negatively than those in the control group. Although the second version of the experiment still caused some frustration to most users, most reported only a moderate amount of frustration. Furthermore, for those in the experimental group, the agent was reported to slightly reduce frustration, in contrast to the control group, which reported that the agent had no influence on their mood during frustrating times.

As is evident from the nature of the responses, the social agent does not try to provide a specific solution to the problem the user was experiencing. That approach would require context awareness of the user task and of the specific problem encountered, which can be hard to infer. Also, note that the social agent does not respond when users encountered a problem *per se*, but only intervenes when a facial expression occurs. This strategy might be less intrusive than trying to infer user problems and intervening, which requires, again, sophisticated user and task modeling, and yet might still not be appreciated by the user. Who of us likes to be continuously observed and interrupted by a Know-it-all? Given the results from the first study, the user is more likely to exhibit facial expressions for the events perceived as most difficult, therefore this form of intervention is more likely to relate to the users' effective perception of a problem, and eventually more acceptable than trying to intervene all the time some incident arises.

It is also important to note that some users seem to react negatively to virtual assistants in general, as indicated by not only their negative assessment of this particular assistant but

also of any previous interactions with virtual assistants. This attitude might negatively bias the appreciation of the social agents that respond to facial expressions. Like it is the case with most user-interface features, user preferences, proficiency, and other human factors play a significant role in the acceptance of such features over time. Therefore, giving the user control over such features remains crucial.

6. Open Research Questions

While the results here described seem promising, there are a number of important open questions that should be considered. It is clear that the face is not only a vehicle for the emotional display but also for conversational signals or cognitive processes. For example, in the context of a conversation, raising the eyebrows is used to lay emphasis while speaking. The question is then raised: *How does the ambiguous nature of facial expressions challenge its interpretation in a traditional HCI environment?* In comparison to a social setting, facial expressions in traditional desktop HCI might be less ambiguous, since the context is more restricted. In this specific domain, facial expressions will reflect mostly a cognitive process, (e.g. the effort on planning the next steps to execute a task) or an emotional reaction (e.g. not finding an option in the menu). Still, that behavior might also refer to a thought (related or not to the task at hand), or just to the degree of the user concentration. The discrimination between the different categories of expression could possibly be inferred from the application context and the timing, for example if a particular facial expression and an interface event occurred within a few seconds. More complex interactions, e.g., where the user attention is divided between multiple tasks or between the computer and other persons, require other forms of disambiguation, namely head pose, or an indication of whether the user is speaking or not. To our knowledge the research on these topics has yet to be done.

Another relevant point that might be raised, especially by those who oppose the idea of having a computer monitoring the user, or the computer taking initiatives without user intervention, is: *Why not rather ask the user to explicitly communicate when they feel frustrated; would it not solve some of the intrinsic problems being discussed?* The disadvantage of such approach is the need for the user to disengage from the task at hand to report the frustration. Depending on the severity of the problem, that extra step might not deserve the consideration from the user when more urgent matters call for attention. Also the extra interface might be a cause of frustration in itself. Notwithstanding there are mechanisms through which users could naturally and intentionally communicate frustration, for example a pressure sensitive mouse. Those modalities are e.g., discussed by Reynolds [REY01]. Along this line of argumentation we can also think of facial expressions as a channel for intentional communication. Ward [WMCJ01] suggests this approach could circumvent some of the ambiguity associated with the interpretation of spontaneous facial expressions. Certainly it seems an interesting perspective to be further investigated. Spontaneous expressions might be accompanied by change of posture or other gestures, (e.g. covering the mouth with the hand) which cause difficulties on the recognition; a deliberate expression might simplify the task. On the other hand, given the innate nature of emotional reactions, we might discover

users resort to that intentional expression but after a spontaneous reaction.

Finally, *what category of usability problems might be detected by monitoring facial expressions?* The monitoring of the nonverbal language and in particular facial expressions is an attempt to measure the perception of the user on the task at hand. Identifying the problems the user recognizes is just one step of the usability analysis. Other levels of analysis are necessary to identify the source of the problems and so the approach suggested is just a complement to all the other existing protocols for usability analysis.

7. Conclusion

For most applications there will be problematic usability occurrences emerging after release. These have the potential to aggravate the user, causing irritation and frustration. This assumption becomes a certainty when we consider the range of users computer proficiency and the number of interaction contexts that can occur. Similar to mechanisms currently in place, that let users submit software crash reports, future usability monitoring systems and software applications, could become attentive of the user frowning and logging the context of that event. Software companies could then use the logs of numerous users to identify -- in real-world tasks -- the most problematic features.

In this paper we presented results of two studies designed to investigate the viability of that approach. In the first study we investigated the occurrence of facial expressions and its relation to the difficulties encountered by the user. The second study applies the results and implements a website where a virtual assistant intervenes as users exhibit facial expressions. The results established a statistically significant relationship between an increase in the task difficulty experienced by the user, and an increase in facial muscle activity. In certain cases, where the user is not overwhelmingly frustrated, the computer intervention in response to the users grim or other negative facial displays seems to be a promising approach to help reducing frustration. In addition, the users' acceptance of being monitored by a camera varied.

Future work needs to address the questions discussed in the previous section; namely the disambiguation of the facial expressions, exploring users' intentional facial expressions, understanding the categories of usability incidents that can and cannot be identified by this method. On the area of video-based facial expression analysis, more work needs to be done building robust non-intrusive solutions that can be deployed outside a testing environment.

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