The Potential of Smartwatches for Emotional Self-regulation of People with Autism Spectrum Disorder

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Abstract: This paper focuses on the potential of smartwatchers as interventors in the process of emotional self-regulation on individuals with ASD. Parting from a model of assistance in their self-regulation tasks, we review the main advantages of smartwatches in terms of sensors and pervasive interaction potential. We argue the suitability of smartwatches for this kind of assistance, including studies that had used them for related purposes, and the relation of this idea with the affective computing area. Finally, we propose a technological approach for emotional self-regulation assistance that uses smartwatches and applies to the mentioned intervention model.

1 INTRODUCTION

People with Autism Spectrum Disorders (ASD) usually show symptoms that affect their behavior. Experts attribute this to their deficit in the executive function, which is defined as the ability to control actions (Baron-Cohen and Chaparro, 2010). Although executive dysfunction is better known because of its effects on planning and organization skills, it also affects behavior and some other abilities, such as impulse control, inhibition of inappropriate responses and flexibility of thought and action (Ferrando et al., 2002).

Considering the daily life of a person with ASD, the aforementioned deficit in executive function may lead to the following practical difficulties:

- Difficulty in organization and sequencing of steps to complete a certain task.
- Difficulty to identify the starting and ending points of a certain task.
- Difficulty in behavioural and emotional regulation.

These are high functional limitations and they are closely related to behavioral disturbances. Proper and adapted support and help are essential to achieve major improvement, even more when the assistance is provided by means of self-regulation strategies. This kind of support reduces dependency on caretakers and makes feasible to adapt these strategies to the users' contexts (Laurent and Rubin, 2004).

In general, the main goal of these supportting strategies is to increase users' self-determination. Self-determined behavior is composed of four necessary features: autonomy, self-regulation, empowerment and self-fulfillment (Nota and Ferrari, 2007). Specifically, self-regulation involves several aspects of self-determined behaviors: choosing and decision-taking, problem solving, goal setting, skill acquisition and internal control.

Regarding emotional and behavioral self-regulation, Pottie and Ingram (Pottie and Ingram, 2008) presented a model set of tasks that new strategies or developments must help in:

1. Define a scale of emotional intensity.
2. Adjust the emotional reaction to the proper intensity
3. Identify situations that provoke varied emotional intensities and adapt the emotional reaction to them.
4. Develop strategies of emotional control.
5. Identify stressful situations.
6. Create ways to avoid non-desired situations.
7. Manage the stress of non-desired situations.
8. Manage anger episodes.

Besides, these tasks can be classified into three groups or stages: preprocessing, identification and management. Table 1 summarizes the mapping between stages and tasks.

Therefore, this supporting tasks can be considered as requirements for technology to aid people with

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ASD in their emotional self-regulation. In further sections, we propose a new approach to enhance the process of emotional self-regulation by means of emerging technologies.

Table 1: Self-Regulation stages and associated tasks.

Preprocessing	Identification	Tasks
1	3, 5	2,4,6,7,8

2 ASSISTIVE TECHNOLOGIES FOR EMOTIONAL FUNCTION

The application of technology to support people with cognitive disabilities is not a new idea. The concept of assistive technology (World Health Organization, 2007) includes the whole set of functional diversity: physical prostheses, glasses, wheelchairs, etc. However, having a specific type of assistive technology that involves cognitive aspects of users became necessary. Thus, assistive technology for cognition (ATC) was born (O'Neill and Gillespie, 2014). Gillespie et al., (2012) reviewed and mapped ATC products to the International Classification of Functioning, Disability and Health (ICF) (World Health Organization, 2007). In other words, they analysed thoroughly the relationship between the cognitive functions and necessities of people with cognitive disabilities and the assistive products made for them. For this mapping they also classified ATC function into alerting, distracting, micro-prompting, navigating, reminding, storing and displaying, and mixed function. Through a systematic review of ATC studies they found a strong relationship between their classification of ATC function and the ICF cognitive functions (see Table 2). Thus, attention problems are usually treated by alerting technology, distracting technology brings emotion regulation, navigating technology covers experience-of-self issues, micro-prompting is for organization and planning, storing and displaying is used for memory problems and reminders for time management.

From this study we can conclude that distracting technologies have been used to propose solutions to emotional and behavioural issues of users with cognitive impairment. ICF defines emotional functions as specific mental functions related to the feeling and affective components of the processes of the mind. "Distracting technologies" is a wide term, which goes from devices that provide with stimuli to prevent from hallucinations (Johnston and Gallagher, 2002) to biofeedback systems (Sharma et al., 2014).

Table 2: Mapping of ICF cognitive functions to ATC functions (Gillespie et al., 2012).

ICF cognitive function	ATC function
Attention	Alerting
Calculation	Mixed
Emotion	Distracting
Experience of self	Navigating
Organization and planning	Micro-prompting
Time management	Reminders
Memory	Storing and displaying

This reasoning serves us to define the type of function that a technological system oriented to assist a user with ASD in his emotion self-regulation should satisfy.

3 SMARTWATCHES AS EMERGING TECHNOLOGY

3.1 Emerging Technologies

The main problem when it comes to speak about emerging technologies is that is a vague, fleeting term. Due to the accelerated course of technology advancement, emerging technologies today are completely different from emerging technologies few years ago.

However, the term itself has been used since the appearance of smartphones and IoT (Internet of Things) related technologies (Bijker et al., 2012). Evidently, nowadays we cannot speak about smartphones as emerging technologies, but as widespread technologies, and this change took only a few years. Once smartphones became widespread technologies, used and accepted by millions of users (File, 2013), researchers started to think about their application to science as a means instead of an end, especially on social sciences (Dufau et al., 2011). Thus, the number of research studies that used smartphones as the main vehicle for experimentation augmented considerably.

ATC studies also took advantage of this phenomenon, and many researchers studied the use of smartphones with users with cognitive disabilities in their daily life. Lancioni et al., (2012), through the observation of the results from several experiments that used widespread technologies on cognitive impaired users, argued the importance of studying the adaptation of new technologies *before* they became popular, parallelizing the design for standard users and its adaptation to users with diverse functionality.

The underlying motivation of this paper is to encourage the adaptation of emerging technologies, whilst they continue being so. This way, relevant emerging technologies will reach an accepted and widespread usage state at the same time for cognitive impaired people and for standard population.

So then, which are the most leading emerging technologies nowadays? Do they project an optimistic future regarding to market and users? Is it feasible to plan their adaptation to users with special needs? Will be the next technological generation, after smartphones and tablets, as popular as them?

Serious predictions are very difficult to engage since they depend on numerous factors, but many of them are oriented towards an emerging device that will be treated in this article: wearable technologies, specifically smartwatches (Kerber et al., 2014) (Rawassizadeh et al., 2014).

3.2 Smartwatches

Smartwatches are wearable, wrist-held devices that are starting to offer similar functionality to smartphones, adapting its use and interaction to a new paradigm, and considering its limitations due to their lower resources (Witt, 2014). The most remarkable feature of smartwatches is their wide sensing set: accelerometer, heart rate monitor, GPS, light sensor, Wi-Fi, etc. These devices also offer varied interaction possibilities: tactile screen, vibration feedback or voice recognition. They can be considered the first wearable technology with true computing power and versatility.

That is why these devices have already raised attention between researchers of cognitive disabilities and social scientists. Kearns et al., (2013) developed their own smartwatch, integrated in a smarthome, which served as support for people with cognitive impairment in their daily life activities. This system also helps them planning and reminding tasks. Researchers concluded that the reminder was the more effective aspect of their system (reminding medications and punctual tasks during a day). This study serves to understand that this platform is useful for these individuals, but regarding our aim, it is not an example of the ATC function that we are looking for (distracting technology for emotional self-regulation instead of micro-prompting and reminders for planning and memory issues) and it has been implemented in their own smartwatches, whereas we look for a widespread use, so commercial or industrial prototypes are preferable.

Similar conclusions can be extracted from the study of Sharma and Gedeon (2012), who used smartwatches connected to smartphones as an aid to the treatment of people with Parkinson syndrome. This system offered the advantage of using a commercial device (Pebble) that made it feasible to reproduce the experiment in larger groups and different conditions.

Smartwatches, understood as portable sets of sensors, were used by Bieber (Bieber et al., 2012) to propose applications for ambient assistant living environments. Their study focuses on the non-intrusive aspect of smartwatches, and their capability of being centers of permanent sensing and notification in your own wrist.

Those studies used smartwatches for assistive technologies related purposes. However, there are no previous experiences of their use for emotional self-regulation, where they have a great potential to cover the necessities commented at earlier sections, as we will discuss in the proposal.

4 AFFECTIVE COMPUTING

Affective computing refers to any computing application or system that “relates to, arises from, or influences emotions”, as stated Rosalind Picard in the paper that coined the term (Picard, 1997). Moreover, some researchers focus on emotions as a new way of interaction with technology (Picard, 1999). However, the main challenge of affective computing is the detection and interpretation of human emotions. In psychology, the Theory of Emotions displays them regarding to two axis: arousal and valence; stress is an emotion of high arousal and low valence, whereas joy comprises high arousal and high valence. An example of both low arousal and valence is sadness, and one of low arousal and high valence is relax (Hernandez and Li, 2014).

5 PROPOSAL

Analyzing the necessity of applying technology to the emotional self-regulation of individuals with ASD has led us to review different applications in this area. However, most of them are based on technology specifically developed for each case, or require certain technology knowledge to be used. Smartwatches can be a natural approach to technology, and a good option to offer technological support in an attractive and normalized way. The intention is that the assistance is given though the smartwatch, not needing external, unknown or stran-

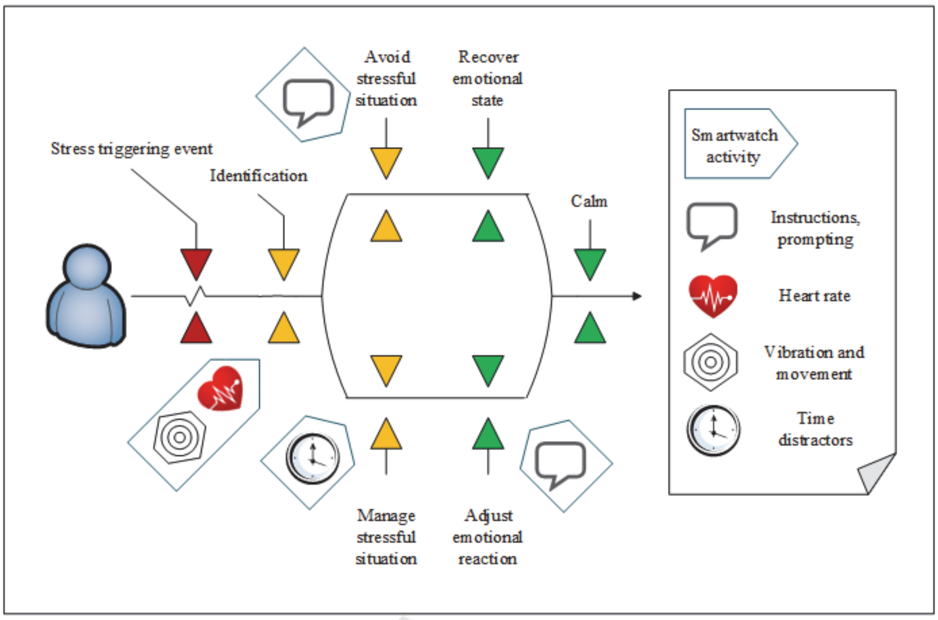

Figure 1: Application of smartwatches in the emotional self-regulation process of an individual with ASD.

ge devices. Situations that require emotional self-regulation arise spontaneously: getting nervous when walking through an unknown environment, receiving stimuli related to user's phobia, stressful situations derived from social interaction, etc. Whatever the situation, the smartwatch can be always directly available for the user, in their wrist. Moreover, smartwatches have enough sensing power to detect these situations, assist and register them.

Our proposal is a technological approach of the model explained by Pottie and Ingram (2008) (see Table 3), using smartwatches as well as computing affective techniques for detection and analysis and ATC procedures for interaction and pervasive assistance. Concretely, the smartwatch system (an application or service) would be able to perform the following tasks (see Figure 1):

- Detect stressful situations: the inward state of the individual with ASD gives signals that imply stress or anxiety; the smartwatch is able to detect them through sensing the heart rate or arm movement, involving affective computing analysis in the process.
- Create ways to avoid non-desired situations: this can be achieved by text, image and audio prompting in the screen of the smartwatch, providing instructions that tell the user what to do to avoid these situations.
- Manage the stress of non-desired situations: not always it is possible or recommendable to avoid certain situations that may cause stress to these individuals. In these cases, smartwatches can act as distractors or prompters, showing media that makes the user pay less attention to the stressful situation and getting feedback about how well it is the situation going.
- Define a scale of emotional intensity: the above mentioned prompting can be made using language that includes vocabulary and image-based media with emotional education purposes, asking the user what is his emotional state within a scale or giving names to different emotions perceived by the user in certain situations.

Table 3: Self-Regulation stages and associated tasks.

Self-regulation model	System function
Identify problematic situations	Smartwatch sensors + Affective Computing analysis
Define a scale of emotional intensity	Affective Computing analysis
Manage stressful situations	Smartwatch distractors and prompting
Avoid non-desired situations	Smartwatch prompting
Adjust emotional reaction to specific situations	Smartwatch timers and prompting
Manage anger episodes	Smartwatch timers and prompting

For example, this stressful situation can be seeing a big dog. If the user is afraid of them, the smartwatch will notice it through his heart rate or arm movement when repelling the dog. The smartwatch will try to catch his attention through vibration and sound, and then the app will tell the user what to do (go to another place, ask a reliable person for going to another place, etc.). After that, a distractor or mini-game in the screen of the smartwatch, that will help the user to recover the initial, calm emotional state. In case it is recommendable to teach the user to manage a situation with the presence with big dogs (for example, if he lives in a zone with several of them), the prompting would help him to understand the lack of danger in these situations, along with more distractions in these situations.

Currently we are developing these ideas by means of two smartwatches based on Android Wear OS, targeting a full-functional version and some user experiments that cover several situations that might provoke stress or uneasiness, so we can tell whether smartwatches can be applied ubiquitously to this learning process, as the discussed theory in this paper proposes.

6 CONCLUSIONS

Smartwatches are devices with great potential in the fields of Assistive Technologies and Affective Computing. They contain a wide –and growing- set of sensors, constantly in touch with the inward and outward state of the user. This implicit interaction produces data that can be used to assist the user in terms of new software possibilities. These capabilities are particularly helpful in the assistance of emotional self-regulation, which is a problematic issue for people with ASD. The most effective techniques to achieve an acceptable skill of emotional self-regulation in these individuals are stated by several authors involving assistive technology and pedagogy, and they include timers, distractors and prompting. These exercises and methods are feasible to be implemented in a smartwatch, as well as the affect detection, necessary to trigger the assistance. Affective computing analysis can be integrated in the sensing process of the smartwatch, and interactive assistance can be modelled and performed through the device's screen. Taking into account these ideas, we map the needs of these individuals in terms of self-regulation to the technological possibilities of these devices, proposing a system that would be able to help ASD to improve their emotional self-management by means of a well-known, widespread device, at the same time it is being popularized in society and normalized its use between mainstream users.

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