Design of Emotion-Aware Mobile Apps for Autistic Children

Abstract

Sensor technologies and facial expression recognition are now widely used by mobile devices to sense our environment and our own physical and mental state. With these technologies today, we have the ability to sense emotions and create emotion-aware apps. One target group that would benefit from emotion-aware Apps are autistic children as they have difficulty understanding and expressing emotions and they are keen mobile device users. However, current mobile apps aimed at autistic children are not emotion-aware.

This led our team to design a suite of Apps, called CaptureMyEmotion, that uses wireless sensors to capture physiological data together with facial expression recognition to provide a very personalised way to help autistic children and their carers understanding and managing their emotions.

This paper describes how we designed CaptureMyEmotion and it discusses our experience while using sensors and facial expression recognition to detect emotion. It presents in more details the first App we developed for Android phone and tablets, called MyMedia. MyMedia enables children to take photos, videos or sounds, and simultaneously attach emotion data to them. The photos can then be reviewed together with a carer providing them a new way to understand emotions and discussing their daily activities.

Keywords: M-health, Emotion Detection, Facial expression detection, Autism, Personalised technology, Affective computing, Emotion-Awareness.

1 Introduction

Mobile technologies and wireless sensors are changing the way we live our lives and the way we perceive our environment. Today, mobile phones and tablets have the ability to recognise facial expressions, and wireless biosensors can measure arousal, attention and meditation levels. These new abilities give a real opportunity to create a new range of emotion-aware apps.

One target group that would strongly benefit from emotion-aware apps are children with Autism Spectrum Disorder (ASD). ASD describes a range of conditions typically characterized by social deficits, communication difficulties, stereotyped or repetitive behaviours and interests, and in some cases, cognitive delays [1]. The prevalence of ASD is estimated to be up to one in eighty-eight children [2].

People with ASD have difficulty expressing emotion and communicating how they feel when compared with people without ASD [3]. Emotion-aware apps could significantly increase the children understanding of their emotion and might allow then to take control, for example when an outburst is eminent. It could also help their carers or educators to better understand the children and make better-informed decisions. This is of major importance for their integration in classrooms and other social groups.

Most autistic children are visual learners and mobile technology appeals to them [4]. They embrace mobile technology and enjoy using smart phones and tablets to learn and play and a lot of apps have been developed for them. This has led a few research labs (e.g. [5-7]) to work on emotion-aware solutions for Autistic children.

Websites like iAutism [8] and Autism Speak [9] are maintaining an impressive list of Apps designed for children with Autism. Existing emotion learning apps in those lists are not emotion-aware. They describe emotions or show typical facial expressions and are used for emotion recognition exercises. Many of these apps have a fixed set of emotions where the child has to identify or understand the emotion. *Moody Me-Tracker* [10] app is of interest since it allows users to take pictures that make them happy or sad. It

allows users to playback pictures to make them happy and it has a diary to track mood changes. *Wonkido Mood Journal* [11] is another app to help children recognize their emotions and journal their feelings. *Micro-Expressions* [12] trains children to identify a facial expression using different characters. A similar app called *What's the Expression?* [13] teaches autistic children to understand and recognise expressions and emotions using a well-known cartoon character. Facial expression recognition is now feasible on smartphones due to improved facial expression recognition algorithms and increased processing power [14-15]. *FaceFetch* [16] and *Beyond Touch* [17] are two smartphone apps that demonstrate the use of smartphones to recognize facial expressions. Many apps use a fixed set of images, videos or audio, which might hinder a child to express its mood based on something very specific. A good example is the video in [18] that shows an autistic child getting very excited when he sees the garbage truck emptying the bins every week. These types of situations are not covered in apps with a fixed set of scenarios and calls for apps that allow the child to record their own scenarios to communicate their feelings. Furthermore, none of the mobile apps use physiological data from a sensor to identify a particular emotion. They are based on self-reporting or on the observation of a carer. However, this can be highly unreliable since many autistics have difficulty communicating emotions [19].

Our research lab investigates how mobile technologies, wireless sensors and facial expression recognition software can help autistic children and their carer understand emotions. We designed a series of apps called *CaptureMyEmotion* aimed at high functioning autistic children. High functioning autistic children respond well to apps, do not suffer extremely narrow interest and are less prone to be overwhelmed by complex multimedia material [20].

The paper is organised as follows: Section 2 describes *CaptureMyEmotion*, its design requirements, novel emotion aware app ideas, how we make *CaptureMyEmotion* emotion-aware, and it focuses on the first app of the series that we developed for android phones and tablets called myMedia. Section 3 presents our lessons learned while using sensors and facial expression recognition algorithms to detect emotions and the paper concludes with our future work.

2 CaptureMyEmotion

2.1 A Suite of emotion-aware mobile apps

CaptureMyEmotion is a suite of emotion-aware apps for autistic children and their carers. The apps are designed to increase accessibility and usability for autistic children and their carers. CaptureMyEmotion consolidates and centralizes all the settings and personalization of emotion-aware apps. The objective is that once the children are logged in, they can navigate through the different apps and get personalized access to their adapted games, music, and educational tools to play and communicate.

CaptureMyEmotion is developed for Android smartphones and tablets. It uses Dropbox [21] to share the data (e.g. photos and sensor data) between several devices and amongst its different apps. CaptureMyEmotion automatically connects to the Bluetooth sensors (if present) and those sensors are then available for all the apps with the child's calibration and baseline.

A lot of current autistic apps would benefit from becoming emotion-aware and our objective is to have selection of apps that the carer can chose from depending on the child's age and abilities. At the time of writing, our research team is focusing on two Apps called MyMedia and MySchedule.

MyMedia combines personally recorded photos, videos or sounds with wireless physiological sensors and facial expression recognition to determine automatically the emotional state. Sensor data is used when the child takes a picture, as well as, when the child discusses the picture with a carer at a later stage. The emotions are recorded and can be used to facilitate a positive social interaction between the carer and the

child. MyMedia features an evaluation phase where the carer is able to discuss feelings with the child. It also keeps track of the child's interests.

MySchedule Autistic children need schedules to help them to prepare for activities so that they will know what to expect and they can function and cope with the change in activities throughout the day [22-23]. This helps lower the anxiety levels and can help lower activity transition time and create a greater sense of independence. MySchedule is similar to existing schedulers and organisers on the market such as AutiPlan [24] in the sense that they help provide for a structured list of daily activities. However, MySchedule uses emotion-awareness to help both the child and the carer identify the activities that the child is having most trouble with. The carer might then choose to modify the activity or the timing of the activity to help the child to deal with the activity.

2.2 User Interface Design Requirements

When designing the user-interface for CaptureMyEmotion we used a flat design Methodology [25] and we paid particular attention to the following aspects to build a usable and autistic friendly suite of apps:

Consistency: Autistic children crave predictability and consistency in their environment and slight changes can cause the child to become stresses and also cause outbursts [9].

Buttons, pictures and text: Autistic children have difficulty converting text to pictures [26]. The placement of text, size of text, dynamic labelling of buttons and graphically labelled buttons are important [27]. The font used needs to be easy to read on the screen, this means using simple sans serif fonts such as Verdana or a serif font such as Times New Roman [28]**.** Autistic children have a high rate of deficiency in fine motors skills. Though the problems will not be as acute for CaptureMyEmotion since we target highly functioning autistic children with finer motor skills [20] it would be beneficial to include large buttons for the children to press.

Simplified Interface and workflow: It is essential that the workflow of the app is simple so that the user can be guided through at a consistent and acceptable pace to avoid frustration [29]. Apps for autistics need to have their workflow simplified, the interface has to be uncluttered and clean with some light space [29]. Autistic children are able to comprehend visual information because the message is there long enough for them to take in and process the information [30] therefore the interface of the app requires a lot of consideration.

Personalisation: ASD is a description given to a range of disorders. Challenges, needs and skills vary by age of a child and severity of autism and each case is unique [31]. It is therefore important to recognize that when designing the apps and offer personalized apps to deal with that diversity. In CaptureMyEmotion, carers can chose the apps that are suitable for their child and configure them. An important feature is that they can choose the language the child prefers to use. Many apps only target the English speaking market and a few support two or more other languages. Carers can also choose the sensors the child is going to use. The sensors and facial expression recognition are tailored for the child the first time the child is using them.

2.3 Emotion Awareness

CaptureMyEmotion combines the data from physiological sensors and facial expression detection software to provide insight into the emotional state of a person.

Emotion can be described by two dimensions i.e. arousal (high versus low) and valence (positive versus negative) [32]. Based on these two dimensions, 6 basic emotions (happiness, sadness, fear, disgust, surprise and anger) can be identified which exist for all human beings independent of race. Those basic emotions are defined in the Facial Action Coding System (FACS) [33] and each emotion has a uniquely corresponding facial expression. There is no perfect measure of arousal or valence. While it is possible to approximate arousal from measurements relating to the sympathetic nervous system (SNS), it is not

possible to do so with valence [34]. For valence, facial expression must be used. For arousal, the measurable expressions of SNS include pupil dilatation, skin conductance [35], heart rate and heart rate variability [36] and increased blood pressure. You can also use EEG to measure concentration and attention levels [37].

CaptureMyEmotion uses 3 types of sensors for arousal detection: Affectiva Q sensor [38], Zephyr BioHarness™ [39] and MindWave [37].

Figure 1. Zephyr BioHarness™ (left), Mindwave mobile (centre) and Affectiva Q sensor (right)

Affectiva Q sensor is a Bluetooth enabled sensor that collects in real time accelerometer, skin temperature and skin conductive data (Figure 1, right). Skin conductance usually increases when a person is more aroused (engaged, stressed, or excited) and it tends to stay low or drop when a person is less aroused (disengaged, bored, or calm) [40].

MindWave mobile is a Bluetooth device (headset, an ear-clip, and a sensor arm) that safely measures and outputs the EEG power spectrums (alpha waves, beta waves, etc.) (Figure 1, centre). The eSense algorithm provides attention and meditation level [39].

Zephyr BioHarness™ is a Bluetooth sensor worn on a strap that measures heart rate, heart rate variability (HRV), respiration, body temperature and movement (Figure 1, left). We are interested in heart rate and HRV since it relates to emotional arousal. HRV is the physiological phenomenon of variation in the time interval between heartbeats. It is measured by the variation in the beat-to-beat interval. Various emotional expressions produce different changes in autonomic activity. For example, anger or fear will increase the heart rate and lower the HRV whereas happiness or being relaxed will decrease the heart rate and increases the HRV.

CaptureMyEmotion uses ***Spatio-temporal facial expression recognition*** [41-42] to identify the valence. The facial expression recognition module uses the OpenCV library [43]. For *MyMedia* App, it requires the training of the app to the child's facial features, in which the child is instructed to take several photos of their personal interpretation of an emotion. The child is instructed through prompts on what kind of emotion to mimic until the training module is completed.

2.4 MyMedia

MyMedia is the first app we developed for CaptureMyEmotion. It enables autistic children to take photos, videos or sounds and to comment on the emotion felt while taking the picture. *MyMedia* lets the children take their own pictures and is not based on an existing set of pictures. This increases the chance that a picture generates a genuine emotion. The child uses the smartphone to take pictures and the carer would use either the phone or the tablet for evaluation together with the child. The main screen for MyMedia allows the child to select the camera, video or sound icon to capture what is shown in the viewer (Figure 2, left).

Once the child has taken a picture, the front camera automatically takes a picture of the child's face. After the self-portrait has been taken, the child assigns an emotion to the picture (Figure 2, right). When the done button is tapped, the selected emotion is stored together with the sensor data, self-portrait picture and other context information (e.g. date, time, GPS coordinates). It is automatically uploaded to the child's Dropbox folder. This will be used as a basis for a discussion between the carer and the child to get a better understanding of emotions and also obtain insight into what makes the child react.

During the feedback session, the child and the carer discuss what the child did and felt using the child's pictures as a basis. The pictures can be organised by date, carer-rating or self-reported emotion and he child and the carer can select the pictures they wish to discuss. When they select a picture, the child is asked to identify his current emotion about the picture and this answer will be compared with his previous answers.

Figure 2. Main screen to take a picture and screen for rating a picture

The data related to that picture is then presented on a summary screen (Figure 3). The right hand side of the screen shows the arousal level at the time the picture was taken. The gauge range is from low to high and the range corresponds to the grey gradient in the gauge, and the general trend (e.g. low to high) is displayed at the bottom of the gauge. It also shows the emotion selected by the child ("You said"), and the result of the facial expression detection software ("Computer said"). Additionally, the carer sees the evaluation data showing the emotion selected by the child during the review. The carer may choose to hide or view all the emotion information on the right hand side by tapping the background picture.

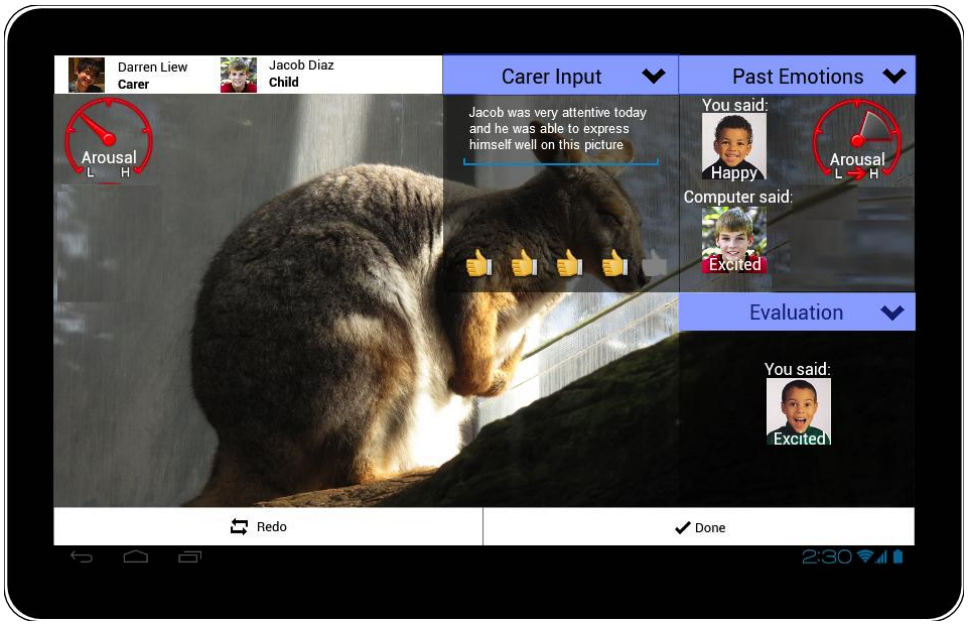

Figure 3. Review pictures

The gauge on the left hand side of the screen shows the live arousal level when the child wears a sensor. This gives the carer insight into what emotion the picture evokes, or can highlight that the child is getting tired of doing the review or being distracted by other external factors. This can be used in the discussion with the child, or as an indicator that the carer should switch to another activity. The carer may also use the sensor information as feedback on how effective their techniques of interacting with the child are.

The carer can comment and rate the discussion related to the picture as seen fit. The number of thumbs-up allows the carer to express the review result (e.g.: 0-no review, 1-very poor, 5-very good). Data accumulated from the carer and child can be used for the progress report. The progress report displays graphs detailing the number of thumbs, ratings or pictures accumulated against time. The information viewed on these graphs can be filtered on emotions, locations, ratings or dates.

3 Lessons learned during the development of emotion-aware apps

3.1 Facial emotion recognition

The preliminary tests conducted on the facial expression recognition algorithm have been very positive. Using a variety of mid to high range smartphones and tablets, the analysis speed can be considered as ‘real-time’, while the lengthy processes of the training algorithm varies from around one to five seconds depending on the device. This result is highly favourable to the spatial approach of facial expression recognition, and can only improve as devices continue to improve. Facial expression recognition does not require extra cost for a sensor and already provides a great indicator for the carer and the kid himself. We could imagine a near future application for autistic children where they use their phone with facial expression recognition that give the kid a clue on the emotion of their interlocutor while the child is looking at them.

3.2 Wireless sensors

Wearability: The three sensors used by CaptureMyEmotion are easy to wear and are able to transmit the data in real time to a mobile phone. The Q sensor can be worn for a long period of time to obtain a reliable baseline. The MindWave sensor is more visible and is therefore less discreet. Bioharness is able

to perform under extreme conditions are confortable and unobstructive enough for the user to wear while conduction their activities.

Cost: Cost of sensors and mobile technologies can be a showstopper. However, it is increasingly recognised that autistic children respond well to personalised technology. Autistic associations such as *FaHCSIA* [44] in Australia or *Autism Speaks* [45] in the USA have identified the potential of mobile technology on the child's progress and are subsidising or giving tablets away to families with autistic children. We can expect that they would also subsidise sensors in the future. Zephyr is the cheapest of the 3. Also as more sensors are getting on the market their price should go down.

Interpretation and display of emotion data: The interpretation of emotion sensor data can be difficult. Sensors need to be calibrated and personalized to the child. The prototype used the Affectiva Q Sensor during testing. While the sensor was functional and reasonably accurate in its function, the algorithm in interpreting an analysis needs to be further examined. The Q Sensor measures skin conductance, which is highly susceptible to external influences, despite long monitoring of a baseline. Testing has shown that spending a whole day in an air conditioned room, and then going out on a sunny day can lead to uncertain results, due to the heat and physical exertion varying thermal regulation and thus the skin conductance. This has been somewhat mitigated through the inclusion of a short-term median, which has met some success in curbing the variance. For MyMedia, we provide a 'calculated' value of valence and facial expression recognition and we also give access to the 'raw' data (e.g. we can show the child's photos to the carer together with the estimated emotion) if the carer is interested.

4 Conclusion

This paper presented *CaptureMyEmotion*, a suite of personalized Apps for smartphones and tablets. It aims at helping autistic children understand their emotions using mobile devices, sensors and facial expression recognition software.

CaptureMyEmotion is a tool and (by choice) it allows the carer to choose what they want to do with the captured information. The frequency of use of the apps, the type of rating and the number of feedback sessions highly depends on the child's interest and capabilities, as well as, on the carer's objectives.

We plan to trial CaptureMyEmotion in a real classroom situation in our city and we are currently talking to the educators to set up the trial. We selected a classroom that has a mix of high functioning children with special needs and normal children. The reason why we selected this form of trials is twofold: the app will be used by professionals that have an experience with autistic kids and also it is important to compare the autistic children's reaction to the app against a baseline from non autistic children [46]. The autistic children in the group will also use the app at home under the supervision of their carers and we will collect feedback from educators, carers and kids and analyse the sensor data collected. During the trial, the sensitivity of the sensors and the user interface will be fine-tuned based on feedback received. Also the carer's manual will be updated with new ideas and tips from parents and carers participating in the trial. The app will then become available on Google Play for people that want to use it with or without the sensors.

Understanding and managing emotions is important for autistic children since it has an impact on how well they integrate into society. We believe that using sensors and mobile technologies has the potential to help them, and their carer in their daily lives.

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