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Technological Advancements in Affective Gaming: A Historical Survey

Thomas Christy & Ludmila I. Kuncheva
School of Computer Science
Bangor University, LL57 1UT
thomas@thomaschristy.co.uk & l.i.kuncheva@bangor.ac.uk

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***Abstract*—Affective gaming (AG) is a cross-disciplinary area drawing upon psychology, physiology, electronic engineering and computer science, among others. This paper presents a historical overview of affective gaming, bringing together psychophysiological system developments, a time-line of video game graphical advancements and industry trends, thereby offering an entry point into affective gaming research. It is proposed that video games may soon reach a peak in perceivable graphical improvements. This opens up the door for innovative game enhancement strategies, such as emotion-driven interactions between the player and the gaming environment.**

***Index Terms*—Affective gaming, emotion, psychophysiology, physiology, input devices, computer graphics.**

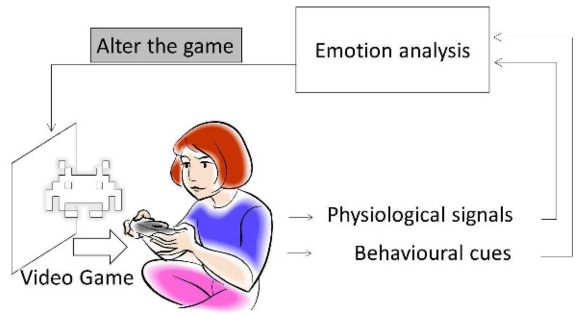

Fig. 1. The real-time affective gaming (AG) loop.

I. Introduction

Video games have become the leading global entertainment industry, overtaking the movie industry on sales and revenue statistics [21]. Provoking profound emotions is deemed to be of vital importance in video game design [63].

Emotion is a crucial component of human interactions, problem solving [62] and entertainment [67]. The role of emotion in human interactions was discovered nearly two millennia ago and has been documented scientifically for well over a century [16], [36]. Affective Gaming (AG) is a relatively new field of research that exploits human emotion for the enhancement of player's experience during video game play.

Conventionally, the video game attempts to elicit emotion by its story lines, characters and video effects. However, there is no precise means to assess if the expected emotion is being experienced. It is even more important to be able to detect a change in the player's emotional state as a result of the game play. There is no provision for assessing such changes within the mainstream gaming practices. AG seeks to remedy this through the use of bespoke psychophysiological input sensors that read and interpret the changes in the player's emotion in real time.

Technically, an AG system acquires emotion-related signals from a set of sensory input modalities, analyses the signals, and provides data to the game engine [35]. The game is subsequently altered taking into account the type and strength of the measured emotion. Figure 1 shows a diagram of a real-time AG loop.

An AG system is expected to stream real-time affect data, be robust, and most importantly be easy to use. The main criticism to experimental research in affective computing thus far has been that it is done in a heavily controlled environment, which limits its chances for practical applications. Affective gaming has to move away from the confides of a laboratory and be deployed in a normal environment [13], [22], [68].

A particular challenge when trying to design a single all encompassing taxonomy of the field comes from the fact that it is comprised of several broad disciplines: physiology, psychology, electronic engineering and computer science. It should also be mentioned that results of research into AG conducted in commercial settings are rarely published.

In this study, we survey the historical technological developments and research efforts that are attempting to bring practical AG to reality, including academic and commercial contributions to the field as a whole. The rest of the paper is organised as follows. Section II summarises the difficulties in measuring and classifying emotion. We argue that affective gaming does not rely exclusively on the accuracy of emotion recognition. Any change of the emotional state of the player that is detected and reflected in the game can contribute to the pleasurable experience. Behavioural and physiological modalities for affective data acquisition are presented in Section III. We put the emphasis on the wealth of physiological modalities as the preferred input for AG. Section IV reviews studies that use physiological modalities in AG. Section V contains a historical perspective of the development of two of AG-related technologies: console platforms and video graphics. Finally, Section VI concludes the paper by listing the tasks and challenges set before modern AG.

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II. EMOTION AND AFFECTIVE GAMING

Can we recognise and classify emotion? Emotion is notoriously difficult to quantify, measure or put into clear-cut categories [53]. The prevailing evidence from psychology and psychophysiology is that emotions do not naturally form distinct clusters in data spaces extracted from representational cues, but are rather facets of a continuum. The relationship between the physiological measurements and the emotional states they are supposed to identify is complex and ambivalent [22]. The list of difficulties faced by researchers in automatic emotion classification has been widely discussed in the literature [10], [22], [41]. It includes but is not limited to

- We don't know what to measure.
- Emotions experienced by the subject may not correspond well to the stimuli.
- Different subjects may react with different emotions to the same stimulus.
- The presentation of emotion will differ between subjects and also at different time moments for the same subject.
- Emotion is not clear-cut and measurable, therefore there cannot be "ground truth" data.
- There is no agreed protocol for stimulating and measuring emotion.
- There is no agreed protocol for testing emotion classification systems.
- The classes of emotions are intricately related to one another.

A vast diversity of results have been reported as the outcome of emotion recognition experiments [11], [47], [65]. Owing to the difficulties listed above, classification accuracy in identifying categorical emotions was found to vary considerably, spanning a range between 51% and 92% [61]. Along with the excitement, the literature contains cautious or even sceptical views [55]. It may be that endeavours to label emotion accurately across different subjects might be an impossible quest using today's technologies [13], [66], [79]. Employing interdisciplinary research effort has been strongly advocated [41], [68].

Video games are designed to entertain, and thus allow a margin of error in recognising a specific emotion. The ultimate aim of an affective game is to make the player aware that the game recognises and interacts with their emotional state throughout the course of the game. Occasional misclassifications will not have a crucial impact to the player's enjoyment or satisfaction.

III. AFFECT ACQUISITION MODALITIES

A variety of input modalities are used to gather affective cues from the player. Figure 2 shows a diagram of the major types of modalities in affective computing.

A. Behavioural modalities

Behavioural affect detection is an extremely instinctive approach and is often used in video game research and development [24]. When engaged in a dialogue with a real person, it is normal to express facial emotions and emotive body gestures, or body language, as a response to the message being communicated. There are at least 100 documented facial expressions to concisely describe the emotion or mood of a person [60]. One need only consider research based on Autism and Asperger Syndrome to recognise the need for visual emotion interaction in social and professional environments. However, when faced with a video game display, such outward expressions of emotion are not expected from the active player. Spontaneous emotions may be displayed but the player will not be compelled to react in the same way as in human to human interaction. Emotion detection using cameras has been criticised for being inefficient in that it requires a lot of processing power to sift through video streams [23]. In addition behavioural affect detection presents cultural, gender, and age differences, making behavioural analysis difficult [73].

Voice modulation is perceived as one of the important behavioural modalities for detecting emotion in video games. However, it has been observed that some players feel uncomfortable talking to a video game [38].

B. Physiological modalities

The two types of physiological modalities in Fig. 2 come from the central nervous system and peripheral nervous system, respectively.

1) Central nervous system signals: It is unlikely that AG will benefit from functional Magnetic Resonance Imaging (fMRI) or functional Near Infra-red Spectroscopy (fNIRS) in the near future. Electroencephalography (EEG), however, is an important technology in modern neuroscience. Compared to fMRI, EEG has a worse spatial resolution but a much better temporal resolution [27]. The electrical potentials related to emotion can be projected widely in an intricate pattern across the scalp, and can therefore overlap with potentials evoked by other activities. EEG has been applied for classification of emotions in various contexts [8], [43], [82], [88] and is progressively becoming a portable lightweight technology. Several commercially available EEG sets can be considered for affective gaming: OCZ Nia[1], Neurosky Mindset[2], Neurosky Mindwave[3], Emotiv EPOC[4]. It is often assumed that the projections of positive and negative emotions in the left and right frontal lobes of the brain make these two emotions distinguishable by EEG. Practice has shown that the granularity of the information collected from these regions through EEG may be insufficient for detecting more complex emotions [8].

2) Peripheral nervous system signals: Psychophysiology (PPG) is the combination of innate human physiological responses in relation to emotional changes. The correlation between emotion and physiology is well founded [67], [93],

[1]http://www.ocztechnology.com/nia-game-controller.html
[2]http://store.neurosky.com/products/mindset
[3]http://neurosky.com/Products/MindWave.aspx
[4]http://emotiv.com

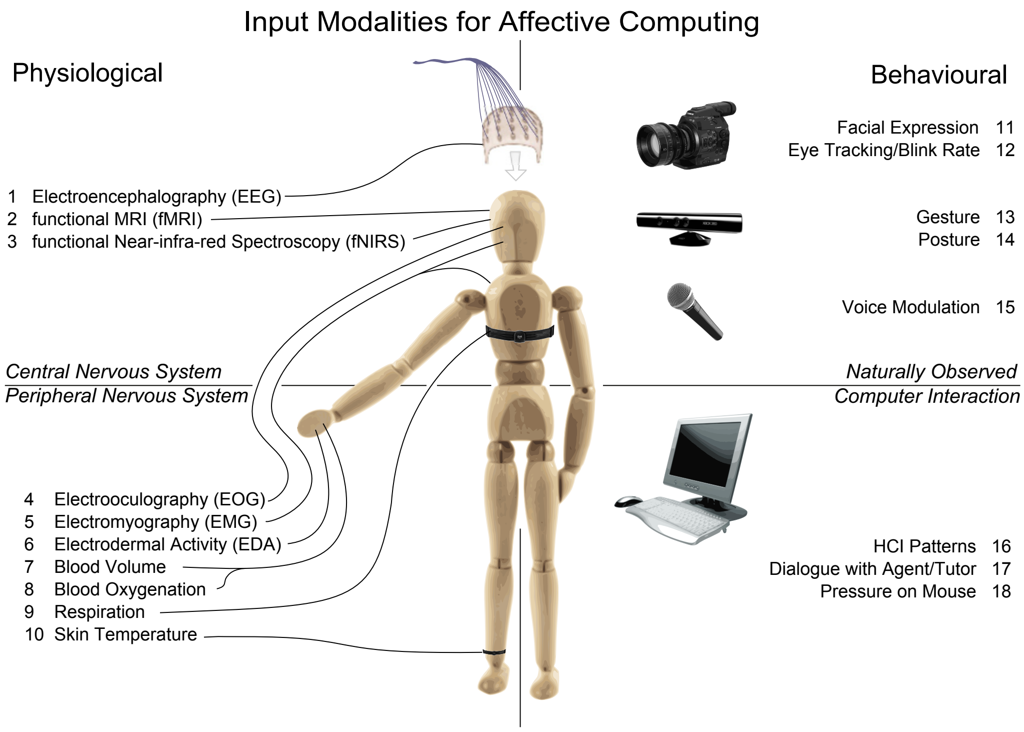

Fig. 2. Main input modalities in affective computing.

[96], [98], and has been thoroughly explored throughout psychological studies [85]. Some of the most commonly used physiological inputs are listed below.

- Electrodermal Activity (EDA) Fig. 2 (#6), also referred to as Galvanic Skin Response (GSR), Skin Conductance Response (SCR) or Psycho Galvanic Reflex (PGR), measures the variance in electrical conductivity through the surface of the skin. EDA readings are effected through the sympathetic nervous system, making it a good indicator of stress and anxiety. EDA suffers from latency, with a delay of approximately one second for a response to be evoked, followed by approximately three seconds for the effect to dissipate. It is among the most basic and low cost physiological modalities available, and is widely used in physiological emotion recognition, including video games [1], [17]. EDA is commonly read between two fingers on either hand, although is not limited to this area of the body [7]. EDA bodes well for adaptation into video-game controllers.
- Blood volume (Plethysmograph) Fig. 2 (#7-8) is the variation in heart rate, and is a good indicator of stress and anxiety. As a sign of its pervasive popularity, heart rate input became the pivotal component of a television game-show, called The Chair [83], [97]. In this show, contestants answered general knowledge questions and were expected to maintain a calm heart rate to win money. The sensing devices suitable for affective gaming come in the form of a clip, which uses optical technology to measure simultaneously heart rate and blood oxygenation [81].
- Respiration Fig. 2 (#9) Emotion can influence breathing rates [6], [34]. The measuring device could be a respiration belt or sensors embedded into clothing. For example, a force feedback vest with embedded breathing rate sensors already features in the avid pro-gamers' arsenal[5]. However, mainstream applications could be hindered by utilising garments to acquire data.
- Temperature Fig. 2 (#10) Body temperature is affected by emotion, specifically joy, anger and sadness [57], [58], and has been used for emotion recognition in video games [7], [90]. Temperature sensors fall into two general types: contact and non-contact. Both types are sensitive to movement, which can introduce inaccuracies in the data collected. Movement is an important issue in the process of an active game play; hence, the positions of the sensors have to be chosen carefully.
- Electromyography (EMG) Fig.2 (#5) measures the electrical activity produced by muscle movement. Activity patterns in muscles such as orbicularis oculi (eye) and zygomaticus major (smile) are often used for affect detection. However across the populous (including nationalities), people differ widely in terms of how they visually display emotion [66], [79]. Besides, EMG sensors may need to be placed at various body locations, which may compromise the player's comfort.

[5]http://en.wikipedia.org/wiki/3rd_Space_Vest

3) Sensors and devices: Table I shows the early patents, designed to detect PPG signals. These systems formed the bedrock of modern PPG technologies.

Sensors and devices for AG can be roughly grouped into thee types.

- *Standard sensors.* Hardware used in AG research has been borrowed from psychological research or commercial relaxation systems, such as the BioPac[6], IOM[7], etc. Commercial hardware for physiological acquisition is considered expensive and awkward to use [42]. For example, standard sensors give better results when they are held still. However, the devices can regraded as a nuisance, being attached to the player's fingers, ear, etc. This makes them unsuitable for active video game play.
- *Wearable sensors.* Wearable sensors implies "body worn", making long term physical contact with the body [66]. In 1997, Picard and Healey [66] introduced an affective wearable system that stored physiological data from Respiration, EDA, Blood Volume Pulse (BVP) and Electromyography (EMG), for later analysis. Picard's work would later become a beacon for affective computing research [7], [32], [45]. Sensors can be embedded into clothing, glasses, gloves, shoes, hats, helmets, jewellery, etc., making this an attractive avenue for AG.
- *Seamless contact sensors and devices.* The sensors in this group come into contact with the body for a limited time, for example through traditional interfaces such as mouse and keyboard. To be considered seamless, the user should not be aware of any interaction with the sensor. For example, EDA could be measured from electrodes embedded into the hand-grip of a console controller or on a mouse. A comprehensive study on devices of this type is provided by Reynolds [76], examples of which are
  - Sentograph – measures and visualises user's touch along a two-dimensional space
  - Touch Phone, touch mouse – measures grip strength
  - Sentic Mouse – senses directional input
  - Sqeekee – click pressure
  - IBM Emotion Mouse – gathers temperature, EDA and somatic movement

Even though the core technology for physiological signal capture is mature and well proven, hardware for affective gaming is still not widely available.

Affective video game input must be comfortable and intuitive to use. If a sensor impedes the enjoyment and competitive edge that video game players expect, it is less likely to be adopted. AG would benefit best from seamless contact sensors. It needs to move from expensive laboratory equipment to reliable and affordable consumer devices [13], [22], [68]. Affective sensors can be incorporated into already adopted video game controllers [2], [7], [13], [50]. Valve[8] and Sony [9] have both implied that EDA and HR could soon be incorporated into standard controllers. Producing bespoke low cost hardware for AG is feasible [7], [13], for example, by using recently released rapid prototyping platforms[10] and 3D printing. It is proposed that this type of rapid prototyping is expected to shape the newly forming landscape of AG.

IV. Using physiological modalities in AG

By 2001, academic research into AG took off [5], [69], [76]. Table II lists the research contributions made within the field of AG, including the physiological sensors and video games used. Many sensors and sensor permutations have been tested, along with several game genres.

Tables III and IV detail game variations in response to changes in physiological data, published by Dekker & Champion [17].

TABLE III
DEKKER & CHAMPION VISUAL EFFECTS AND PHYSIOLOGICAL THRESHOLD CONDITIONS; USED IN THE MODIFIED VIDEO GAME *Half Life 2*.

Emotion	**Game Change**	**Criteria***
Comatose	Sound (heart beat), new enemy or boss	HR + EDA < 0.8 or < 0.4 below avg
Bored	Black & White	HR $< 0.8-$ avg
Calm	Shader (White filter)	HR $> \times 2+$ avg
Worried	Shader (Red filter)	HR $>$ avg $\times 2$
Panic	Shader (Bright red filter) $+$ FOV $= 130$	HR $> \times 3$ above avg
Berserk	Shader (Red screen)	HR $> \times 3.5$ above avg

*Abbreviated terms: Heart Rate (HR), Electrodermal Activity (EDA). Shaders refer to graphical overlay alterations

TABLE IV
DEKKER & CHAMPION CONDITIONS APPLIED TO PSYCHOPHYSIOLOGICAL THRESHOLD CRITERIA IN THE VIDEO GAME *Half Life 2*.

Condition	**Criteria***
Stealth	EDA $0.5 \gg 0.7$
Invisible	HR < 0.5 and EDA < 0.5
Weapon damage	HR & EDA $\times 40$
Speed	HR
Sound volume	EDA$^2 \times 0.8$
Bullet time (Slow motion)	EDA $>$ cal $\times 3$
Shake	HR > 3.8 above avg

*Abbreviated terms: Heart Rate (HR), Electrodermal Activity (EDA).

In this example, visual and audible effects are introduced to the game when particular electrodermal activity (EDA)

[6]http://www.biopac.com/psychophysiology
[7]http://www.wilddivine.com/iom-feedback-hardware/iom-active-feedback-hardware/
[8]http://www.valvesoftware.com/
[9]http://www.sonyentertainmentnetwork.com/
[10]https://www.ghielectronics.com/, http://www.netmf.com/

TABLE I
EARLY DAY DEVICES PRE-DATING AFFECTIVE GAMING TECHNOLOGIES.

[h] Year	Author	Acquired a patent for:
1928	Schrawzkopf & Wodtke [80]	An electrocardiograph.
1928	Hathaway [30]	A circuit design of an EDA device *Apparatus for measuring psychogalvanic responses*.
1943	Raesler et al. [72]	*Psychogalvanometer*; a fluid-aided EDA device.
1944	Milne et al. [56]	*Psychometer*; an easy to use device.
1953	Koller [44]	*Cardio-Pneumo-Electrodermograph*; an advance upon earlier machines.
1953	Holzer & Marko [33]	*Arrangement for recording variations in the electrical resistance in the human body*.
1954	Mathison [51]	*Electropsychometer or Bioelectronic instrument (v1)*; a sponge-aided EDA device.
1955	Golseth & LeGrand [29]	*Electronic Diagnostic Instruments*; a portable EDA device.
1956	Mathison [52]	Second instalment of the *Electropsychometer or Bioelectronic instrument (v2)*; a low cost EDA device.
1958	Douglas [18]	*Psychogalvanometer*; EDA plus phonographic recorder.
1964	Ryan [77]	An improved Novelty (Toy) lie detector.
1965	Takagi [87]	An EDA device.
1967	Weidinger et al. [95]	A portable heart monitoring device.
1969	Tygart [91]	*System for FM transmission of cardiological data over telephone lines*.
1972	Burlyl R. Payne [64]	*Audible Psychogalvonometer* (AP); smaller and low-cost EDA device.

and heart rate (HR) signal threshold combinations are met. Tijs et al. [89] use 7 physiological parameters to guide the speed of Pacman (Table V).

TABLE V
Tijs et al. [89]: EFFECTS OF GAME SPEED OF *Pacman*, BASED ON PSYCHOPHYSIOLOGICAL DATA INPUT

Physiological features*	**condition identified (action)**
Mean SCL	slow (speed up)
Number of SCR	slow (speed up)
Mean HR	slow (speed up)
Mean respitory	slow (speed up)
CORR	fast (slow down)
ZYG	fast (slow down)
Key pressure	slow (speed up) & fast (slow down) & normal (nothing)

*Abbreviated terms: Heart Rate (HR), Skin Conductance Level (SCL), Skin Conductance Response (SCR), corrugator supercilii muscle, (CORR), zygomaticus major muscle (ZYG).

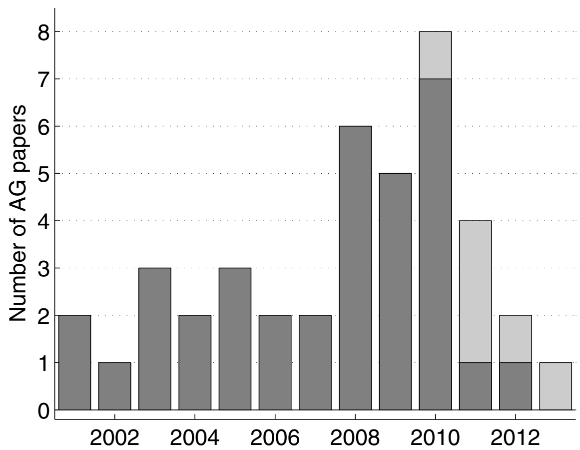

Fig. 3. Time-line view of AG research publications. Publications addressing bespoke psychophysiological hardware are shown in a lighter colour.

To illustrate the developmental potential of the physiological input modalities, we collated the accessible publications explicitly devoted to affective gaming, and noted which ones address the engineering of bespoke psychophysiological hardware. Figure 3 gives a bar chart of the distribution of the publications over the years. The papers whose main focus are psychophysiological sensors and devices are marked in a lighter colour.

Even though the publication numbers are not high, an emerging trend could be identified. Affective input devices are beginning to make their way to the centre stage of affective gaming.

Judging by the achievements and the potential of using physiological modalities in AG, the future is likely to see smarter and more sophisticated implementations on progressively smaller, more robust, reliable and noise-free devices.

V. TECHNOLOGIES FOR AG

A. Generations of console platforms

Historically, the introduction of the electronic computer heralded the beginning of a new era [14]. No sooner had the computer become affordable to the masses; video games became an arising staple of popular entertainment [70]. Interactivity plays a pivotal role of video games. Typically, video games allow the player to interact with the virtual environment using joysticks, joy-pads, keyboards, mice, trackballs, cameras, touch-screens, etc. Video game consoles became a dominant symbol of the mainstream video game market. Several attempts have been made to introduce AG to commercial environments [3], [15], [25], [26], [94]. The companies involved manufactured the necessary hardware and software to foster the use of affect in video games. However, none of the systems were successful in the long term. Below we take a closer look at the developmental context and the possible reasons for the delayed progress.

Figure 4 shows a time-line representing the introduction and commercial duration of 8 video console generations. The thick black lines show the time span of each generation and the vertical dashed indicate the year of key commercial contributions.

The first video game console, called the Magnavox

TABLE II
AFFECTIVE GAMING MODALITIES AND THE CURRENT CONTRIBUTORS, LISTED IN ORDER OF YEAR. MODALITIES INDICATE WHICH COMBINATION OF PSYCHOPHYSIOLOGICAL OR BEHAVIOURAL AFFECT DETECTION SENSORS CONSIDERED AND GAME DETAILS WHICH GAMES AND GAME-GENRES USED.

Modalities & year published*	**Game**
EDA [5], 2001.	Racing Dragon
HR, EDA, EMG, video [79], 2002.	Puzzle
HR [28], 2003.	Action based
Game pad pressure [86], 2003.	Space Invaders
EMG [31], 2006.	Juiced (THQ)
EDA,EMG [4], 2005.	Cards (Skip Bo)
ECG, ICG, HR, HS, EDA, EMG temperature, questionnaire [73], 2005.	Pong
User control knobs [78], 2005.	Generic
HR, EDA [54], 2006.	Treasure Hunt (Source)
HR, EDA, facial EMG [74], 2006.	Monkey Ball 2
EDA, HR [17], 2007.	Half Life 2
EDA, ECG, HR [49], 2007.	NHL 2003
HR, EOG, EDA, EEG, respiration, temperature [12], 2008.	Tetris
Time, eye movement [37], 2008.	Half Life
Audio (vocal cues) [39], 2008.	Half Life Mod
EEG [71], 2008.	Break-Out (Arkanoid)
HR, EDA, facial EMG [75], 2008.	Monkey Ball 2 & James Bond 007
HR, EDA, respiration [89], 2008.	Pacman
EDA, HR [19], 2009.	Prey, Doom3 & Bioshock
EDA, HR, EMG, temperature [48], 2009.	Pong & anagrams
EDA, EMG [59], 2009.	Half Life 2 Mod
Control tilt, pressure [92], 2009.	Need 4 Speed
EDA, respiration [46], 2010.	Emoshooter (FPS)
EDA [90], 2010.	Racing
(Use) EDA, *(tried)* HR, eye movement, EEG, pupil dilation, EOG, posture, gesture, voice, face expression, respiration [2], 2011.	Left 4 Dead 2, Portal 2 & Alien Swarm
EDA, HR, pressure [7], 2011. temperature, gyroscope	Racing Car
EDA, HR, temperature [13], 2013.	Custom game

*Abbreviated terms: Heart Rate (HR), Heart Sound (HS), Electrodermal Activity (EDA), Electrooculography (EOG), Electroencephalography (EEG), Electromyography (EMG), First Person Shooter (FPS), Impedance Cardiogram (ICG).

Odyssey, was released in 1971, as shown in Fig. 4. In 1982 Atari planned to release an input device called the Mindlink, but the company collapsed prior to its release [94]. The Atari Mindlink was a head-mounted device that used Electromyography (EMG) to detect electrical changes in the player's forehead. The Mindlink was to be used as an input device in lieu of a standard joystick controller. The device was abandoned when Atari was redistributed in 1983 [94].

In 1984 CalmPrix was introduced with a psychophysiological system called CalmPute. CalmPrix was a car racing video game that used EDA signals to alter the speed of the racing car. It used a commercial EDA sensor called the Mantra Mouse or GSR2 [25] as an input device. The CalmPrix video game was meant to teach a relaxation technique, using an extremely primitive racing car game (even for the time). CalmPrix would have been pitted against games such as the highly successful *Mario Brothers* (1983)[11], *Return of the Jedi* and *Elite* (1984)[12]. Commercially, it didn't stand a chance.

Tokimeki memorial oshiete your heart was a provocative, alluring arcade game that was released in 1997. Unfortunately, the game was available only in Japan which limited its global success. Tokimeki memorial oshiete my heart was a curious cartoon dating game, far flung from the popular games of the day, such as *Herc's Adventure, Backyard Baseball* and *Claw*[13]. It encouraged players to express

[11] www.IMDb.com - Highest Rated Video Games Released In 1983
[12] www.IMDb.com - Highest Rated Video Games Released In 1984
[13] www.IMDb.com - Highest Rated Video Games Released In 1997

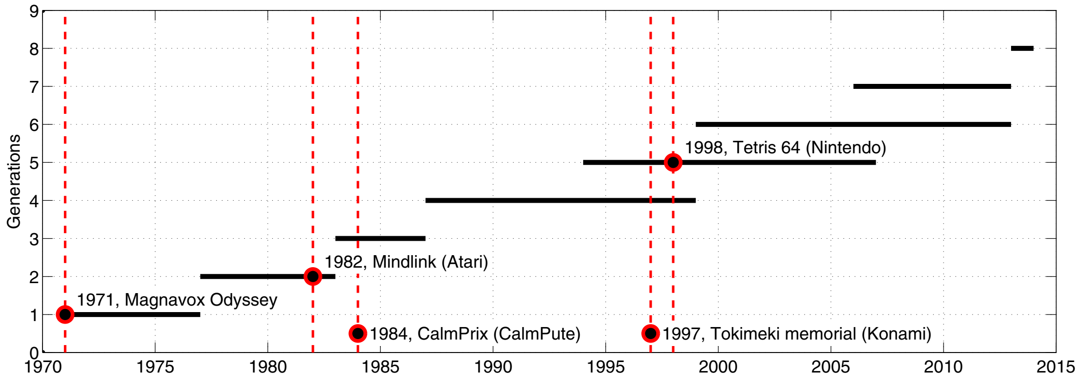

Fig. 4. Video game console time-line representing the introduction and commercial duration of each console generation, shown in thick black segments. Key commercial contributions are indicated with vertical dashed lines pinpointing the year of release. Given in brackets are the names of the relevant companies. CalmPrix and Tokmeki Memorial are plotted at the bottom of the figure because they were not console based.

affect towards cartoon characters (Manga art), which was measured by EDA and Heart Rate (HR).

Tetris 64 was released on the Nintento 64 in 1998. It used HR taken from a clip attached to the player's ear to control the speed of the falling shapes. The game allowed up to four players to compete on the same screen, making it possible to alter the outcome of the competition using emotional feedback. Unfortunately, the game concept was rather old. Although Tetris remains a popular relic, it was competing against games such as *Half Life, Crash Bandicoot, Sonic Adventures, etc.*[14]. In addition, it was reported that Nintendo was experiencing issues with its latest console. Among these were expensive cartridges, poor graphical rendering and a complex programming interface [20].

Other physiological devices have since been considered, such as the Wii Vitality. However, this device was not released due to speculation that it would not prove commercially successful [40].

B. Graphical advancements

Immersion is important for emotional experiences within video game environments [9], [37]. The illusion of immersion and interaction with surroundings, materials and substances in modern video games cannot be achieved without the giant steps in video graphic hardware and software. Graphic technology and video games evolved synchronously, from primitive monocohrome pixelated-blocks being controlled on a cathode ray tube (CRT) to advanced visually realistic, fully immersive, simulated environments, presented on ultra high definition (4K) organic light emitting diode (OLED) liquid crystal displays (LCD). Detailing advanced graphical techniques, such as particle systems, billboards, shadow-maps, etc., is beyond the scope of this paper. Here we are interested in the exponential technological growth in video graphics performance and its relationship with AG.

Companies such as Intel, Array Technologies Industry (ATI) and nVidia made vast efforts in the graphic rendering technology arena, through competitive video card releases. An advanced programming interface (API) called OpenGL[15] (Open Graphics Library) was introduced in 1992. It offered a single graphical programming interface across all popular technologies and platforms, thereby speeding up game development. Notably, nVidia released the Graphical Processing Unit (GPU) in 1999. Mega (1000^2) Texels (MT) are defined as the number of texture elements graphic hardware processors can manipulate per iteration. Figure 5 demonstrates the exponential growth of MT graphics hardware performance since 1997. In 1997, the maximum MT expected from a 3D rendering graphic processor was $\log_{10}(100)$, which grew exponentially to $\log_{10}(1875000)$ by mid-2013[16].

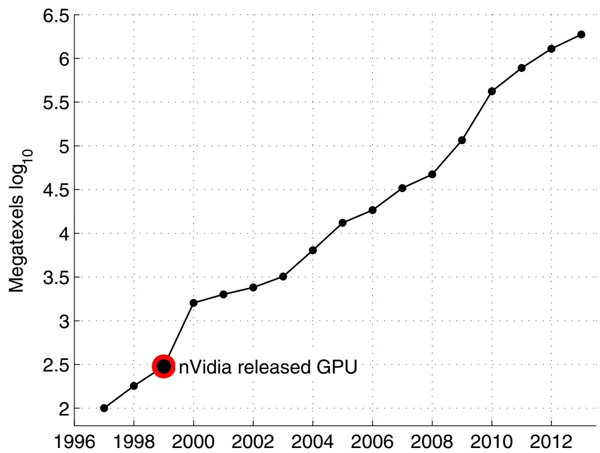

Fig. 5. Graphic card technology advancement since 1997 beginning in 1997 at 100 mega-texels (MT) and growing exponentially to 1,875,000 MT by mid-2013. The vertical axis is $\log_{10}(y)$, where y represents maximum MT per year.

It is suggested that graphical advancements could soon reach a plateau. High-end video game systems are now

[14]www.IMDb.com - Highest Rated Video Games Released In 1998

[15]http://www.opengl.org/about/

[16]http://www.techspot.com/article/650-history-of-the-gpu/

capable of animating real-time graphic renderings that are becoming visually close to that of real life video footage. In addition, video graphic displays have pixels that are so minute, they cannot be discriminated individually by the human eye, with pixel density greater than 300 pixels per inch. As the visual component of video games reaches a peak, more emphasis on player's interaction and immersion is expected. Games are now appealing to a more sophisticated audience, with the average age of the frequent game purchaser being 35 [21]. This calls for exploring new avenues in simulated intelligence and affect manipulation.

Commercial video game publishers are rumoured to be considering psychophysiological hardware, as part of their next generation of video game consoles [84]. This may herald the birth of real commercial investment into AG.

VI. Conclusion

The general consensus is that using the player's affective state to manipulate the video game adds to the enjoyment and immersion experienced. AG will form an important role in the future of human computer interaction. The tasks remaining for modern AG can be summarised as follows

1) Bring together expertise from the various fields that AG draws upon: psychology, physiology, computer science and engineering.
2) Create unobtrusive, robust and accurate devices for inputting physiological signals such as electrodermal activity (EDA) and heart rate (HR) among many.
3) Develop state-of-the-art pattern recognition and machine learning methodologies for reliable emotion recognition as well as algorithms for detecting changes in the player's emotional state.
4) Move AG out of laboratories and into the developer's hands. A step in this direction would be the creation of an open affect application protocol interface (OAAPI) for affect acquisition. When no affect acquisition hardware device is present the interface would emulate the required emotive techniques necessary using software. This would enable the developer to code the game for affective video games with or without hardware specific knowledge.

We speculated that video graphic advancements are heading towards a plateau, which will likely shift the focus towards intelligent interactivity and affective gaming. Such a shift is expected to open up commercial perspectives for AG.

Taking a look into the not so distant future. Equipped with inventive affective input devices, using fast and powerful pattern recognition algorithms and realistic graphical rendering technology, the game developer is facing the most exciting challenge of all: creating the affective gaming loop to maximise the gamer's entertainment pleasure.

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Thomas Christy was born in Caernarfon, Wales, UK. He obtained his BSc in Computer Science, Bangor University, in 2009. He won a Eurographics award for *Best use of graphics*, through an advanced video game, utilising a haptic input device. He is working towards his PhD at Bangor University, specialising in the field of Affective Video Games. His work continues towards advancing video game immersion through intuitive technological methods of human computer interaction.