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A framework of technology-supported emotion measurement

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Abstract Emotion measurement is a vital aspect for new product development and product improvements (see e.g. P. Desmet & Schifferstein, 2012). Nowadays, new technological devices, data mining, and social media offer many opportunities to invigorate design research. This paper tries to combine both aspects by exploring the question, how new technologies can be utilized for emotion-focused design research. The range of applicable technologies spans from eye-tracking, to EEG measuring, to semi-automated facial expression recognition in photographs or texts based on data mining technologies or crowdsourcing, etc. Furthermore, many traditional technologies for emotion tracking are becoming smaller and mobile, which allows also in-field research (e.g. mobile EEG headsets). Triangulating different data sources might result in new insights and improve user research significantly. This paper provides an overview of related literature indicating the current state of emotion measurement in the design field, and presents a framework that outlines possible new approaches utilizing new technologies. Thus, this work might contribute as a source of inspiration for other researchers to develop new research approaches for technology-supported emotion measurement.

Keywords *Research methodologies and methods, New technologies, User research, Emotion measurement, Science theory*

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Introduction

The possibility to measure people's emotions can be useful for design research in two ways: The emotions people experience when interacting with a product can provide valuable insights about problems, flaws, and difficulties, but also pleasures and enjoyments that this particular product triggers. In so-called usability tests, researchers can investigate these emotional reactions and hence improve the product. This sort of emotion research is mainly conducted by marketing or user experience (UX) experts and usually happens in laboratory situations to exclude other possible influences on the emotional responses. On the other hand, context-related emotions measured in a realistic environment can provide valuable insights about users' tacit feelings, wishes, needs, and concerns, and hence result in ideas for new product development and innovations (P. Desmet & Schifferstein, 2012).

Although both approaches are important and reasonable for design research, the context-related emotion measurement seems to be of more relevance for design research, because it produces more authentic data, which is gathered directly in the field and in the situation, rather than in the laboratory or having to be recalled later-on through a questionnaire. Moreover, this context-related research might result in new design insights, which open up new product or service design opportunities.

However, our literature search reveals that design research on context-related emotions is still in its beginnings, which can be partly explained by the relatively complex and obtrusive equipment that used to be necessary for emotional measurement. However, nowadays new technological advancements resulted in devices that are becoming more mobile, wearable, unobtrusive, and affordable, which allows also for ethnographic studies in the field, to gain real-time insights on people's emotions while they are actually in that particular situation. Moreover, such technological advancements also lead to emerging societal phenomena, such as life-logging and fitness-tracking. These phenomena, along with the ubiquitous presence of smartphones and the rise of social media, offer new opportunities for design research, and emotion research in particular.

This survey paper presents a literature-based overview of the current state of research about technology-supported emotion measurement. The main contribution of this paper is a framework that categorizes different possible approaches and types of emotion measurement. This framework will hopefully inspire other researchers within the Design & Emotion community to utilize such technologies for their own research and might help to identify the right technology for their own research projects.

Related work

Our literature search focused on studies about technology-based emotion measurement. We limited the search criteria to a) the top 14 design journals (based on Gemser, de Bont, Hekkert, & Friedman, 2012), b) relevant journals from sociology, psychology, medicine, and computer science (based on an impact factor greater than 1), and c) papers published in the previous Design & Emotion conferences. The searched databases were Web of Science and Scopus, using the following search terms: emotion, cognition, behaviour, neuromarketing, neuroscience, emotion measurement, and psychophysiological measurement. In addition, reference lists of review articles were manually searched for further literature on the topic (backward and forward citation analysis).

These searches resulted in a total of 72 papers identified as relevant for our review. For inclusion in the review, papers had to deal with measuring emotions using neuro-physiological, observational, self-report or physiological methods. We used matrices to summarize the results and clustered them into thematic groups.

A detailed literature review of these 72 papers would exceed the scope and word limit of this short paper, which is why we summarize only the main findings here.

Eight papers can be categorized as survey papers, which provided overviews of emotion research in different areas and with different contexts, for example: Poels and Dewitte (2006) provide an overview of methods for emotion research in the advertising field over the past 20 years. They distinguish between automated (unconscious) “low-order” emotions (e.g. pleasure) and cognitive (conscious) “high-order” emotions (such as the fear to loose one’s job). Their findings indicate that most studies on emotion research in this area were conducted in unnatural laboratory situations, with the goal to test existing products or marketing campaigns. Mauss and Robinson (2009) present an overview of emotion research. They distinguish between 1) self-report measures, 2) autonomous measures (reactions of the autonomic nervous system, such as sweat or blood pressure), 3) startle response magnitude measures (reflexes like muscle tensing or eye blinks), 4) brain states measures (EEG or Neuroimaging/fMRI), and 5) behaviour (vocal, facial and whole body behaviour). Kanjo, Al-Husain, & Chamberlain (2015) present a state-of-the-art overview of currently available emotion monitoring tools. Lopatovska and Arapakis (2011) review literature on the theories of emotions, methods for studying emotions, and their role in human information behavior, but without a specific focus on technologies. Rebelo, Noriega, Duarte, & Soares (2012) present an overview of emotion measurement tools and techniques. Based on their findings that most studies were conducted in laboratory settings they propose the use of Virtual Reality (VR) and Virtual Environments (VE) to substitute real in-field research. Desmet (2015) discusses the phenomenon of mood in various dimensions. For example, he presents an overview of several innovative technologies to assess mood, as well as the influence of technology itself on people’s mood. Wrigley, Gomez, & Popovic (2010) present an overview of methods and basic technologies to measure emotions in qualitative research. They distinguish between observation techniques, think-aloud protocols, questionnaires, diaries, interviews, and they discuss advantages and challenges for each category.

From the analyzed 72 papers, 12 were from the field of Medicine (Psychiatry, Neurology, Neuroscience), 18 from Psychology and/or Marketing, and 34 from the fields of Computer Science, Electrical Engineering, and HCI. Only 8 papers were directly related to design, new product development, and design engineering. The used methods for emotion measurement can be differentiated into three categories: 21 papers mainly used neuro-physiological methods (body responses such as brain activity, skin conductance, pulse rate, etc.), 19 papers used observational techniques (facial expressions, gestures, etc.), and 11 papers used self-reporting methods (questionnaires, interviews, diaries, etc.). The remaining 13 papers used mixed method approaches (e.g. physiological measures that were additionally validated by self-reports). Only four studies were conducted in real-life environments; a fifth one used a Virtual Reality environment to simulate a real environment. The remainder of the studies were conducted in laboratory settings. Only one paper (Behoora & Tucker, 2015) addresses data mining as a possible approach for emotion measurement combined with commercially available motion sensors (Kinect).

Thus, our literature research shows that technological opportunities for emotion research are not much implemented in design research and design projects, but are rather limited to the fields of HCI, Computer Science, Medicine, Psychology, and Marketing. Almost all of the studies were conducted in laboratory settings, which demonstrates a significant prospective potential for ethnographic and in-field design research.

Framework of technology-based emotion measurement

Desmet and Schifferstein (2012) distinguish between four types of emotion measurement, based on: 1) behavioral actions (such as type and pace of movement), 2) expressive reactions (such as facial or vocal expressions, tone of voice, postures, and

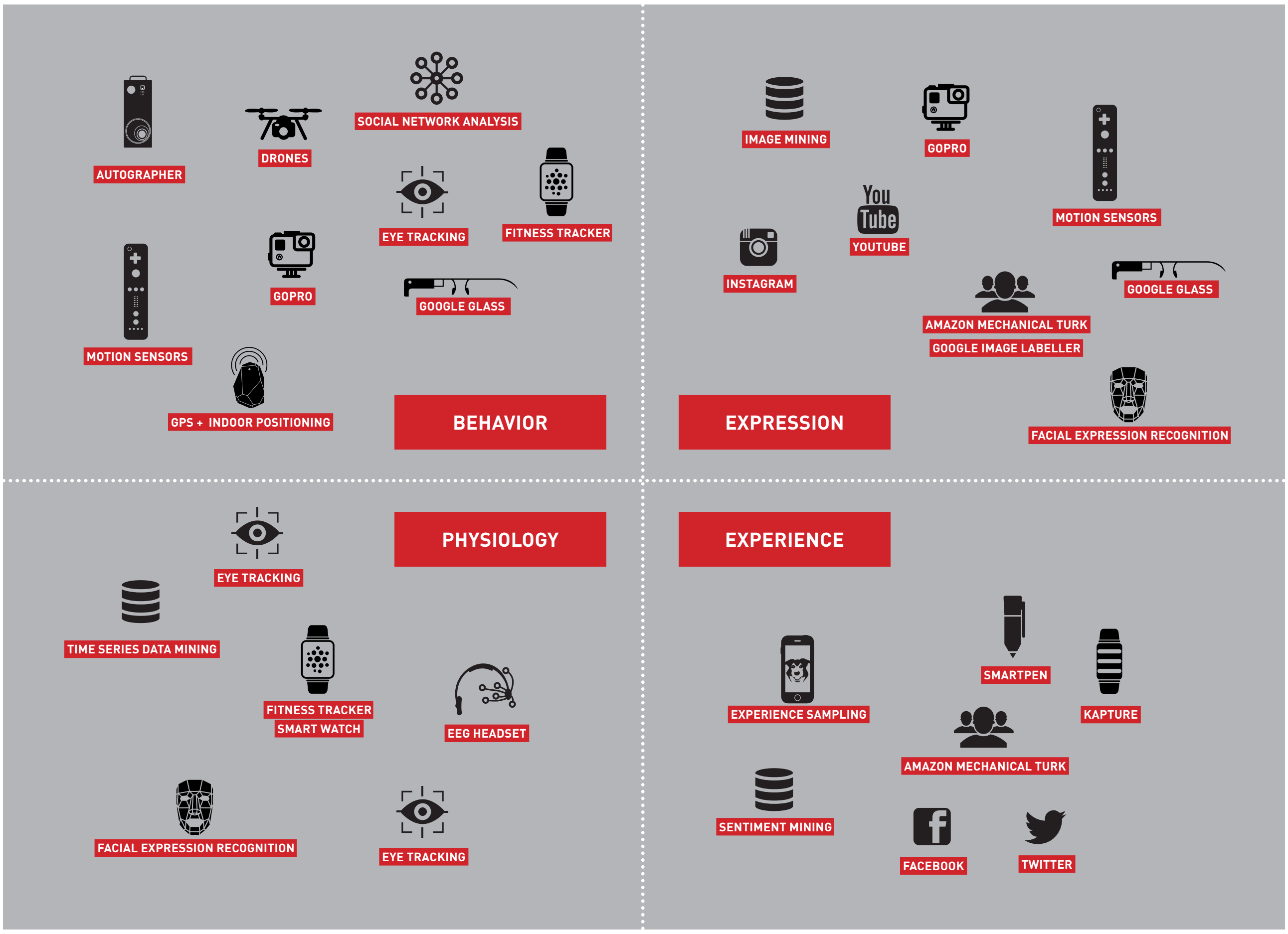

Figure 1. Framework of technologies according to the four categories of emotional measurement.

gestures), 3) physiological reactions (such as heart rate, pulse, pupil dilatation, or sweating), and 4) subjective experiences and (verbalized) feelings. They give a brief overview of research methods in general emotion research.

Thoring, Mueller, and Badke-Schaub (2015) present an overview of technological devices, software tools, social media, and data mining technologies, and suggest opportunities how these could be utilized to invigorate design research in terms of data collection and data analysis, but they do not focus on emotion research in particular.

We use the two above mentioned frameworks and classifications to develop these further into a new framework, which is focusing on the technological opportunities for *emotion* research. Our definition of the term technology is not limited to hard- and software, but includes also concepts and phenomena that are based on a technological infrastructure, such as social media or crowdsourcing. We also present technologies that are not manly focusing on emotion research, because the triangulation of different data sources facilitates the interpretation of emotional responses. For example, measuring people's emotions with a mobile EEG scanner in relation to their various locations (measured through GPS data) might indicate the influence of the environment on that person's wellbeing.

We aligned different technologies according to the four types of emotion measurement: 1) behavior, 2) expression, 3) physiology, and 4) experience. In the following section we describe the different technologies briefly, per category, and summarize the results in a table overview (Table 1). Figure 1 shows the resulting framework of technology-based emotion measurement.

Technologies for behavior measurement

Behavior means the more or less conscious activity of a person as a reaction to an emotion, for example, the behavior of *running* as a reaction to *fear* (P. Desmet & Schifferstein, 2012). Such behavior can mainly be measured through technologies that observe people's movements either visually (video cameras, drones), or data-driven (GPS, indoor positioning). Specific gestures can also be interpreted as conscious behavior (e.g. hitting someone or something), which can be measured through motion sensors (Kinect, Wii). Cameras that automatically take pictures based on sensor changes, such as environmental temperature, light, movement, etc. (e.g. Autographer) can also provide insights about people's behavior in relation to their respective context and environment. Fitness trackers capture metadata about the wearer, such as step count, running, swimming, etc. and hence can reveal insights on that person's behavior. Social media can partly be utilized to extract insights about people's emotion-related behavior, for example by analyzing published videos in YouTube. Social Network Analysis can be used to detect relationships (and hence dependencies) between people, which can also be interpreted in terms of emotional behavior. Eye Tracking can reveal external causes for specific actions (either in the environment or when interacting with a product or website).

Technologies for expression measurement

Expression means the mainly unconscious reactions to emotions that can be inferred from facial expressions, tone and volume of voice, and gestures. These can best be measured through tools that deliver photo, video, or audio data. On the one hand, these can be captured through recording devices (cameras, voice recorders), or through self-published data in social media (e.g. YouTube movies). And on the other hand, there are tools available that facilitate the interpretation process (e.g. data mining, crowdsourcing, etc.). Motion sensors, such as Nintendo Wii or Microsoft Kinect, can be used to measure bodily gestures. Not only people in real-time, but also people's pictures in social media channels, such as Instagram or YouTube, can be analyzed for facial and bodily expressions.

Technologies for physiology measurement

Physiology measurement usually requires sophisticated sensor-based equipment. Nowadays, such equipment has become affordable, unobtrusive, wireless, and wearable, which allows for in-field and

Table 1. Overview of technologies aligned with type of emotional measurement.

Technology	**Examples / Link**	**Behavior**	**Expression**	**Physiology**	**Experience**
Fitness Tracker	www.fitbit.com www.nikeplus.com withings.com	+		+	
Experience Sampling	www.pacoapp.com				+
Smartpen	www.livescribe.com				+
Kapture	www.kaptureaudio.com				+
Autographer	www.autographer.com	+			
GoPro	www.gopro.com	+	+		
Drones	www.parrot.com www.3dr.com	+			
Google Glass	www.google.com/glass	+	+		
Eye Tracking (mobile/stationary)	www.tobii.com www.eyetracking-glasses.com www.smivision.com	+		+	
Facial Expression Recognition	www.emotient.com www.affectiva.com www.nviso.ch		+	+	
EEG Measurement	www.emotiv.com			+	
Skin Conductor	www.biopac.com			+	
Motion Sensors	www.xbox.com (Kinect) www.nintendo.de (Wii)	+	+		
GPS / Indoor Positioning	www.indoo.rs www.infsoft.de www.indooratlas.com www.redpin.org www.goindoor.co	+			
Facebook	www.facebook.com		(Photo)		+
Twitter	www.twitter.com		(Photo)		+
Instagram	www.instagram.com		+		
Youtube	www.youtube.com	(+)	+		(+)
Image Data Mining	www.rapidminer.com www.knime.org www.projectoxford.ai		+		
EEG Signal Processing	sccn.ucsd.edu/eeglab			+	
Sentiment Mining	www.sentiment140.com				+
Social Network Analysis	gephi.org	+			
Amazon Mechanical Turk	www.mturk.com		+		+
QDA Analysis Software	www.dedoose.com www.maxqda.com www.atlasti.com www.qsrinternational.com		+		+
Data Management Software	www.imotions.com	+	+	+	+

remote research. EEG scanners and related software can turn brainwaves into meaningful data. Life-logging movements result in millions of people tracking their own bodily functions, such as heart rate, pulse, temperature, etc. Infrared cameras can indicate skin temperature. And certain eye-tracking glasses can measure pupil dilatation.

Technologies for experience measurement
Experiences or "feelings" are usually verbalized and self-reported by the participants. Specific Experience Sampling applications (e.g. PACO) allow to send questionnaires to people via their smartphones. Thus, the emotions can be measured in real-time, while people are in the respective situation. Written or spoken texts (e.g. from Twitter feeds or Facebook pages) can be analyzed for emotional indications, either manually, or through data mining (sentiment mining) technologies, or by utilizing a crowdsourcing approach. Sophisticated audio recording devices also facilitate this process, for example by providing time buffers so that no important information will get lost (Kapture), or automated matching of written notes to audio timestamps (Smartpen).

Figure 1 outlines the categorization of different technologies regarding their capabilities to measure emotions according to the four types of emotion measurement.

Discussion
The presented framework of technology-supported emotion measurement (Figure 1) is considered a first attempt to classify currently available technologies according to their potential for facilitating emotion research in the design field. The classification is intended to help researchers identify the appropriate technology for their respective research question. However, the borders between the suggested four categories are not always sharp. For example, a measured smile can be either an unconscious expression, or a conscious behavior, which might not be differentiated by the used technology. And similarly, a specific technology, like a video camera, can be used to measure different types of emotions (behavior, expression, or even experience). Thus, the suggested framework is only a guideline and can be adapted as the researcher sees fit.

One of the main contributions of utilizing several technologies is the possibility for triangulation of different data sources. Complementing the data from one source (e.g. emotions measured through a mobile EEG headset) with metadata from a different source (e.g. GPS data from a smartphone) can further improve emotion measurement and help the researcher understand reasons for specific emotions.

Technologies can also facilitate the interpretation of emotion-related data. Data management software, such as iMotions (www.imotions.com), provide interfaces for different tools and lets the researcher combine and evaluate the data in one data hub. Although the presented technologies provide valuable opportunities to facilitate emotion research, the data interpretation through a human researcher remains crucial. However, interpreting emotion-related data is complex and not an easy task. Many of the tools and technologies presented in this paper need lots of preparation, training of the researcher, and intense calibration of the data. These tasks are, however, not the focus of this paper.

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