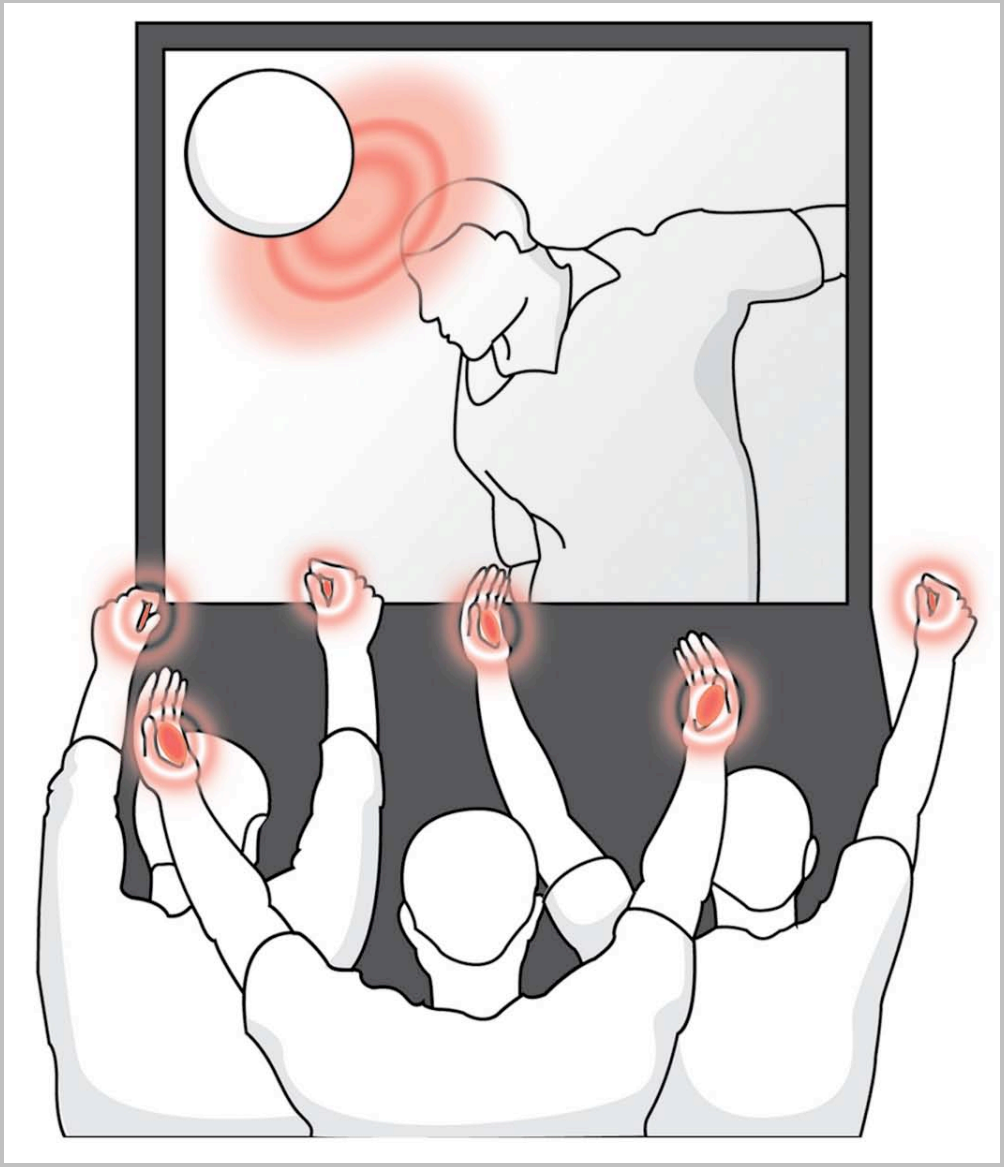
SPECTATE



A Design for Manufacture Project

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CONTENTS

EXECUTIVE SUMMARY

The emotional atmosphere of a live sports is said to be tangible, a physical entity.

Disconnection from the emotional involvement of live sports events, through removal from the live event environment, or lack of understanding of the emotional impact of the action unfolding, lessens the overall viewing experience for the spectators.

SPECTATE enhances the emotional experience of a live sports event for these spectators by reconnecting them more directly to the physicality of the emotions and actions viewed in the event. The eMote device provides a deeper understanding of the action unfolding in the live event. Spectators can feel and empathise with a tactile heart beat sensation representing the intensity and pace of the movements in the match. The spectators can also communicate their own emotions back to the live event, allowing them to share their responses and experience with the other spectators.

SPECTATE unites the audience with the athlete, individual spectators with the entire crowd, and multiple viewing environments with the central location; reconnecting, enhancing and sharing the emotional experience of a live sports event.

I. PRODUCT DEVELOPMENT

1. CONTEXT

i. BACKGROUND AND AIMS

Live sporting or performance events both communicate and create very emotional messages. The action unveiling in a sports event, or theatre or music performance builds a shifting flow of emotion both in the messages communicated by the athletes and performers, and by the emotive atmosphere felt by the spectators.

Emotions are felt in our bodies through changes in our physiological state such as increased heart rate, higher body temperatures and heavier breathing. While some of these subtle emotional signals can be perceived by others, most of our emotions are communicated through our body movements. Be it distinct gestures, or the overall energy and size of movement, we can understand another's emotions simply by observing their movements; sensing them through visual and aural signals. The empathy we feel for these emotions observed in others can be increased in several ways: by having a cognitive understanding of the reason for the movements, by physically mimicking the movements we observe, or by feeling the actual physiological responses of the observed person (see APPENDIX I. EMOTIONAL EMPATHY for more detailed research on emotional empathy).

But what if the spectator doesn't fully understand the context of the actions, or couldn't see or hear the details of the movements or physiological responses? In sports, a more inexperienced spectator may lack the detailed knowledge required to fully understand the subtle variation in emotional involvement in the action unfolding. In theatre, dance and music, visually or aurally impaired viewers lack the necessary sensory stimulation to fully experience the emotional connection and empathy for the actions being performed.

Sensory impaired spectators and inexperienced spectators both desire enhanced experiences of the event they are observing: an enhanced physical connection to enhance the cross-senses communication for the sensory impaired viewer, and an enhanced cognitive understanding of the action being observed for the inexperienced viewer. They both want to feel the same experience that a fully sensory, knowledgeable viewer might be experiencing.

Taking inspiration from the enhanced tactile sensitivity of sensory impaired users, and the emotional connection that can be developed by communicating our emotions on a deeper physiological level, this project aimed to:

- Augment the sensory communication of a live sport or performance event to affect and enhance the emotional experience for the spectators
- Create an enhanced physical and cognitive connection to the action being observed to improve the emotional involvement for sensory impaired or inexperienced viewers

ii. REMOTE VIEWING ENVIRONMENTS

The disconnection of the sensory impaired user and the inexperienced user from the physical emotionality of the actions unfolding in a live sports or performance event is similar to that of the disconnected experience of viewers, even experienced viewers, when viewing the event from a remote location.

The phenomenon of live broadcasts of big sports and music events on 'Big Screens' has been around since the 1990s. Starting life as live televised viewings of sports in pubs, the occurrence of live broadcasts of big events on large screens to multiple audiences has increased greatly over the last seen years, due to the BBC's Public Screen Broadcasting project[i]. There are currently 16 Big Screens[ii] installed in cities across the country and several temporary installations, and regularly draw in very large crowds when large events such as the Proms, the football World cup and the Commonwealth Games are broadcast, underlining the enduring desire spectators have to share watching a live event with other people in a crowd environment, even if they can't be in the real event environment itself.

Although the crowd environment at the Big Screen locations provides some aspect of the emotional experience of viewing a live event, it does not create the exact same experience as being at the real event itself. Consider a drama performance: the difference between live theatre and a film is that of the direct connection which physical human presence can bring. The reason people go to the real event environment itself is to be closer to the people carrying out the actions being observed; be closer to the physicality of the event itself. Even though it is improbable, when we are in the real event environment, it is still possible for the actor to gaze directly at us, for us to feel the sweat of the athletes, to catch the wayward ball. When we are viewing this action on a Big Screen, no matter how large or high definition, there is still a psychological barrier to the physical connection which is felt when in the same actual environment as the action taking place.

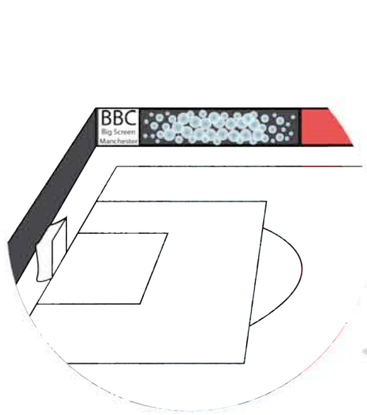
During Big Screen events with multiple audiences, cameras often record the reactions of the crowds and play a few seconds of them back real time as part of the national broadcast. This brief inclusion of the remote audiences in the real event broadcast often heightens the levels of excitement of the crowd, and enhances the feeling of involvement in the real event[iii]. The generation of this feeling of involvement of the audience connects the viewers to the real event, and creating this connection for the whole viewing experience would enhance the experience for remote viewers, making it almost the same as being in the real event environment.

2. DESIGN BRIEF

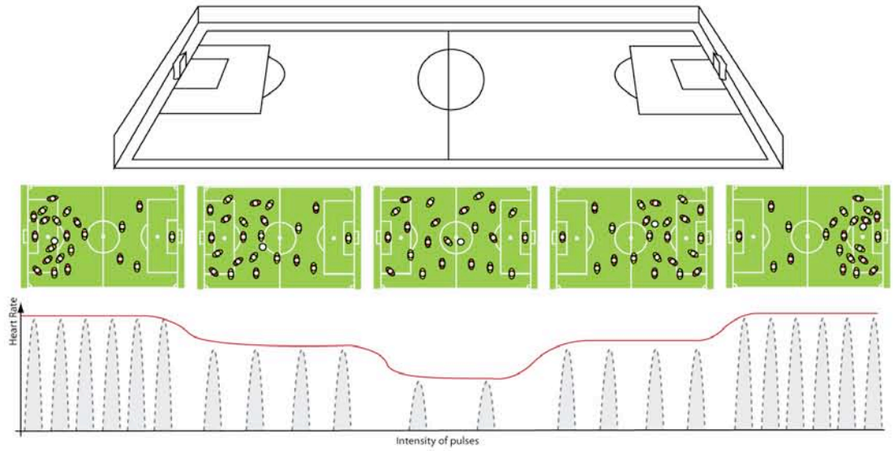
To design a product which enhances the emotional experience of a live sports or performance event for viewers who feel less involved in the action being observed (i.e. inexperienced viewers, remote viewers, sensory impaired viewers). The product will create an enhanced physical and cognitive connection to the action being observed by communicating the physical nature of the movements and action between the 'performers' and the spectators.

3. PRODUCT SPECIFICATION

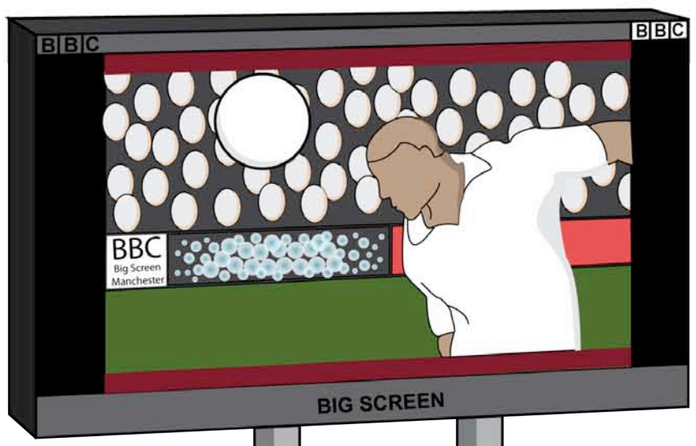
PRODUCT DESCRIPTION:		A small interactive communication device which provides a deeper understanding of the action unfolding in the live event by representing the intensity and pace of the movements in the match using a varying heart beat pattern communicated as a tactile sensation. The device also enables the spectators to communicate their own emotions back to the rest of the crowd or the athletes/performers
SCENARIO OF USE:		Product used by audiences at BBC Big Screen broadcasts, such as live sports fixtures (including football matches and the Olympic Games), and large music events
INTERACTION SYSTEM (Figure 1):	**1: EMOTIONAL ANALYSIS**	An emotional response of the action on the football pitch is created in the form of a varying heart rate. Variables such as the ranking of the player's skills, the distance to the goal and the speed of the action contribute to the increasing or decreasing frequency of the heart rate output
	2: TACTILE COMMUNICATION OUTPUT	The varying heart rate is transmitted from the Big Screen wireless transmitter to the tactile receiver (eMote) held by the spectators. A solenoid creates pulses which increase in frequency and intensity to represent the emotional heart rate and create an empathetic response to the action being watched. The eMote can be held in the spectator's palm, strapped around their hand or clipped onto their top, for the user to interact with as they prefer
	3: SPECTATOR EMOTION INPUT	Galvanic skin response sensors in the eMote device detect changes in the spectator's emotional state, and so can monitor their emotional response to the action being watched. The BBC Big Screen receives the crowd's galvanic skin response information and transforms it into a graphic to visualise the spectator's collective emotional response. Input of spectators emotion to each other and to the Big screen broadcast and real event environment connects spectator to the physicality of the live event
	4: VISUALISATION OF SPECTATOR EMOTIONAL RESPONSE	Graphics relating to the varying intensity of the spectator's emotional states are created by BBC and displayed in real event environment, e.g. on LED display screens around pitch or large screens in the stadium
	5: CROWD VIRTUAL PRESENCE	When spectators can see their emotional input in the real event environment on the TV they feel more connected to the live event
TARGET USER:		Novice sports user seeing the event live but from a remote location
MARKET:		Big Screen events currently occurring are Football and Proms, but the project will look to expand the product capabilities to cater for the London Olympics in 2012



4: Visualisation of spectator emotional response
Graphics relating to the varying intensity of the spectator's emotional state are created by the BBC and displayed in real event environment, e.g. on LED display screens around pitch or large screens in the stadium

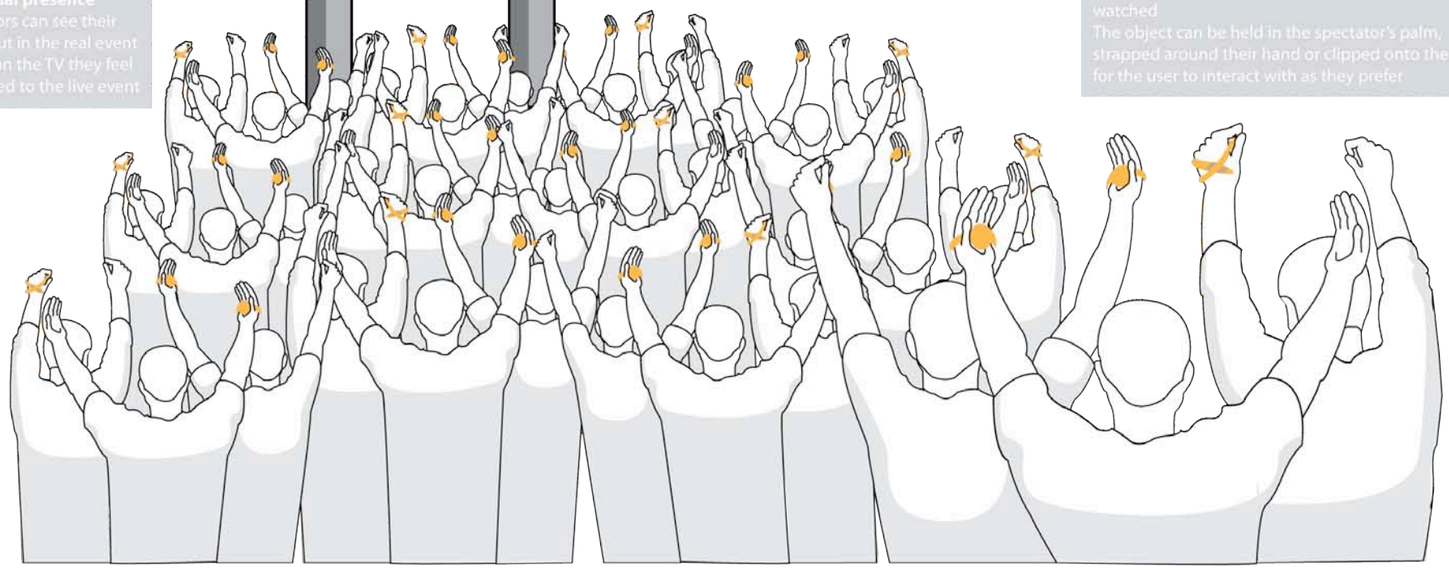


1: Emotional analysis
An emotional response of the action on the football pitch is created in the form of a varying heartrate
Variables such as the ranking of the player's skills, the distance to the goal and the speed of the action contribute to the increasing or decreasing frequency of the heart rate output



2: Tactile communication output
The varying heart rate is transmitted from the Big Screen wireless transmitter to the tactile receiver held by the spectators
A solenoid creates pulses which increase in frequency and intensity to represent the emotional heart rate and create an empathetic response to the action being watched
The object can be held in the spectator's palm, strapped around their hand or clipped onto their top, for the user to interact with as they prefer

5: Crowd virtual presence
When spectators can see their emotional input in the real event environment on the TV they feel more connected to the live event



3: Spectator emotion input
Galvanic skin response sensors in the object detect the spectator's emotional state, and so can monitor their emotional response to the action being watched
The BBC Big Screen receives the crowd's galvanic skin response information and transforms it into a graphic to visualise the spectator's collective emotional response
Input of specators emotion to each other and to the Big screen broadcast and real event environment connects spectator to the physicality of the live event

Figure 1: SPECTATE Interaction System

II. PRODUCT DESIGN

1. CONCEPT SELECTION AND DEVELOPMENT

i. CONCEPT DEFINITION

Initial concepts developed through analysis of observations at theatre and music performances and interviews with performance and sports experts and sensory impaired theatre and sports spectators, highlighted themes relevant to the project brief of enhancing a live spectator event experience. These included:

- Representing the performers' and spectators' emotions in the viewing environment
- Directly connecting the performer to the spectator
- Directly connecting the spectator to other spectators
- Sensing the real time emotional physiological responses and movements and conveying them directly to invoke emotional empathy and create a greater emotional immersion
- Communicating the emotion of a live event to spectators outside of the local event environment

(A map of the early concepts can be seen in APPENDIX III.1. INITIAL CONCEPT THEMES, Figure 12).

Development of these theme areas resulted in of four defined concept directions (see Table 1 below):

- Communication of emotion of movement to sound and touch
- Communication of emotion of movement to vision and touch
- Creating emotional empathy by communicating emotional heart beats
- Creating emotional immersion for remote spectators

The key innovation in these concepts and their relevance to the creation of a enhanced experience for the viewer of a live performance or sports event lies in the communication of unknown or unseen emotional reactions. The latter two concept directions relate to this communication of 'hidden' emotional responses. These two concept directions were developed into a final concept direction: **the enhancement of the experience of a live spectator event by the creation of emotional empathy through the communication of emotional heart beats, particularly focusing on the emotional immersion for remote spectators.**

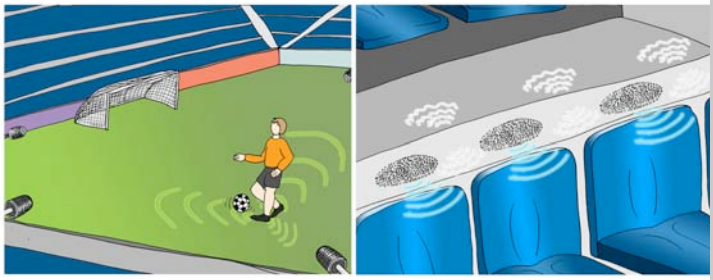
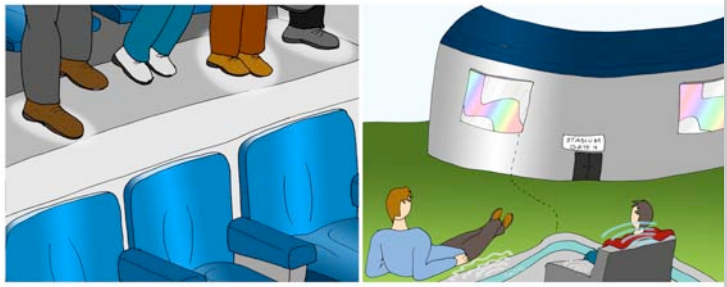
DIRECTION 1: MOVEMENT TO SOUND AND TOUCH	
Through the recording and transmitting the sounds and tactile vibrations of the performer or athlete's movements through the spectators' seating environment, the user can better engage with the subtle sounds of the movements	
DIRECTION 2: MOVEMENT TO VISION AND TOUCH	
Through the recording of the intensity and pressure of the performer or athlete's movements on the ground, and transmitting the responses through dynamic tactile textures on smart fabrics, the emotional response of the action being observed can be integrated into the spectators' seating environment	
DIRECTION 3: EMPATHY WITH EMOTIONAL HEART BEATS	
Through recording the heart rate of the performers or athletes and spectators and communicating a 'group' heart beat back to the spectators through vibrations in the seating environment, the spectator can empathise with the emotional response of the action being observed	
DIRECTION 4: EMOTIONAL IMMERSION OF REMOTE SPECTATORS	
Through the recording of the intensity of the spectator movements within the main event environment and transmitting the emotional responses to locations outside of the main viewing environment using visual, aural and tactile signals, remote spectators can feel more involved in the main event	

Table 1: Concept Directions

Further definition of the project brief included specifying the scenario in which the product would be used. Three different scenarios were chosen to be key areas where the enhancement of the emotional communication of the event could be relevant: **live sports events, live theatre performances and live music concerts**.

A questionnaire was developed and completed by a range of potential users which posed questions relating to the specific experiences the users had when viewing a sports, music or theatre event in different environments: at the actual event, in a crowded environment outside of the main event, and in the home environment (see APPENDIX II.1.i. SCENARIO QUESTIONNAIRE, Table 5). Insights gained from the user feedback generated by these questions enabled refinement of the scenarios to focus on which would be most suitable to enhancing the experience for the spectator.

Responses from the varied collection of users who were interviewed and surveyed highlighted a range of characteristics which could be divided into several user groups:

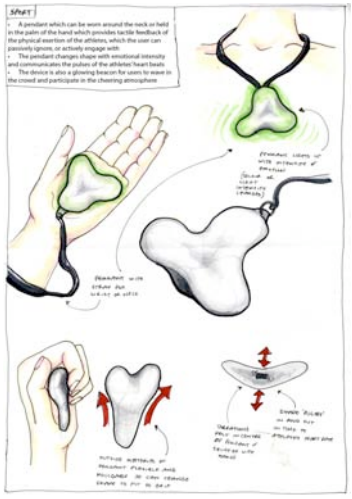
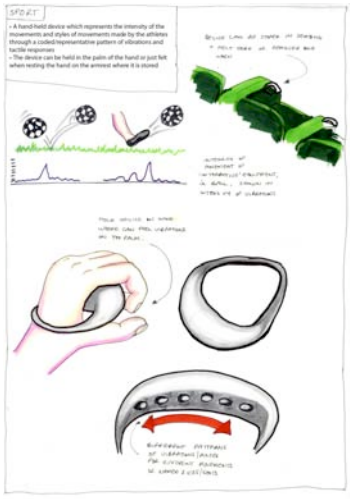
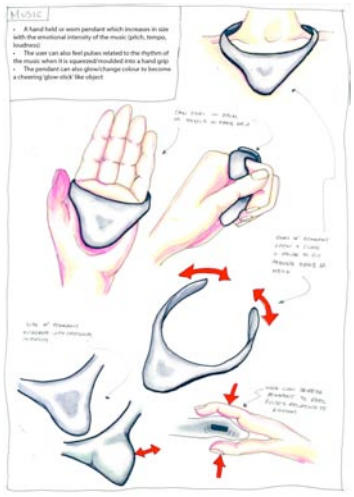
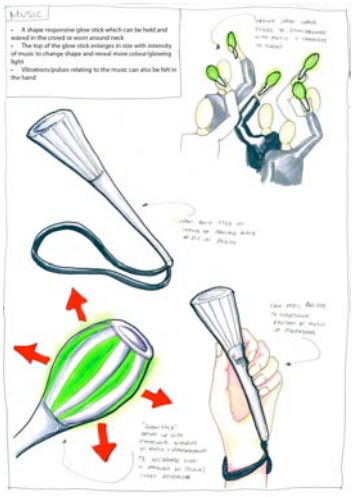
- **Expert spectator**, who has a detailed knowledge of the action being observed and would always like to be at the live event if they can
- **Novice spectator**, who has an interest and limited knowledge in the action being observed and will attend live events as a more social occasion
- **Remote spectator**, who can have a range of knowledge of the action being observed, and would like to attend the live event but cannot due to location/cost/availability and so views it at Big Screen public broadcasts
- **Impaired spectator**, who has developed a sensory impairment (visual or aural) which prevents them from experiencing the full sensations of the event which they may have experienced earlier in life

(See APPENDIX II.1.ii. USER GROUP DEFINITIONS, Table 6 for details of the specific interests, capabilities and requirements which each user group has)

The user groups were further classified into 12 distinct user profiles when correlated with the specific spectator event to which the user was involved with i.e. expert sports spectator, novice theatre spectator, impaired music spectator etc. Specific quotes from interviews from the users helped to highlight certain characteristics of the user definitions and identify features which they would require in a product to enhance the experience of a live event. (See APPENDIX II.2.i. SPORT SCENARIO PROFILES: Table 7, II.2.ii. THEATRE SCENARIO PROFILES: Table 8, II.2.iii. MUSIC SCENARIO PROFILES: Table 9 for detailed profile descriptions and relevant user research).

For each of the 12 user profiles, a specific concept brief was developed by considering how the performers or spectators would interact with their environment or an object, what emotions could be sensed and affected, and what changes in the environment or the object could enhance the connection of the spectator to the performer and other spectators. The development of these briefs highlighted key design features required by each user profile, and 12 different product concepts were designed and visualised. Feedback from a selection of users was obtained for each of the 12 concepts, which highlighted desirable features in a product to enhance the spectator experience of a live event.

From the 12 concepts proposed to the users, the following four received the most positive feedback:

NOVICE SPORT SPECTATOR	IMPAIRED SPORT SPECTATOR
	
– A pendant worn around the neck or held in the hand which provides tactile feedback of the physical exertion of the athletes – The device becomes a glowing beacon for the user to wave in the crowd – Engages less interested spectators more by connecting them to the physicality of the action	– A hand-held device which represents the intensity of the movements and styles of movements through tactile responses – Signals generated which represent actions e.g. contact with ball, specific movements – Tactile feedback can help visualise the actual movements better
NOVICE MUSIC SPECTATOR	**REMOTE MUSIC SPECTATOR**
	
– A hand held or worn pendant which increases in size with the emotional intensity of the music – The user can also feel pulses related to the rhythm of the music – Personal interaction with device enhances connection to music/performer and enhances emotional empathy	– A shape responsive glow stick which can be held and waved in the crowd – The top of the glow stick enlarges in size with intensity of music to change shape and reveal more colour/glowing light – Vibrations/pulses relating to the music can also be felt in the hand

Comments made by the users about the concepts and prototypes included:

- *'It would be nice to feel the heart rate'*
- *'Being able to feel athletes' exertion adds to excitement and tension'*
- *'It would give good sense of the different pace of action throughout the match and add to the atmosphere'*
- *'It would be good to have a feeling in your hand about the length, intensity of*
- *'It would be good to have something that you can connect to the performer but also respond to them yourself by participating in crowd'*
- *'I like that the spectator can 'feedback' into crowd'*
- *'Good to be targeted at sensitive hand area'*
- *'I like that it is small and easy to hold/wear around neck so it isn't something the person has to use all the times in an exciting match'*
- *'I would want to buy one to take to different events'*
- *'I would like it to be my own, as it's then mine to use how I want'*

(The full selection of concept sketches, briefs and feedback for each of the 12 user profiles are included in APPENDIX III.2. CONCEPT BRIEF DEVELOPMENT AND USER FEEDBACK: Table 10.)

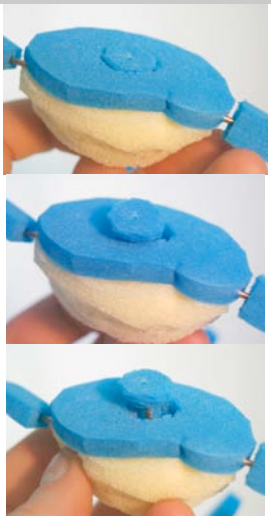
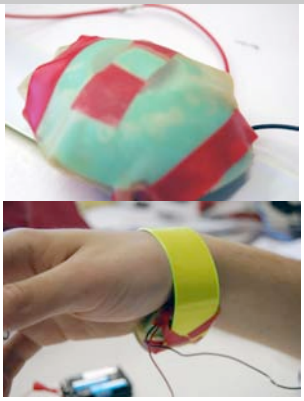
From the user feedback, important characteristics of the product included:

- Having a product which provides a deeper understanding of the action unfolding in the event would enhance the experience for less knowledgeable spectators
- Representing the intensity and pace of the movements in the match using a tactile communication would involve the spectator in the action more
- Using a heart beat pattern as the tactile communication would make the spectator feel more connected to the physical exertion of the athlete/performer
- Enabling the spectators to communicate their own emotions back to the rest of the crowd or the athletes/performers would make them feel more involved in the event
- A small hand-held device would enable the spectator to interact with it when they want, and also transport easily from home to different events

This user feedback on the concepts highlighted the most relevant user for this product to enhance the spectator experience of a live event as the novice sports viewer as they want a general knowledge of what's going on, and something to keep them interested. The remote viewer also needs this product as they want to feel more connected with the performer and also input their own emotional response back to the main event environment. The scenario chosen as most relevant was therefore the viewing of live sports events from a remote environment. A relevant application is for the BBC Big Screen public broadcasts of large events, but could also include any large screens which broadcast a live event to multiple audiences outside of the main event (e.g. Henman Hill in Wimbledon, Proms in the Park). The broadcasts of live football matches was also chosen as a relevant application for this product as this is currently a regular broadcast on BBC Big Screens, but it could also be applied to other sports events, such as the upcoming London Olympics in 2012.

ii. TECHNOLOGY DEVELOPMENT

Prototypes and models were developed to demonstrate the tactile nature of the communication of the emotional responses and movements being observed. The most successful models with the most appropriate technical features are shown below:

'FEELS LIKE' MODEL: SINGLE POINT TAPPING	ELECTRONIC STIMULATION: SOLENOID	ELECTRONIC STIMULATION: SOLENOID IN RECESS
		
– A small section of the hand held device pulses to create a 'tapping' sensation in the palm of the hand to represent the beating of a heart	– A solenoid moves a section of the device in and out which can be felt in the palm of the hand to represent the beating of a heart	– A solenoid taps out a beating heart rate in a recess in the device which can be distinctly felt on the wrist or palm

The technology most suitable to create the 'heart beat' sensation desired by the users as a means of communicating the emotion of the action they are observing in a tactile way was found to be a solenoid concealed beneath a flexible membrane, which could generate a distinct but not unpleasant beating sensation when held next to the skin. Areas of the body found to communicate the beating sensation most effectively included the palm, wrist and chest. The very personal nature of tactile communication and the variable sensitivity between users meant that one exact position in which to communicate the beating sensation to the users could not be defined. The tactile communication object itself must therefore be able to be used at several positions on the body.

Connecting the solenoid to a processor enabled varying frequencies of 'heart rates' to be generated, allowing different emotional states to be communicated to the user, and a greater emotional empathy to be invoked.

The general emotional 'heart rate' which represents a combination of the intensity of the movements being observed and the strategic meaning of the action unfolding was developed by analysing the emotional responses of an expert spectator and a novice spectator to the same football match. Galvanic skin response and heart rate

measurements were taken from both users during the viewing of a live football match broadcast, and the readings were analysed against key aspects of the action in the football match. Key variables of the action in the match considered in the analysis included: the distance of the ball from either goal, the speed of the action, the type of action (e.g. passing, tackling, free kick, penalty etc) and the ranking of the player's skills.

A comparison of the novice and the expert's heart rates highlighted a difference in the peaks of activity at key points, as indicated in Figure 2 below. At an obvious goal attempt, both the expert and the novice spectators' heart rates went up by the same amount (an increase of around 15 beats per minute, bpm, from the respective baseline levels). However, at a free kick, the expert's heart rate increased by about 15bpm more than the novice. This stability in the novice's heart rate during a moment which the expert spectator's heart rate, and hence emotional response, increased greatly, highlights the importance of knowledge on the emotional response of watching certain situations; the expert knew that the player taking the free kick was likely to score, and this information increased their emotional response. If the novice spectator could have this knowledge, or feel the emotional response of the expert spectator, they too would have the same emotional experience in key moments in the action.

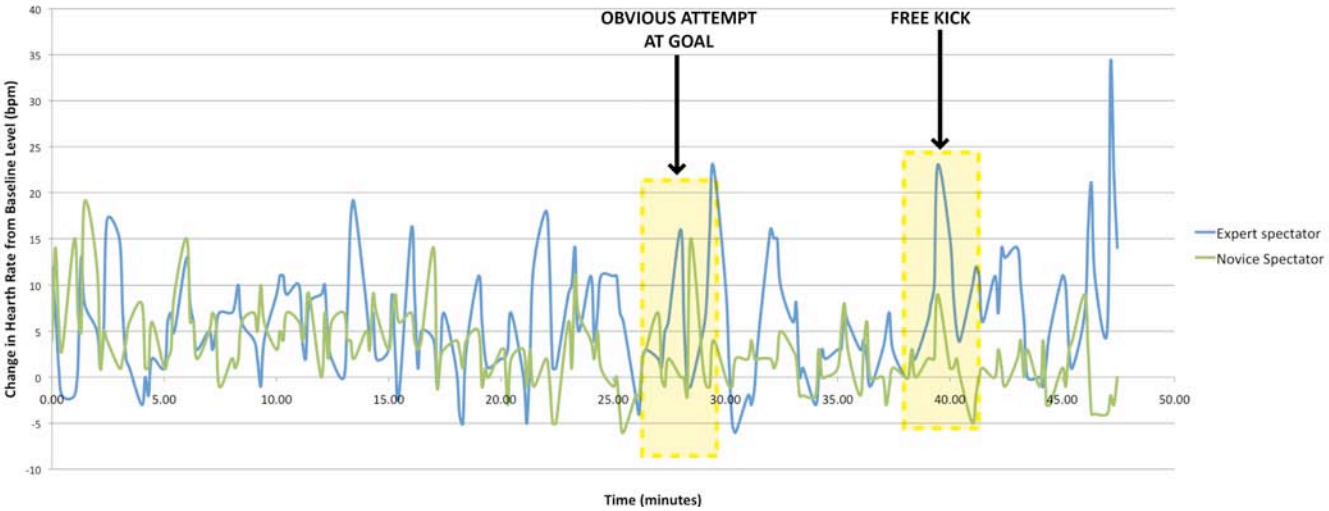


Figure 2: Comparison of expert and novice spectator heart rates

Further analysis of the biometric and statistical data collected highlighted several key numerical correlations which together can form the algorithm for calculating the appropriate 'expert' emotional response for the action unfolding in a match:

- Baseline heart rate level increases throughout the duration of the match
- Change in heart rate increases with decreasing distance to either goal end of the pitch
- Change in heart rate increases with increasing speed of the movement of the ball
- Variable change in heart rate with different types of action and the ranking of the skills of the player carrying out the action

(Full analysis including graphs of the biometric and statistical data are included in APPENDIX V. ANALYSIS OF EMOTIONAL RESPONSE TO VIEWED SPORTS EVENT)

iii. INDUSTRIAL DESIGN

Taking insights from user feedback on early sketch models, prototypes and questions about how the user would like to interact with the object, a brief for the industrial design of the eMote device was created, which included the following features:

- An 'active' area which provides communication in the sensitive areas
- An ergonomic shape to fit comfortably into the palm so the sensations can be felt in the palm
- A method to hold the device securely to the hand to allow freedom of movements
- A method to attach the device to clothing so the sensations can be felt on the chest

Development of the design from this brief included sketching, form finding using clay and blue foam modeling, and materials experimentation. The form was optimised in terms of ergonomics and affordances for each of the three key features of the product: holding the eMote in the palm of the hand, wrapping the eMote around the hand, and clipping the eMote to clothing. Through a process of design iteration, the separate designs were then morphed into one final object with all three functionalities. The development of the design from its initial concepts to the final form is detailed in the design morphology (Figure 3).

The features of the final design include:

- A symmetric shape which can fit in either hand
- An asymmetric profile which affords which side to hold in the palm
- A handle to secure around the hand which collapses around the main body of the eMote
- The handle also allows attachment to the users' clothes

Figure 3: Product form morphology

One aspect mentioned by users in early research was the importance of spectator-to-spectator feedback when interacting with the emote device; the spectators wanted to know and see that other people were experiencing the same feelings as them. The handle affords a functionality of holding the eMote to the users' hand to allow for freer movement, but it also becomes a beacon to other spectators in the crowd; alerting them to their shared experience with other spectators in the crowd. The design of the handle was therefore developed to have a highly communicative aesthetic related to the shared cheering atmosphere of the crowd in which the users are participating.

A cheering spectator brand logo was developed which forms a 3D profile over the shape of the handle. A small graphic version of the logo is also embossed on the back of the main body to represent the brand to the user as they are using the emote device. Figure 4 below visualises how the branding on the product will be evident during its use.

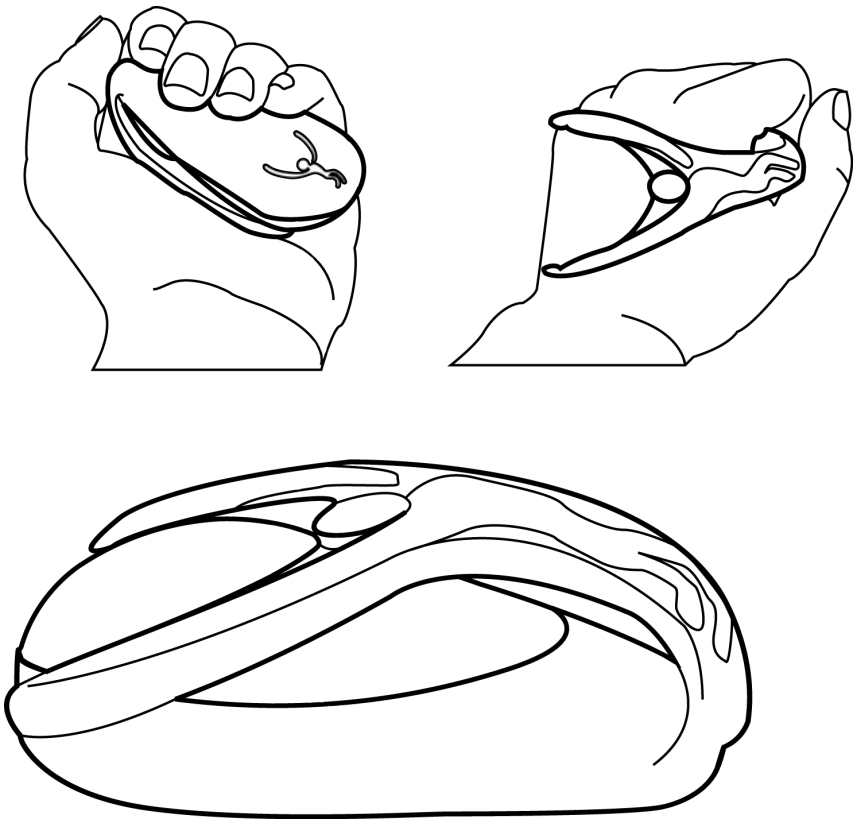


Figure 4: 3D logo and branding on product

The functionality of the product requires it to be made out of two materials; polypropylene for the main body casing and handle to be tough and durable but also allow flexibility for the handle to bend around the hand, and silicone for the shell of the 'active' part of the main body where the solenoid acts to allow for greater sensitivity and tactility. The design of these two parts intended to highlight the difference of the active area from the rest of the object. An analysis of colours used in clothing across many different sports and looking at both male and female athletes was carried out to identify common colour schemes used (see APPENDIX VI. INDUSTRIAL DESIGN, Figure 18). A two colour scheme is proposed for the two materials, and variants of the colours are shown in Figure 5 below.

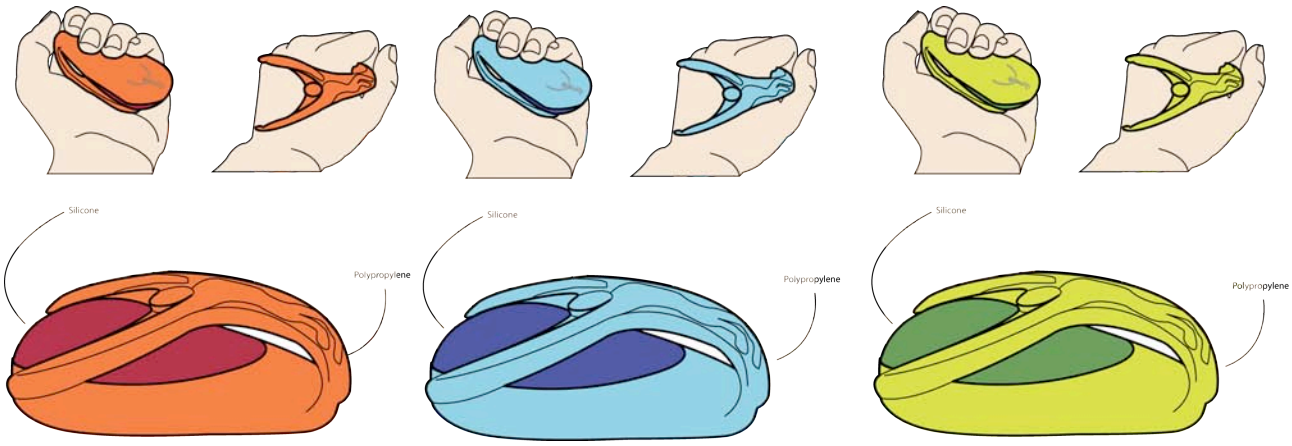


Figure 5: Colour ranges for the eMote

2. FINAL DESIGN

The final concept features:

- *Emotional heart rate algorithm:* A 'heart rate' corresponding to the action unfolding in the live event being viewed and the associated emotional response is created using an algorithm which uses variables collected from real time analysis of the movements of the players and generates an appropriate 'emotional response' heart rate
- *eMote device:* The varying heart rate is communicated to the spectators via a small device which the user can hold in the hand or clip to their clothing. The heart beats are generated by a small solenoid encased within a flexible membrane for the user to feel on their skin
- *Emotional response of spectators:* The spectators' own emotional response is sensed by galvanic skin response sensors contained within the surface of the eMote device and relayed back to the live broadcast as a visual graphic relating to the changing emotional state of the audience

i. EMOTIONAL HEART RATE ALGORITHM

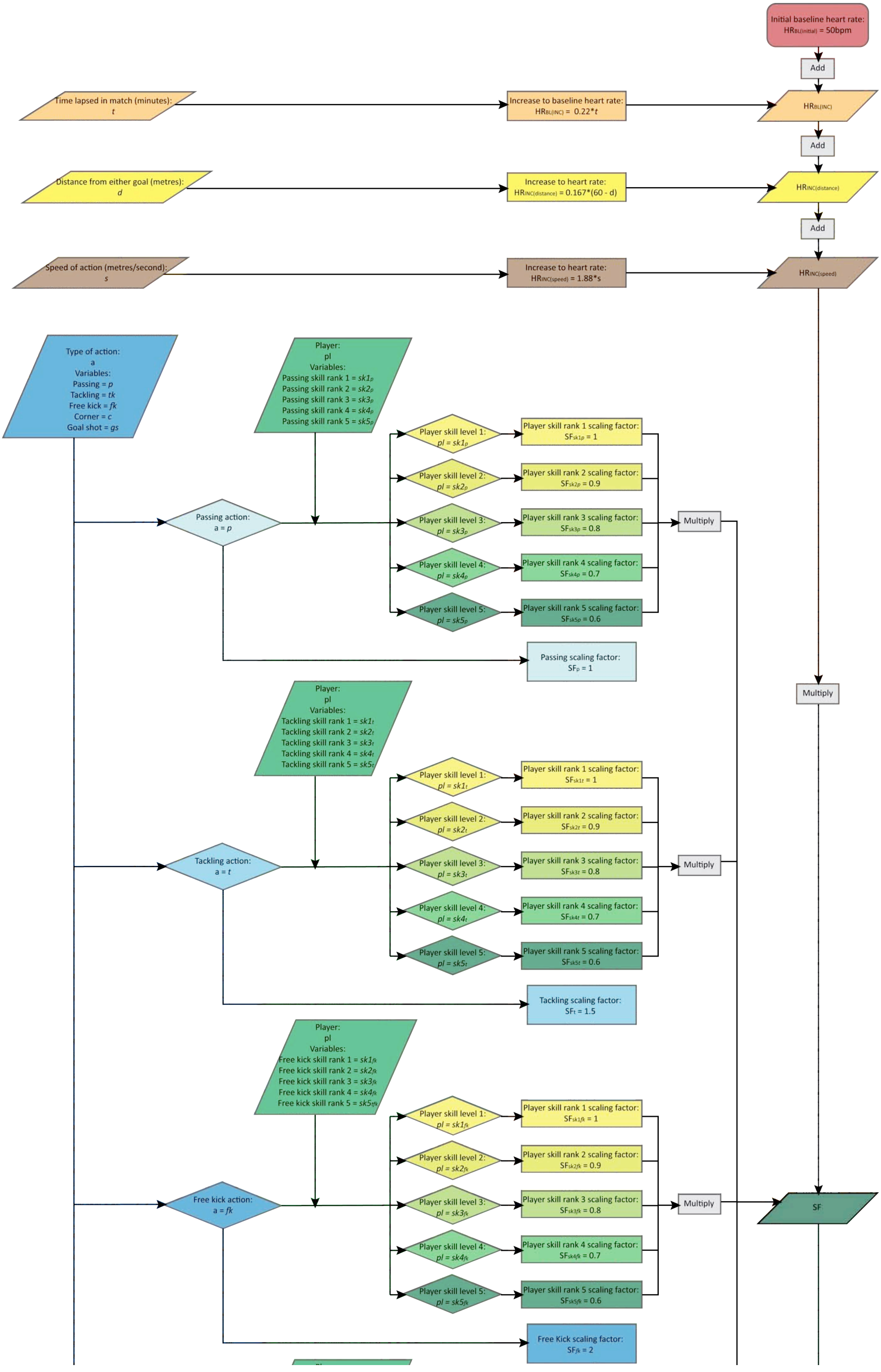
The algorithm used to generate the 'emotional heart beat' communicated to the spectators uses information collected from real-time analysis of the action of the event to output a varying heart rate level which represents an 'expert' emotional response to the viewed action. The variables which affect the generated heart rate include:

- Baseline heart rate increase (HR_{BL}) with time passed in the match (t)
- Heart rate increase ($HR_{INC(distance)}$) with distance to the goal (d)
- Heart rate increase ($HR_{INC(speed)}$) with speed of the action (s)
- Scaling factors relating to the type of action (passing, tackling, free kick, corner, goal shot) and the ranking of the players for each type of action (SF)

The algorithm results in a formula for the emotional heart rate ($HR_{emotional}$):

$$\mathbf{(HR_{emotional}) = 50 + [\ \{\ HR_{BL} + HR_{INC(distance)} + HR_{INC(speed)}\ \}\ x\ SF\ ]}$$

The full algorithm is shown in Figure 6 below and the derivation is included in APPENDIX V. ANALYSIS OF EMOTIONAL RESPONSE TO VIEWED SPORTS EVENT)


Initial baseline heart rate:
HRBL(initial) = 50bpm
Add
Time lapsed in match (minutes):
t
Increase to baseline heart rate:
HRBL(INC) = 0.22*t
HRBL(INC)
Add
Distance from either goal (metres):
d
Increase to heart rate:
HRINC(distance) = 0.167*(60 - d)
HRINC(distance)
Add
Speed of action (metres/second):
s
Increase to heart rate:
HRINC(speed) = 1.88*s
HRINC(speed)
Type of action:
a
Variables:
Passing = p
Tackling = tk
Free kick = fk
Corner = c
Goal shot = gs
Player:
pl
Variables:
Passing skill rank 1 = sk1p
Passing skill rank 2 = sk2p
Passing skill rank 3 = sk3p
Passing skill rank 4 = sk4p
Passing skill rank 5 = sk5p
Passing action:
a = p
Player skill level 1:
pl = sk1p
Player skill rank 1 scaling factor:
SFsk1p = 1
Player skill level 2:
pl = sk2p
Player skill rank 2 scaling factor:
SFsk2p = 0.9
Player skill level 3:
pl = sk3p
Player skill rank 3 scaling factor:
SFsk3p = 0.8
Player skill level 4:
pl = sk4p
Player skill rank 4 scaling factor:
SFsk4p = 0.7
Player skill level 5:
pl = sk5p
Player skill rank 5 scaling factor:
SFsk5p = 0.6
Passing scaling factor:
SFp = 1
Multiply
Player:
pl
Variables:
Tackling skill rank 1 = sk1t
Tackling skill rank 2 = sk2t
Tackling skill rank 3 = sk3t
Tackling skill rank 4 = sk4t
Tackling skill rank 5 = sk5t
Tackling action:
a = t
Player skill level 1:
pl = sk1t
Player skill rank 1 scaling factor:
SFsk1t = 1
Player skill level 2:
pl = sk2t
Player skill rank 2 scaling factor:
SFsk2t = 0.9
Player skill level 3:
pl = sk3t
Player skill rank 3 scaling factor:
SFsk3t = 0.8
Player skill level 4:
pl = sk4t
Player skill rank 4 scaling factor:
SFsk4t = 0.7
Player skill level 5:
pl = sk5t
Player skill rank 5 scaling factor:
SFsk5t = 0.6
Tackling scaling factor:
SFt = 1.5
Multiply
Player:
pl
Variables:
Free kick skill rank 1 = sk1fk
Free kick skill rank 2 = sk2fk
Free kick skill rank 3 = sk3fk
Free kick skill rank 4 = sk4fk
Free kick skill rank 5 = sk5tfk
Free kick action:
a = fk
Player skill level 1:
pl = sk1fk
Player skill rank 1 scaling factor:
SFsk1fk = 1
Player skill level 2:
pl = sk2fk
Player skill rank 2 scaling factor:
SFsk2fk = 0.9
Player skill level 3:
pl = sk3fk
Player skill rank 3 scaling factor:
SFsk3fk = 0.8
Player skill level 4:
pl = sk4fk
Player skill rank 4 scaling factor:
SFsk4fk = 0.7
Player skill level 5:
pl = sk5fk
Player skill rank 5 scaling factor:
SFsk5fk = 0.6
Free Kick scaling factor:
SFfk = 2
Multiply
SF

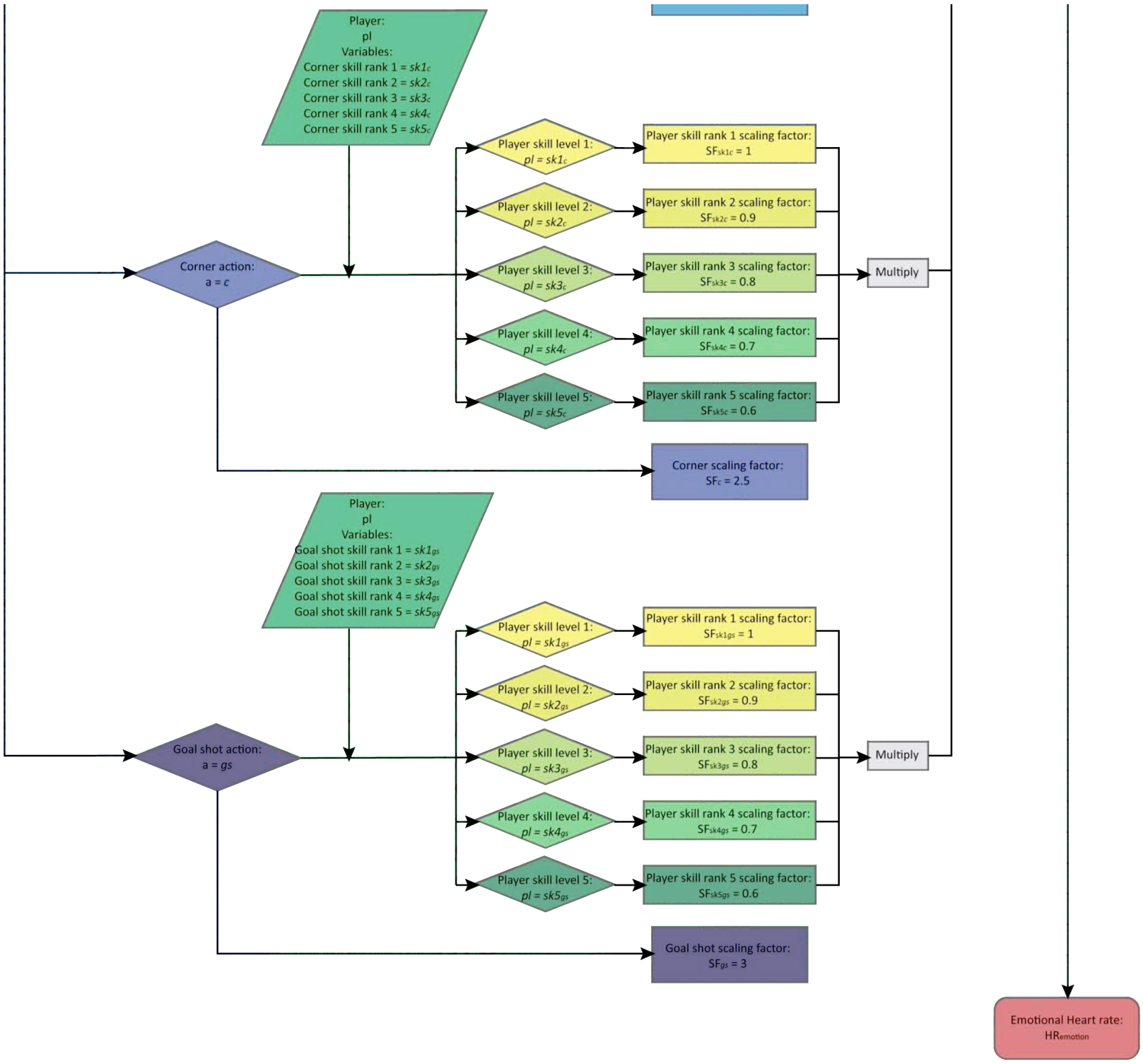


Figure 6: Algorithm for calculation of emotional heart rate for a football match

ii. eMote

The product which the user will interact with is a small device which the user can hold in the hand or clip to their clothing. The design and materials used afford the user to hold it in the most effective way for the tactile heart beat pulses to be felt. The design of the product includes a 3D logo which adds to the identity of the brand and also allows users to see other spectators using the product, and hence feel a shared experience. A visualisation of the final design is shown in Figure 7 below (full general assembly diagrams are included in).

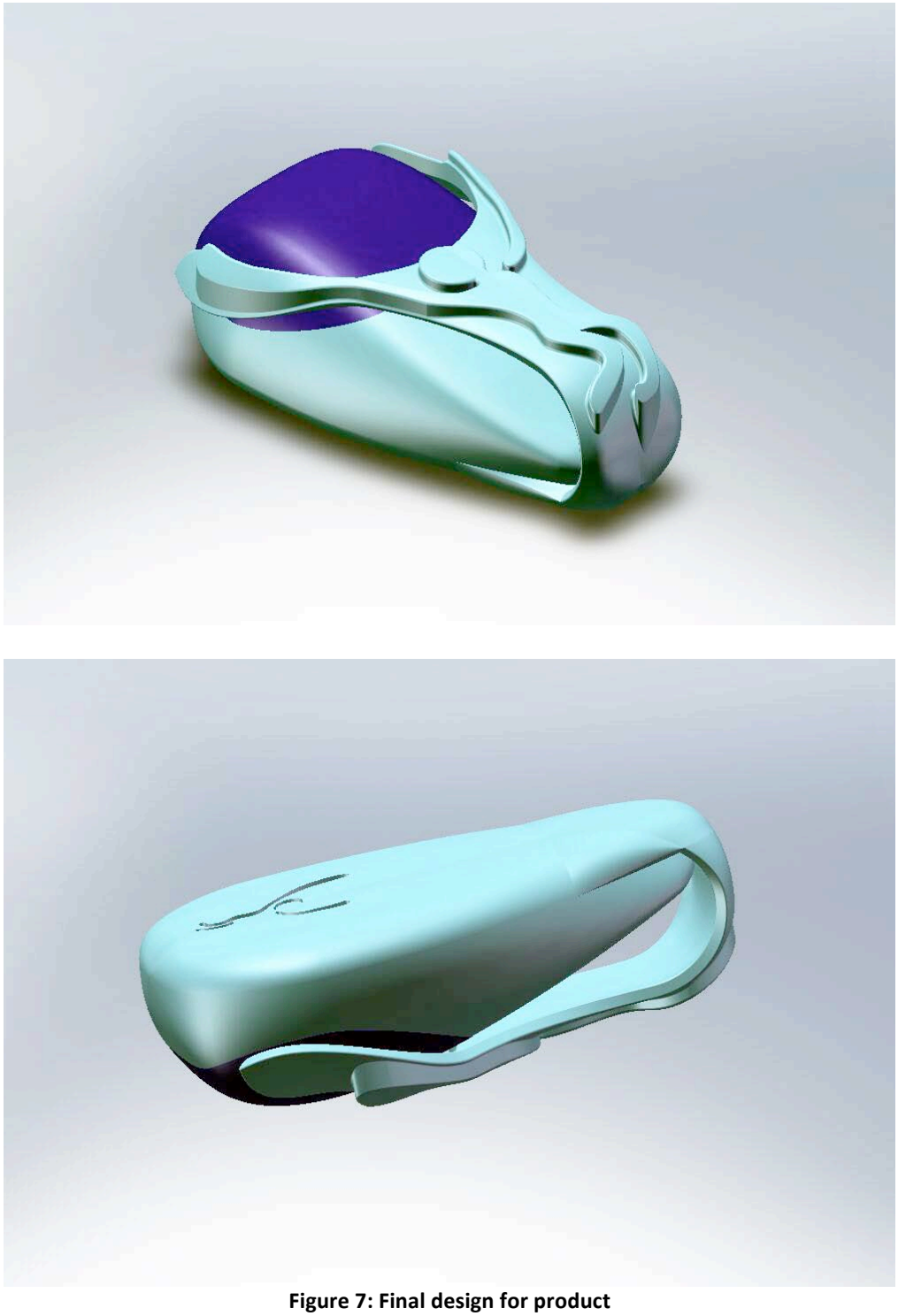


Figure 7: Final design for product

iii. EMOTIONAL RESPONSE OF SPECTATORS

The spectators' emotional response data sensed by the galvanic skin response sensors in the eMote is collected and relayed back to the live broadcast as a visual graphic relating to the changing emotional state of the audience. Galvanic skin response (GSR) readings taken from the viewer during the sports analysis data collection showed responses within a 30 unit range throughout the duration of the match. The GSR readings didn't correlate as closely with the action occurring in the match, but did follow the general level of emotional intensity. GSR readings were chosen as a means of emotional response input for the spectators as the readings are very easy and unobtrusive to take (only two skin contacts required) and represent the general level of emotional arousal in the user.

The visualisation developed to represent the spectators GSR responses is show in Figure 8 below. The height of the dots relate to the level of GSR and they move up and down as the galvanic skin response changes; the changing emotional intensity like that of the changing energy of a bouncing ball. The different levels of GSR are represented by the six colours used in the eMote devices themselves, connecting the visualisation of the spectator's emotional response to the object which they are directly interacting with. Part of the collective spectator experience is the joining together and expressing a joint emotional response through loud cheering. Alluding to this relationship between louder cheering with a greater emotional response and general involvement, the collection of the whole crowds' GSR visualisations will form a dynamic, moving line of bouncing dots, similar to the very familiar volume level graphics.

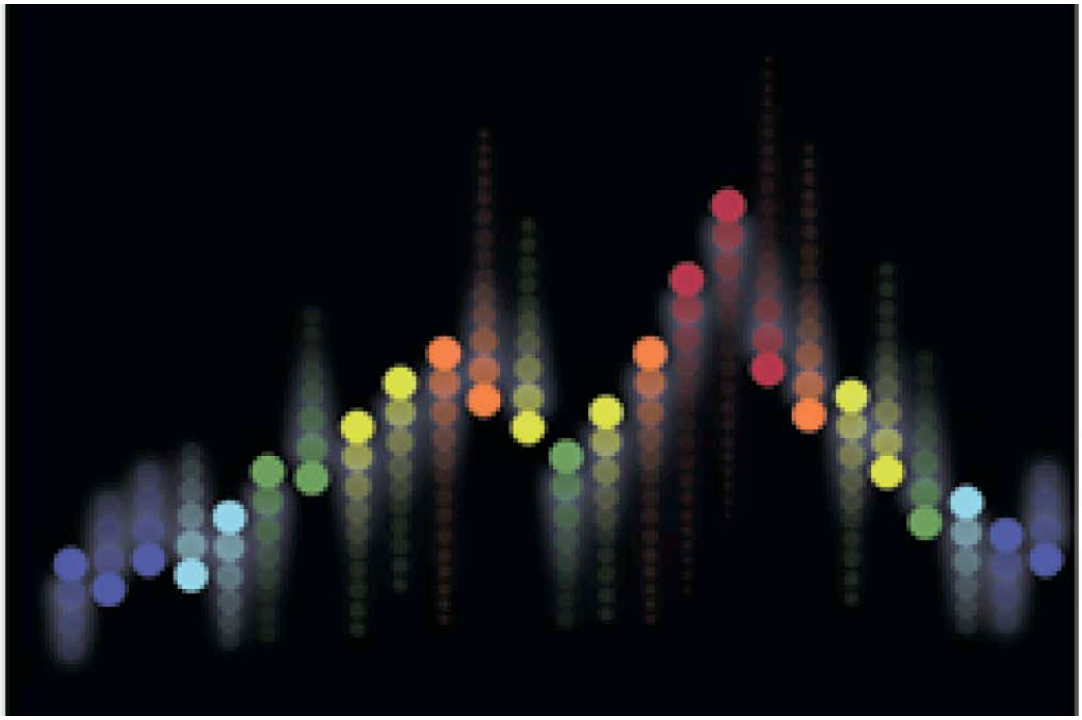


Figure 8: Visualisation of spectator galvanic skin response

Initially the spectator feedback visualisations will only be included as part of the edited broadcast footage, but development could include broadcasting the visualisations on screens within the main event environments, and recorded as part of the main event broadcast.

iv. MATERIALS AND TECHNOLOGY

Figure 9 and Table 2 detail the materials and technology used in the product.

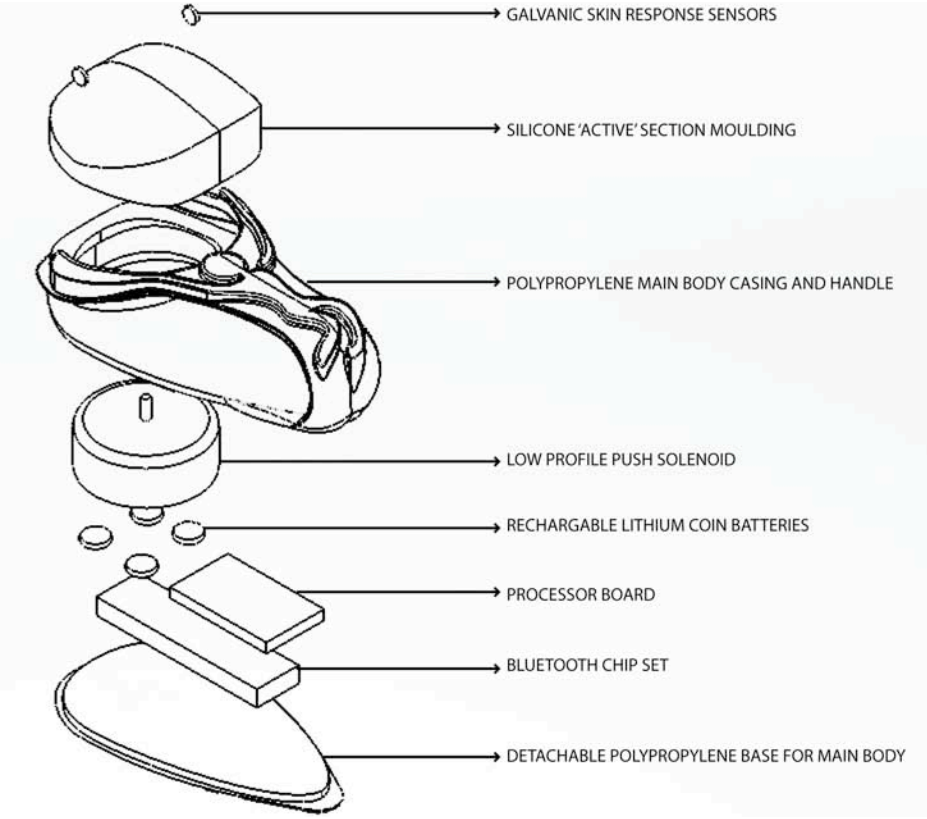


Figure 9: Exploded schematic of product

FEATURE	COMPONENT	DETAILS
EMOTIONAL HEART RATE SENSATIONS	Low profile push solenoid	– Minimum voltage: 6.5V – Maximum stroke: 6.1mm – Force increases to 14.2N – Dimensions: dia. 24.5mm, height 13.5mm – Weight: 42.5g
EMOTIONAL FEEDBACK OF SPECTATOR	Galvanic skin response sensor and circuit	– Metallic contacts – Operational amplifier – Various resistors
WIRELESS TRANSMISSION OF DATA	Bluetooth chip set	– Low power consumption (25mA) – Operating voltage: 3.3 – 6V – Dimensions: 51.5 x 15.8 x 5.6mm
PROCESSING OF DATA	Processor board	– Various resistors, diodes, processing chips – Dimensions: 29.5 x 17.8 x 3.6mm
POWER OF DEVICE	Rechargeable lithium coin batteries	– Voltage: 3V – Dimensions: diameter 6.8mm, height 1.4mm – Weight: 0.17g
MAIN BODY AND HANDLE CASING	Polypropylene	– Tough and durable – Flexible to allow movement of handle
TACTILE 'ACTIVE' SECTION	Silicone	– Flexible to allow for movement of the solenoid to be felt

Table 2: Technology used in product

v. MANUFACTURE

The product will be mass-manufactured using well established injection moulding and electronics assembly methods, as detailed in Table 3.

COMPONENT	MATERIAL	MANUFACTURE
CASING MOULDING	Polypropylene	Injection moulded
'ACTIVE' SECTION MOULDING	Silicone	Injection moulded
SOLENOID	Various	Standard component
GALVANIC SKIN RESPONSE SENSOR	Various	Standard component
BLUETOOTH MODEM	Various	Standard component
PROCESSOR BOARD	Various	Custom Manufactured
BATTERIES	Various	Standard component
SCREWS	Steel	Standard component

Table 3: Manufacture methods for production of product

The design of the product enables complete disassembly of all different parts and materials separately, enabling reuse of electrical components when the product has reached the end of its life and recycling of the polypropelene and abs moulded parts.

The life cycle of the solenoid is approximately 10,000 cycles per event therefore the solenoid should function for at least 100 uses. The battery life is between 100 and 1000 hours depending on usage, and so should function for at least 50 events. The bottom section of the hard outer moulding will be detachable by unscrewing two screws, enabling the batteries to be replaced or recharged.

The aim of the product is for it to be durable and desirable, and so reused by the spectator at different public broadcast events.

(Relevant BSI standards are included in APPENDIX VIII. BSI STANDARDS)

vi. COSTINGS

Estimates for the cost of manufacture of the eMote device are show in Table 4 below. Manufacture cost estimates for the eMote device are based on a batch of 30000 being manufactured.[1]

COMPONENT	COST PER COMPONENT (£)	NUMBER OF COMPONENTS PER UNIT	TOTAL COST (£)
INJECTION MOULDED PARTS (INC. SHIPPING FROM CHINA)	1.50	1	1.50
SOLENOID	1.35[iv]	1	1.35
GALVANIC SKIN RESPONSE SENSOR	0.50	1	0.50
BLUETOOTH MODEM	1.00[v]	1	1.00
PROCESSOR BOARD (FABRICATION AND TEST)	2.00	1	2.00
BATTERIES	0.35[vi]	4	1.40
SCREWS	0.01	2	0.02
		TOTAL COST PER UNIT (£)	6.77

Table 4: Manufacture Cost Estimates

The total manufacture cost per unit is therefore estimated to be £6.77. Additional costs include:

- Tooling: Approximately £10,000 per set of tooling (replaced every 30,000 uses)
- Development: Approximately £20,000 for software development of real time analysis of sports action and integration of algorithm

[1] Data obtained from quote based on comparison to existing similar product manufacturing costs

III. PRODUCT BUSINESS

1. MARKET

There are currently 16 BBC Big Screens in cities around the country, showing over 10 large live events a year. Each of the large live events has gathered crowds of up to 6000 people in the past. The BBC is expanding their public space broadcasting project in time for the London Olympics in 2012, developing more 'Live Sites' where remote audiences can gather to view the sports events.

The consumers of eMote are the audiences at these large scale events and will have characteristics close to that of the novice of spectator, who will be more likely to buy specialist products relating to a specific event in order to enhance their experience and memory of it. The design of the product relates to the fun and social atmosphere at the BBC Big Screen events, making it desirable to the consumers who wish to enjoy their viewing experience as much as they can.

The development of this product is focused on a completely new need identified from the research described in this report. Hence, eMote has no direct competitors. Products which may share the market into which eMote will inhabit include: cheering devices such as glow sticks and banners, spectator merchandise such as branded clothing and accessories, general sports accessory products such as watches and bags.

2. DISTRIBUTION AND PRICING

The distribution model of eMote is direct consumer sales at the Big Screen event locations. Due to the spontaneous nature of the collection of crowds at the Big Screen public broadcasts, the sales strategy of eMote must cater for the 'impulse buy' of first time buyers at these events. Complete sale of the eMote device was chosen instead of a rental system due to the logistics of collecting up to 6000 eMote devices after an event broadcast. The personal, tactile nature of the interaction with the eMote device also meant that the users would prefer to consider the product their own, and be able to bring it back to future events.

Considering the pricing of similar products sold on site at live spectator events (ranging from £2 for glow sticks and banners, to £40 for specialty branded watches and bags), eMote will be priced at £9.99. This price enables a product margin of 17.6% (£1.19) per unit sold (taking into account manufacture and distribution costs and tax), while still not creating a price barrier to prevent the 'impulse buy'.

3. BUSINESS PLAN

SPECTATE is unique in that it is creating an active connection between remote audiences and the real environment of the live events.

The SPECTATE interaction system includes many key stakeholders: the sports analysis companies who create the real time analysis of the sports events, the BBC who broadcast the events on the Big Screens, and the local councils who manage the

big live public broadcast events. Development of this proposal would include further liaison with the sports analysis companies in the design of appropriate software to implement the emotional response algorithm, and with the BBC to expand the capabilities of the product to fit with upcoming events and broadcasts planned.

SPECTATE would look to partner with the sports analysis companies and the BBC, but to keep it's own identify, visualised by the 'cheering' logo (see above).

Development of the product design and software, with the relevant user testing would commence this year, and aim to be at a stage to create the first batch of product by 2010. Further development of the software to expand the range of events the product is applicable to would be carried out up to 2012, at which point the London Olympics will expand the market for this product. The number of products manufactured would increase up to this increased market size in 2012. The market share for the consumers who attend the Big Screen broadcasts is estimated to be 5%.

Financial projections for the development of SPECTATE and distribution of the eMote devices are included in APPENDIX IX. FINANCIAL PROJECTIONS. Table 11 and shown below in Figure 10.

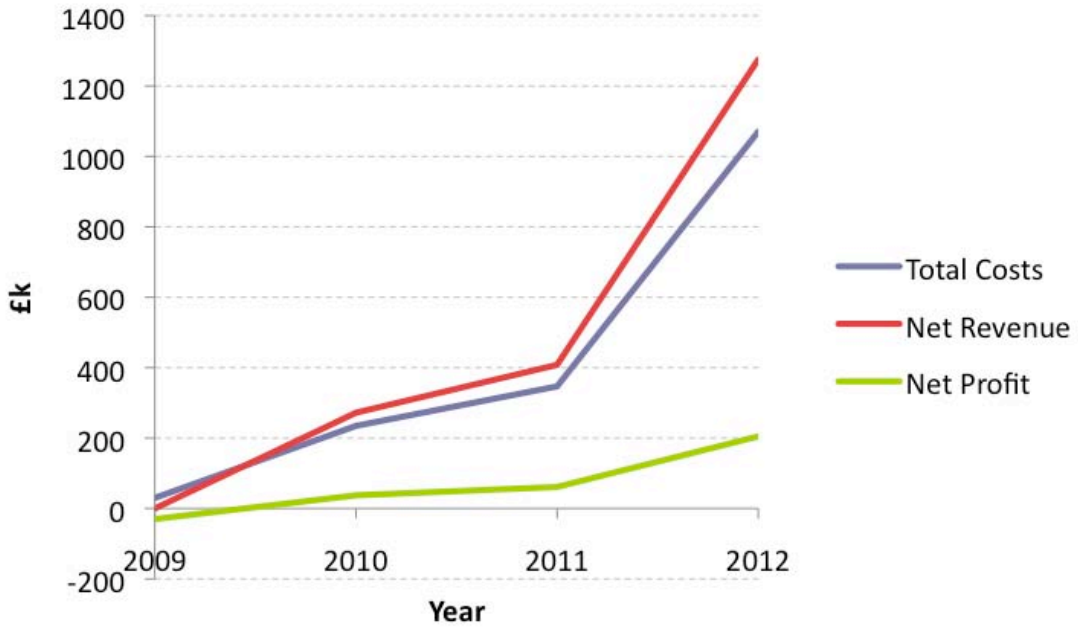


Figure 10: Financial Projections

IV. SUMMARY

The brief for this project was to design a product which enhances the emotional experience of a live sports or performance event for viewers who feel less involved in the action being observed. The creation of the SPECTATE interaction system and the eMote device will enhance the experience of spectators viewing the events at Big Screen broadcasts by connecting them more directly to the physicality of the emotions and actions viewed in the event. The tactile heart rate sensations representing the physical emotional responses of the action unfolding both connect the spectator to the emotional exertion of the viewed action, and aid understanding and involvement through empathy with an 'expert' spectators emotional response. Seeing their own emotional response broadcast in the environment further connects the spectator to the live event by directly adding their own input to the event they are viewing.

The next steps in this project are to manufacture and user test the eMote device to gain user feedback on the effectiveness of the communication in a live crowd event scenario. Development of the software and liaison with the relevant sports analysis companies would also be key, to understand the full complexity of the ongoing development of real-time sports analysis and alter the algorithm accordingly to fit with the current (or near time) software capabilities.

APPENDIX

I. EMOTIONAL EMPATHY

> *"…we live, for most of the time, in a continuous and constantly-shifting emotional atmosphere that infuses all our actions and experience…"*[vii]

The creation and expression of our emotions is a complex journey: the brain comprehends our emotions, our inner body feels our emotions, our outer body expresses our emotions and our environment enhances our emotions. Within the brain and the inner body we develop an understanding of our emotions and a need to communicate them to provoke a reaction from others or as a creative emotional expression. We use the outer body and our environment to visualise our emotions and communicate them to others, mainly in the form of movements, facial expressions and gestures.

It is understood that facial expressions have a strong relationship to our emotions, and much research has been carried out by Ekman[viii] to analyse the connection of emotions to exact facial expressions. Our facial expressions are one of our most controllable means of non-verbal communication, and thus can often be deceiving. If we feel that our cognitive interpretation of our emotions is not suitable to be communicated in a social situation, then we can easily mask them with the opposing facial expression, e.g smiling when actually upset. Morris[ix] describes this inconsistency between our true felt emotions and the emotions we choose to communicate as having a "scale of credibility of communication means", i.e. there is a range of controllable and uncontrollable emotional communication which can uncover our true emotions to a viewer. The most credible form of emotional communication are spontaneous signals, such as blushing, which is a direct link to our physiological state. Credibility in our emotional communication then moves up through fairly credible leg, feet and chest movements, to semi-conscious and conscious hand movements, to facial expressions at the least credible. From this analysis it can be seen that facial expressions, while the most easy to identify as communicating specific emotions, can be less credible in expressing our true emotions. Whole bodily movements on the other hand, can convey more truthful emotional information, but can often be less easy to interpret by the viewer.

The clarity in our emotional body movements simplifies the interpretation by the viewer. Dancers and actors use slightly exaggerated body movements to express an emotion through their body to a large audience. Academic work in this field by Meijer[ix], Russell[x] and Laban[xi] has identified which body movements and styles of movement are associated with different emotions, and how they are interpreted by the viewer.

This exaggeration of emotional movements used by actors and dancers to communicate to a large audience could be applied to our everyday emotional movements to enhance our non-verbal communication of emotion and simplify the

interpretation of them by a viewer. Clarity of communication can be brought by exaggerating our emotions and enhancing their effect on our environment.

Empathy with another person's emotions can also be developed by actually feeling some of the physiological responses happening during that particular emotion. Creating a more physical and tactile form of communication enables a more direct physiological emotional response to be invoked, and greater emotional immersion in the communication itself. Much research has been carried out in the field of synesthetic (cross-modal sensation) and tactile communication, in areas as broad as assistive technologies to video game enhancements. Some projects particularly relevant to this work included: SkinScape[xii], a body suit which transferred a musical composition into tactile stimulations over different parts of the body to enable deaf users to experience music; Enactive Cinema[xiii], an interactive cinema experience which monitors the audiences emotional responses and alters the storyline of the film accordingly; Philips 'Emotion Vest'[xiv] which creates tactile stimulations on the body to represent different emotional responses, i.e. a shiver up the spine, or an increasing pulsing heart rate.

The physiological responses and body movements which enable this emotional empathy can be generalised using several key variables, including heart rate, breathing rate, body temperature, movement size, movement style and movement speed. Research into the key aspects of our physiological and physical expression of emotions, from scientific investigations into emotional recognition from biosignals[xv] to theory of dance[xvi] and movement analysis[xvii], enabled a detailed map of the relationships between different emotional states and physiological responses and body movements to be constructed (see Figure 11 below).

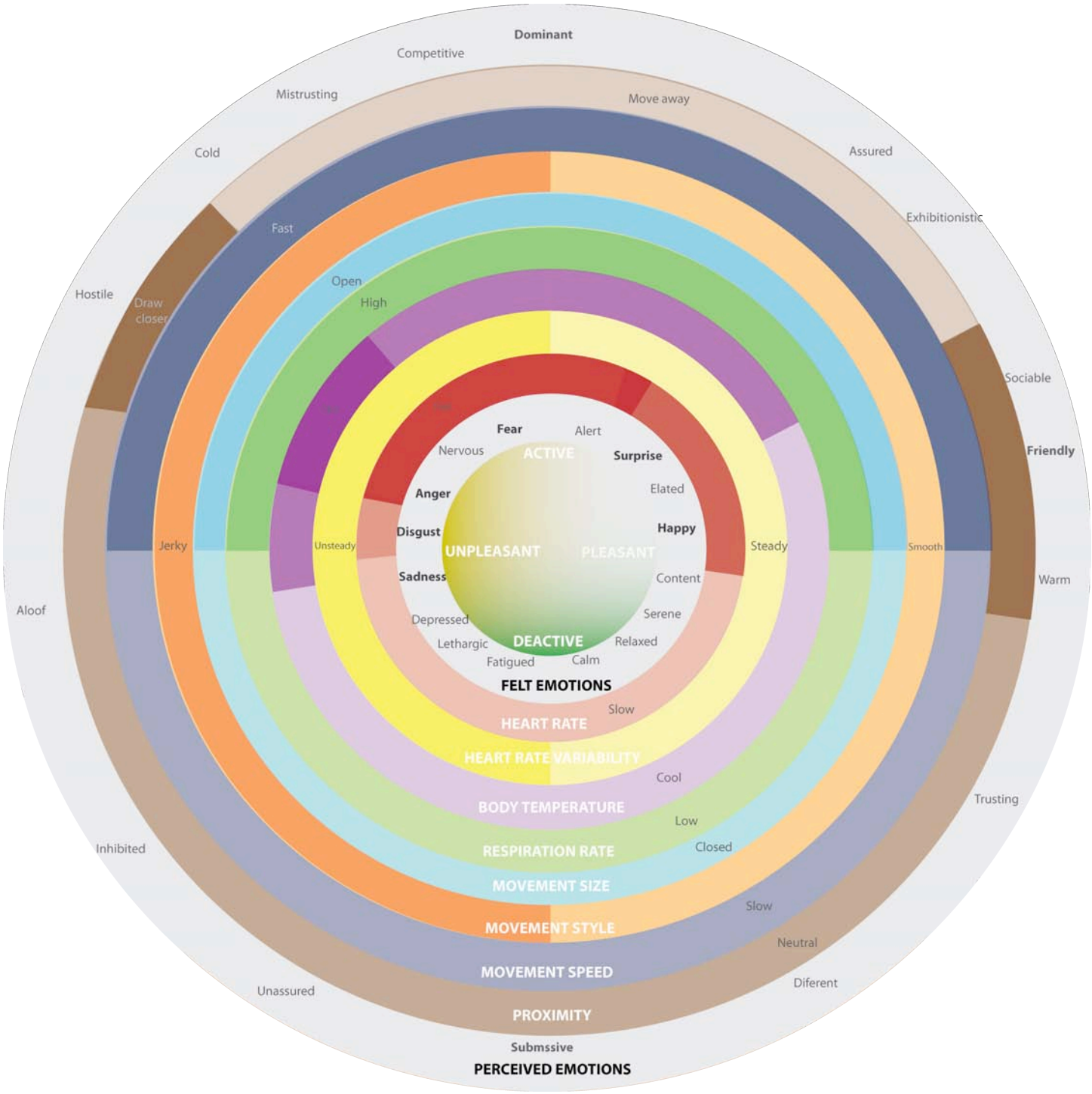


Figure 11: Map of Emotional Physiological Responses and Body Movements

II. USER RESEARCH AND DEFINITIONS

1. SCENARIOS AND USERS

i. SCENARIO QUESTIONNAIRE

SPECTATOR EVENT	QUESTIONS POSED TO USER
SPORTS	– Could you compare your experiences of viewing a sports event (football/tennis/rugby/racing/olympics etc) in these different environments: • *At the venue itself* • *In an environment outside of the home, e.g. a pub/bar* • *In the home environment e.g. TV/over the internet* – Could you also include your specific reasons for viewing the event in that environment and what aspects of the experience are important?
MUSIC	– Could you compare your experiences of viewing a music event (festival/gig/mtv etc) in these different environments: • *At a live (outdoor) festival* • *In a concert hall/indoor venue* • *At home e.g. on TV/radio* – Could you also include your specific reasons for viewing the event in that environment and what aspects of the experience are important?
THEATRE OR DRAMA PERFORMANCE	– Could you compare your experiences of viewing a performance event (theatre/dance etc) in these different environments: • *In a closed/indoor environment e.g. a traditional seated theatre hall* • *In an open environment e.g. an open (indoor or outdoor) promenade performance space* – Could you also include your specific reasons for watching the event in that environment and what aspects of the viewing experience are important?
MULTI-VENUE ENVIRONMENT	– Could you describe your experiences in going to an event where there are multiple events (matches/gigs/performances) occuring in different parts of the space e.g. at a music/theatre festival or large scale sport tournament (e.g. Wimbledon/Olympics). – How did you decide which mini-venue/event to go to? – Was your focus/attention ever diverted from the action you were viewing by thinking about other venues/hearing responses from people at other venues? – Would other people's reactions to an event you weren't viewing encourage you to move to that event? – Would you like to know how people in an event you weren't viewing felt about it? – How do the people viewing the same event as you affect how you viewed the event/your enjoyment level?

Table 5: Spectator Event Experience User Questionnaire

ii. USER GROUP DEFINITIONS

USER GROUP	INTERESTS	CAPABLITIES/REQUIREMENTS
EXPERT SPECTATOR	– Watched/participated in events for years – Has preferred 'performers', teams, styles – Has in-depth knowledge of rules/themes – Looking at specific performance quality - wants more in-depth knowledge of details e.g. energy/skill/style to enhance experience – Wants to understand more about the process, psychology and physiology etc to empathise more	– Full sensory viewing experience – Normally has some physical experience/empathy with actions being observed – Likes watching TV/online (finding out background/stats/opinion) – Likes seeing real event (connection to real performer, multitude of experience/opinion from other spectators)
NOVICE SPECTATOR	– Recent interest in event or taken by expert spectator – Wants to learn more/general social inclusion/enjoyment – Has basic understanding but would like more explanation to become more engaged (e.g. understand comparative physical exertion/feel it/hear it/understand passion/dedication) – Wants to understand more about general rules/story/emotions	– Full sensory viewing experience – Concentrate on understanding (not intuitive) and can get bored/feel disengaged if too complex – Likes to have commentary/'friend whispering in ear' to understand – Will buy items from 'event' to remember it as a social occasion
REMOTE SPECTATOR	– Interest in event and desire to go to 'real' event but restricted by cost/availability/children – Likes social atmosphere – Feels more excited/involved as it's more of an occasion than watching on TV – Lacks direct focused attention/connection of real event – Wants to feel like they are connected to real event (feeling performer/crowd at real event or inputting their feelings back to real event)	– Full sensory viewing experience – Get extra stats/info on broadcast event (but editing etc reminds viewer of disconnection from real event) – Wants to feel 'sucked in'/transported to event
IMPAIRED SPECTATOR	– Academic interest/participation gained from pervious full-sensory experiences or occupation – Always searching new events to find ones that they can connect to/enjoy – Often jaded/expect not to enjoy themselves as don't think people/event will cater for their needs – Wants to feel like they are getting the same experience as everyone else and can discuss/socialise with other full sensory viewers	– Varied - generally people with more severe impairment (people with milder impairment will 'make do' and not want to admit to needing help) – People going there will use extra services as have made effort, but do not want to feel event is 'dumbed down' – Want extra infor so get full experience/'keep up' with actions

Table 6: User Group Definitions

2. USER PROFILES

i. SPORT SCENARIO PROFILES

	USER CHARACTERISTICS	USER QUOTES
EXPERT SPECTATOR	– Will often go to live event – Will have membership/season ticket – Will pay extra from extra merchandise, equipment, services – Wants to know about statistic and physiology (detailed, direct info) – Spectator to performer connection very important	Matt Steeds, ex-professional rower: – '*What makes me feel more involved is knowing how much work and focus has gone into the action before the event*' – *'Feeling the intensity of what the athlete is feeling/doing can help me connect to the emotional intensity of the event'* Chris Holden, dedicated football, rugby and cricket spectator: *'You get to watch the game on your own terms… this sometimes means missing the critical moment, but the crowd usually alerts you to this.'*
NOVICE SPECTATOR	– Not often go to live event – At event they are excited/feel it is a social occasion, will buy 'tourist' spectator stuff e.g. clothing/gadgets – Like to have 'expert' whispering in ear, pick up emotion/info from other spectators – Spectator to spectator and spectator to performer connection important	Harriet Mothersill, attends sports events occasionally when taken by expert spectator: – *'The event instills interest in you for that moment - you create attachments with other views in the pub just for the game and then its lost again.'*
REMOTE SPECTATOR	– BBC Big Screens/Henman Hill – Service paid for by company to encourage people to come and spend in screening environment – Groups of people, talking, wandering around and having a picnic – Only half-attention to event – Want crowd involvement to connect to 'real' event – Buy extras/services as part of fun social experience	Chris Holden, dedicated football, rugby and cricket spectator, often watches in the pub: – *'The pub is about experience beyond what can be achieved at home. It is the best place to enjoy an event with friends and to get involved in the partisan aspects like chanting and cheering, this does give the event additional depth.'* – *'you can choose how emotionally involved to get'*
IMPAIRED SPECTATOR	– Audio description/special seating – Important to connect to action of event (not get over-powered – Take cues from crowd reactions as well – Dedicated viewer will have own equipment (but needs to work in all environments), not dedicated viewer will expect environment to cater for their needs	Hugh Huddy, developed blindness with age, used to got to live sports events before loss of sight: – *'Sports can be uninteresting because they're a very visual/movement based knowledge'* – *'Need to immerse yourself in the environment to find the natural cues - but when you do you can come away with the same experience'* – *'I'd like to have the extra info that I would hear if I was in the action/on stage'*

Table 7: Sports User Profiles

ii. THEATRE SCENARIO PROFILES

	USER CHARACTERISTICS	USER QUOTES
EXPERT SPECTATOR	– Often go to live performance (membership) – Sometimes buy book (connoisseurs don't need it) – Will want 'extras' to be incorporated into performance (don't want it to detract from the illusion) – Company can use extra service/environment as marketing for shows – Spectator to performer connection very important	Liz Luthman, avid theatre viewer and amateur dancer: – *'Need to be able to empathise with the observed person to understand their emotion'* – *'The sound and strength of movements, and breathing can tell you a lot about movement and emotion'* Sebastian English, Performance student, Dartington College of Arts, Totnes: – *'Involving different muscles/senses makes the experience more engaging'* – *'Live performance is about creating a direct connection between the performer and the viewer'*
NOVICE SPECTATOR	– 'Special occasion' e.g. date/family – Go for 'luxury'/'magical' experience – Will use 'extra' services – Wants to feel engrossed in story/connected to performers – Crowd interaction not as important	Chris Holden, occasionally goes to the theatre as a special occasion: – *'I would much prefer to watch a theatre production in a traditional hall, I think the confined aspects allow for an atmosphere to be created throughout the production enabling me to become engrossed in what is happening'* Harriet Mothersill, goes to theatre occasionally as a social event*:* – *'in a traditional theater it reminds me of being little and dressing up for a special occasion'*
REMOTE SPECTATOR	– Like watching in cinema – Don't feel as connected to actors (no direct gaze into audience) – Wants to feel drawn in to emulate real theatre – Will buy extras as part of experience	Harriet Mothersill, goes to promenade theatre occasionally: – *'The audience often have a choice to participate or decide how long they will stay for which is good as you make you own experience.'* – *'risk of not seeing everything or getting lost- your senses become heightened as you feel as though you are part of it or searching for clues'*
IMPAIRED SPECTATOR	– Audio description/special seating – Understand details to add layers to emotional experience – Feel like they are on stage with performers to better understand space/movements – Expects environment to provide extra communication	Tara Sethi, profoundly deaf: *'Much more emphasis on physical actions, improving visual and physical impact, which would improve it for everyone'* Hugh Huddy, avid theatre-goer when sighted and still attends theatre performances, works for RNIB on integrating audio description into theatres*:* *'sound of feet can communicate movements/emotional dynamics'* *'hold the hand of partner, feed off their tactile responses to visual aesthetics'*

Table 8: Theatre User Profiles

iii. MUSIC SCENARIO PROFILES

	USER CHARACTERISTICS	USER QUOTES
EXPERT SPECTATOR	– Early tickets – Energy/concentration required in performance – Shouldn't have to buy anything else to hear it – Better vision maybe at gigs – Spectator to performer and vice versa connection important	Jamie Schacklar: – *'I like to sit close so I can see the musicians playing'* Chris Holden, attends live music concerts regularly: – *'The smaller the venue the more intimate the experience with the band and the more you engage directly with them (rather than with the crowd in larger venues)'*
NOVICE SPECTATOR	– Make it a social event - music becomes 'background' – Take enjoyment from crowd atmosphere – Wants to know interesting details about person/music – - Happy to be ignorant/just listen/daydreaM	Harriet Mothersill, attends small concerts and festivals with groups of friends: – *'it becomes background music or to dance to - as a tool to fill the space'*
REMOTE SPECTATOR	– More background/social occasion – Use it for dancing – Live compere makes audience feel more connected	Chris Holden, attended several large scale music festivals and concerts where performers are often very distant: – *'In large events generally, people have different levels of involvement depending on there position'* – *'When everyone is engaged the experience becomes much more rounded.'*
IMPAIRED SPECTATOR	– Origin of music can be disorienting, but can be more involving as fewer distractions – Tempo/emotion can be confusing if no obvious motion of performer	Tara Sethi, profoundly deaf, regularly attends music festivals and concerts as a social event – *The atmosphere of a live event is important - feeling the bass/rhythm and having a better visual impact*

Table 9: Music User Profiles

III. CONCEPT BRIEF DEVELOPMENT AND SELECTION

1. INITIAL CONCEPT THEMES

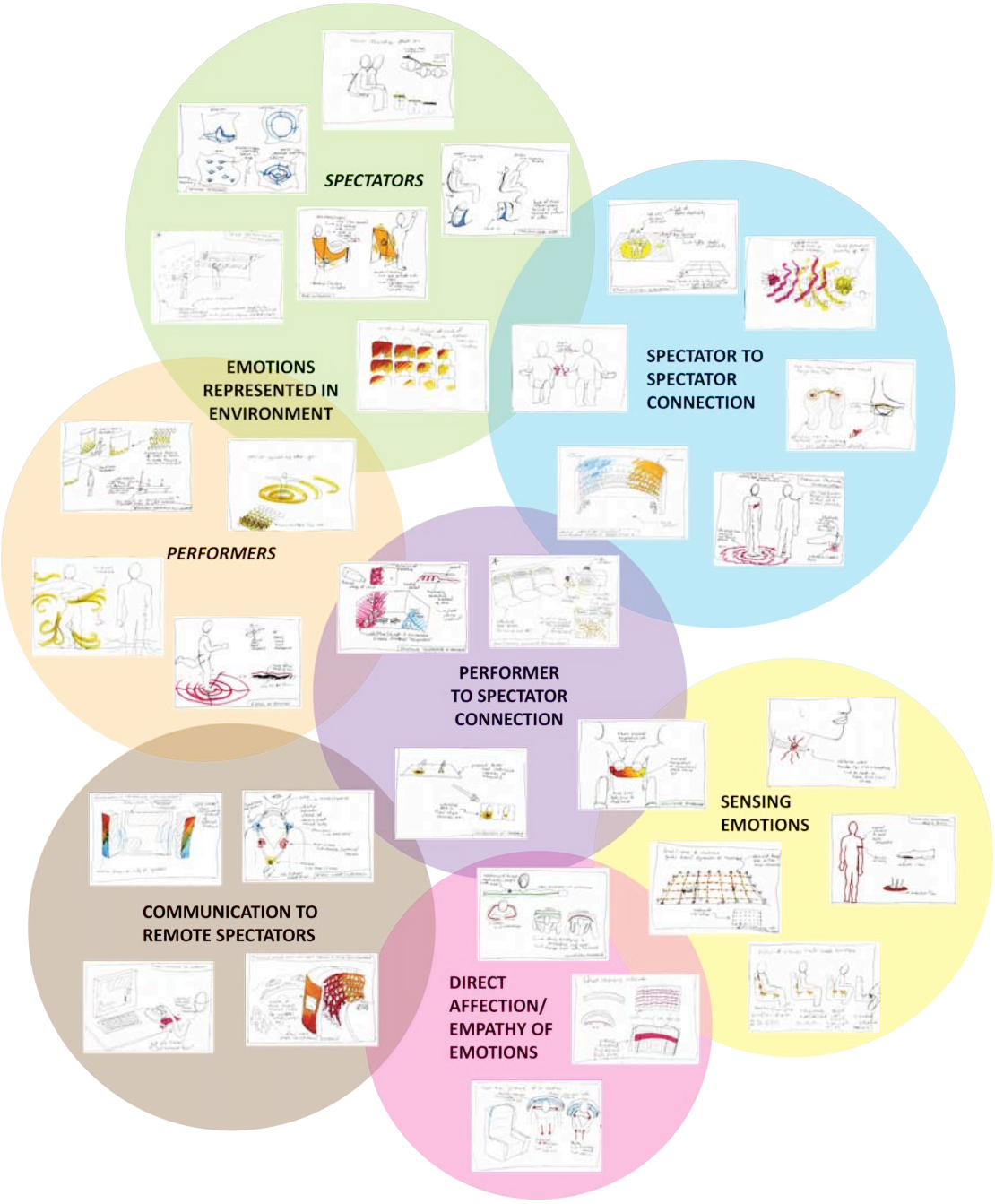
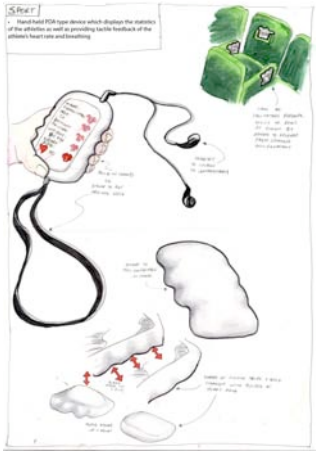
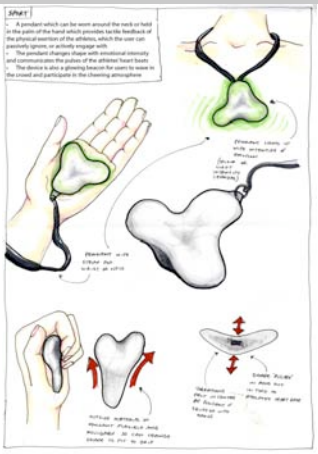
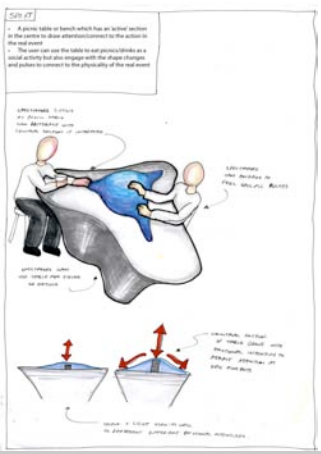
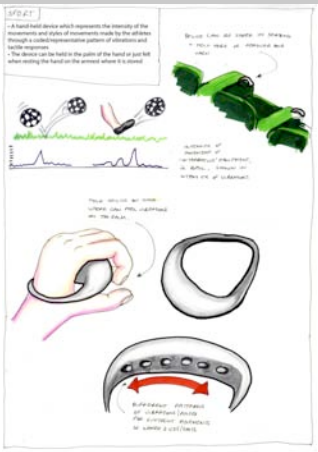
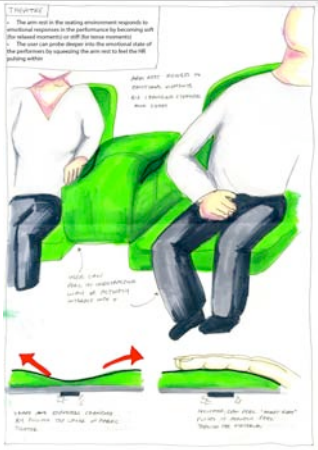
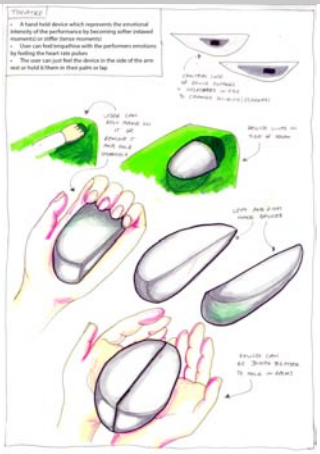
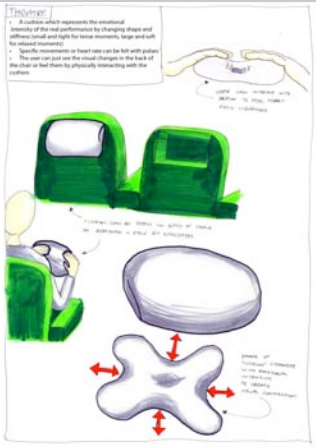
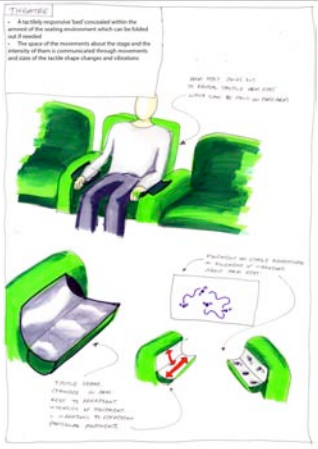


Figure 12: Concept Theme Map

2. CONCEPT BRIEF DEVELOPMENT AND USER FEEDBACK

	SPORT		
	CONCEPT SKETCH	CONCEPT BRIEF	USER FEEDBACK
EXPERT SPECTATOR		– Hand-held PDA type device which displays statistics of athletes as well as providing tactile feedback of the athlete's heart rate and breathing – 'Plug into ' seat or pay for use of extra 'channel' – Enhances experience by having deeper connection to athlete's physiology	– *'It would aide my knowledge and understanding more than my viewing experience'* – *'It would be nice to feel the heart rate'* – *'I like that it is small and easy to hold/wear around neck so it isn't something the person has to use all the times in an exciting match'*
NOVICE SPECTATOR		– A pendant worn around the neck or held in the hand which provides tactile feedback of the physical exertion of the athletes – The device becomes a glowing beacon for the user to wave in the crowd – Engages less interested spectators more by connecting them to the physicality of the action	– *'It would be nice to have a souvenir of the event'* – *'Being able to feel athletes' exertion adds to excitement and tension watching athlete'* – *'I would want to buy one to take to diff events and have my own'* – *'I like that it is a sort of glow stick as well to cheer with'*
REMOTE SPECTATOR		– A picnic table or bench which has an 'active' section in the centre to draw attention/connect to the action in the real event – User can engage with the shape changes and pulses – Provides something which users can engage with to feel more physically connected and engages in the real event	– *'I like the idea of connecting the action to the remote picnic area; it would add to the atmosphere'* – *'I would like information as well as emotion'* – *'It would be good for kids'*
IMPAIRED SPECTATOR		– A hand-held device which represents the intensity of the movements and styles of movements through tactile responses – Signals generated which represent actions e.g. contact with ball, specific movements – Tactile feedback can help visualise the actual movements better	– *'It can be a good device for impaired people that also benefits normal users'* – *'It would give good sense of the different pace of action throughout the match'* – *'A feeling in your hand about the intensity of the action would make you feel more part of the action'*

	THEATRE		
	CONCEPT SKETCH	CONCEPT BRIEF	USER FEEDBACK
EXPERT SPECTATOR		– The arm rest in the seating environment responds to emotional responses in the performance by changing texture – The user can feel the heart rate of the performers pulsing within the arm rest – Tactile response of the environment creates a direct connection between the performer and the user	– *'The passive response of environment interesting'* – *'Completely different sense from seeing and hearing'* – *'It's nice to have something moving in your chair or in your lap to feel it and add to the intensity'* – *'It would enhance sensory and feeling experience to add what is seen on stage'*
NOVICE SPECTATOR		– A hand held device which represents the emotional intensity of the performance by becoming softer (relaxed) or stiffer (tense) – User can feel/empathise with the performers emotions by feeling the HR pulses – 'Active' device to interact with and extend the performance/interest of the user	– *'It needs to be either passive and incorporated into environment or actively engaged/hand-held'* – *'It is more versatile than fixed seat'*
REMOTE SPECTATOR		– Cushion which represents the emotional intensity of the real performance by changing shape and stiffness – Specific movements or HR can be felt with pulses – The user can just see the visual changes in the back of the chair or feel them by physically interacting with the cushion	– *'I like this more than individual small hand held, can hug during performance or provide back or head support'* – *'It could be a targeted addition to the performance'* – *'It would be nice to have it in your hands and feel it change in your lap'*
IMPAIRED SPECTATOR		– A tactilely responsive 'bed' concealed within the armrest of the seating environment which can be folded out if needed – The space of the movements about the stage and the intensity of them is communicated through movements and sizes of the tactile shape changes and vibrations	– *'It shouldn't be considered a specifically 'accessible' tool'* – *'I like idea of being able to track movement'*

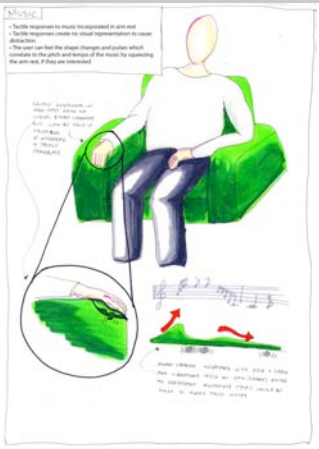
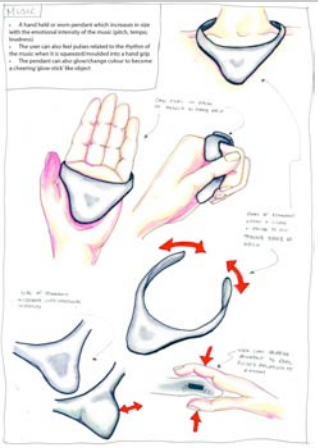
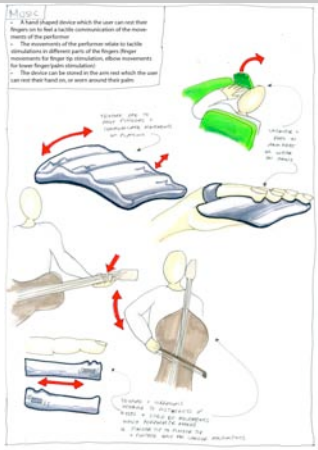
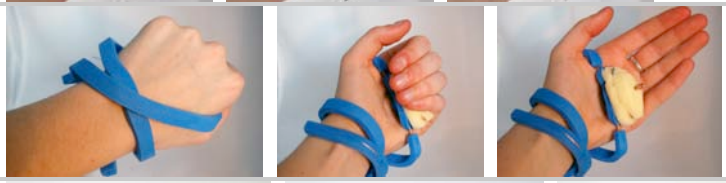
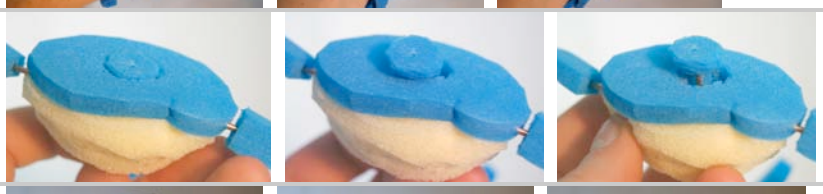
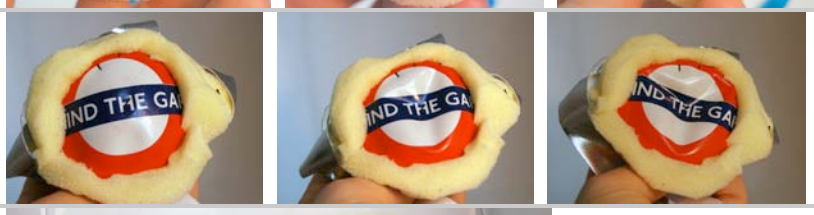
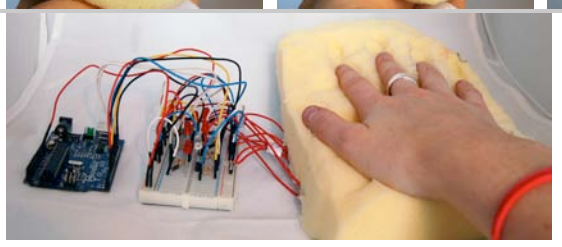
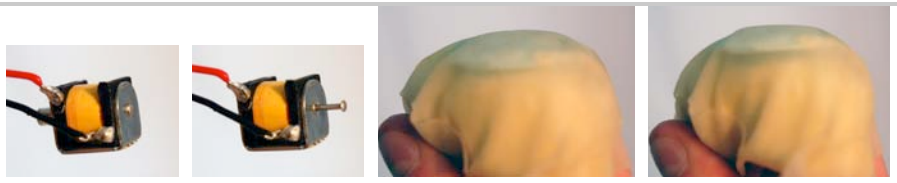
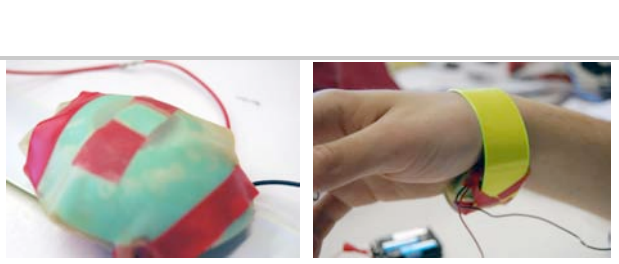
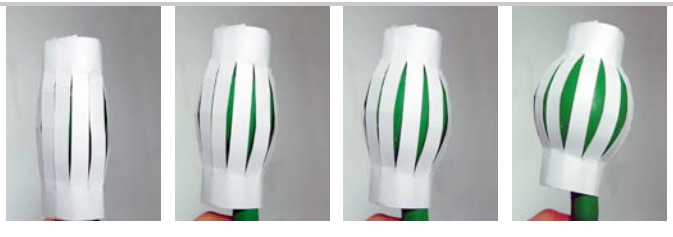
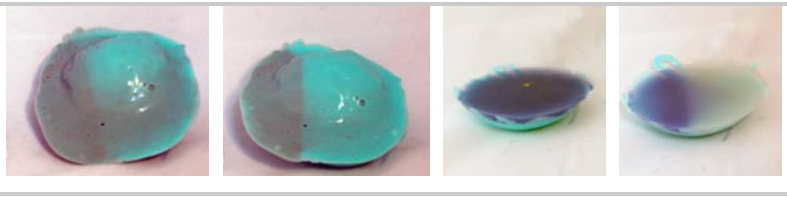
	MUSIC		
	CONCEPT SKETCH	CONCEPT BRIEF	USER FEEDBACK
EXPERT SPECTATOR		– Tactile responses to music incorporated in arm rest – User can feel the shape changes and pulses which correlate to the pitch and tempo of the music by squeezing the arm rest if they are interested – A tactile response in the environment to engage more senses in the experience	– *'Good to be targeted at sensitive hand area'* – *'Good for hearing impaired people, also for children'*
NOVICE SPECTATOR		– A hand held or worn pendant which increases in size with the emotional intensity of the music – The user can also feel pulses related to the rhythm of the music – Personal interaction with device enhances connection to music/performer and enhances emotional empathy	– *'I like that the spectator can 'feedback' into crowd'* – *'It would be good to have something that you can connect to the performer but also respond to them yourself by participating in crowd'* – *'I would like it to be my own, as it's then mine to use how I want'*
REMOTE SPECTATOR		– A shape responsive glow stick which can be held and waved in the crowd – The top of the glow stick enlarges in size with intensity of music to change shape and reveal more colour/glowing light – Vibrations/pulses relating to the music can also be felt in the hand	– *'I like that it 'reveals' itself as emotion builds'* – *'I like that it changes shape for others to see and enjoy but also adds to music experience with pulses and vibrations with melody/beat'* – *'I would buy it if I could travel easily with it'*
IMPAIRED SPECTATOR		– A hand shaped device which the user can rest their fingers on to feel a tactile communication of the movements of the performer – The movements of the performer relate to tactile stimulations in different parts of the fingers	– *'The movements made making the music is an interesting angle that you don't really think about'* – *'It would be good for visually impaired or for intense study of detail'*

Table 10: Concept brief, sketch and user feedback for each user profile

IV. PROTOTYPE DEVELOPMENT

Early prototype development included models to show changing textures in an environmental scale, models to show the interactions of the device in the hand, models to simulate a range of tactile communications, and models with changing shapes, lights and colours for the user to feedback their emotional response to the other spectators and athletes.

		PROTOTYPE	COMMENTS
ENVIRONMENT	ARM REST		– The stiffness of the arm rest changes to represent the emotional atmosphere (soft for relaxed, hard for tense)
	CUSHION		– The shape of the cushion changes to represent the emotional atmosphere (soft for relaxed, hard for tense)
HAND HELD DEVICE	GRIP IN PALM: HOLD		– The memory foam hand held device conforms to the shape of the users hand, becoming a 'stress ball' as they become more tense during the action
	GRIP IN PALM: WRAP AROUND		– The small device can fit into the palm and wrap around the hand or wrist to secure it
TACTILE COMMUNICATION DEVICE	'FEELS LIKE' MODEL: SINGLE POINT		– A small section of the hand held device pulses to create a 'tapping' sensation in the palm of the hand to represent the beating of a heart
	'FEELS LIKE' MODEL: SINGLE POINT TAPPING		– The whole area of the device in contact with the palm moves in and out to represent the pulsing of a heart rate
	ELECTRONIC STIMULATION: MULTIPLE ARRAY		– An array of vibration stimulations across the fingers and palm create a representation of different movements across the stage or pitch or different movements of the performers body
	ELECTRONIC STIMULATION: SOLENOID		– A solenoid moves a section of the device in and out which can be felt in the palm of the hand to represent the beating of a heart
	ELECTRONIC STIMULATION: SOLENOID		– A solenoid taps out a beating heart rate in a recess in the device which can be distinctly felt on the wrist or palm
CROWD COMMUNICATION DEVICE	GLOWING LED: TRANSPARENT CASE		– Different glowing lights in a hand held device represent different actions being observed or different emotional responses
	GLOWING LEDS: OPENING CASE		– The device opens up and reveals a glowing colour as the emotional intensity of the action increases
	THERMO-CHROMIC SAMPLES		– The colour of the device is changed by the changes in the users own body temperature

V. ANALYSIS OF EMOTIONAL RESPONSE TO VIEWED SPORTS EVENT

Figure 13 below shows the baseline heart rate (the lowest level to which the heart rate returned) increased steadily from 50bpm to 70bmp over the 90 minute duration of the match. The actual trend line shows polynomial characteristics, but for simplicity, the relationship between the increase in baseline heart rate (HR_{BL}) and the time passed in the match (t) will be considered linear, with a gradient of (70-50)/90 = 0.22bpm/minute, and can therefore use the following formula:

$$\mathbf{HR_{BL}\ (bpm) = 50 + 0.22t}$$

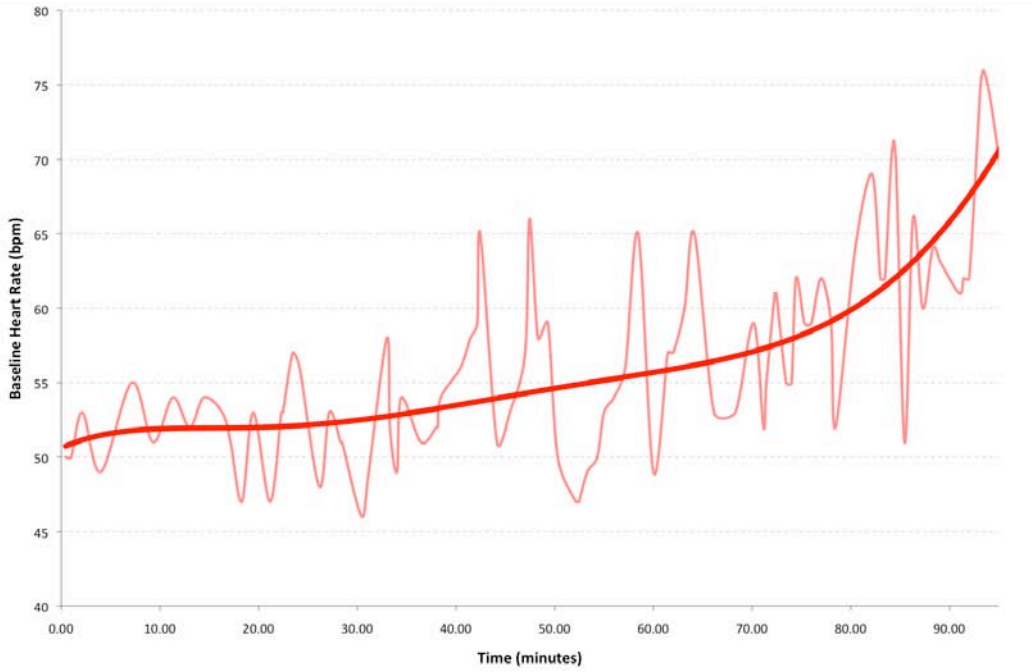


Figure 13: Graph of Baseline Heart rate over time

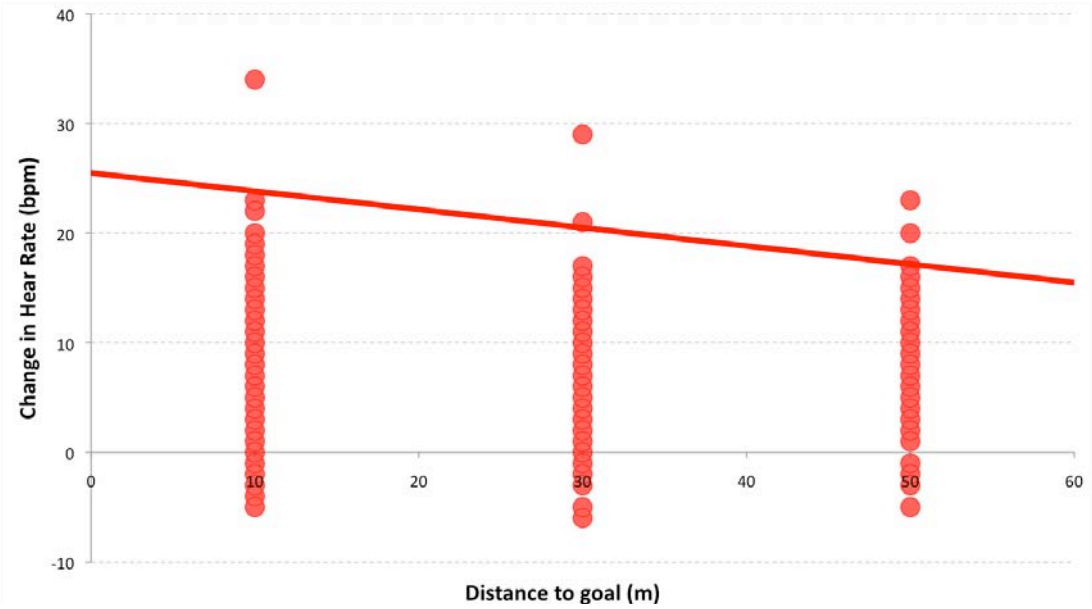


Figure 14 below shows the change in heart rate with the distance to either goal (i.e. 60m from either goal is the middle of the pitch, and 0m from either goal is at the goal). The maximum change in heart rate increases from approximately 16bpm when the action is in the middle of the pitch, i.e. distance to goal equals 60m, to 26bpm when the ball is at the goal, i.e. the distance to the goal is zero. A simple linear relationship, with a gradient of (16-26)/60 = -0.167bpm/metre, can be applied here to approximate the increasing change in heart rate (HR_{INC}) with decreasing distance to goal (d):

$$\mathbf{HR_{INC}\ (bpm) = 0.167*(60 - d)}$$

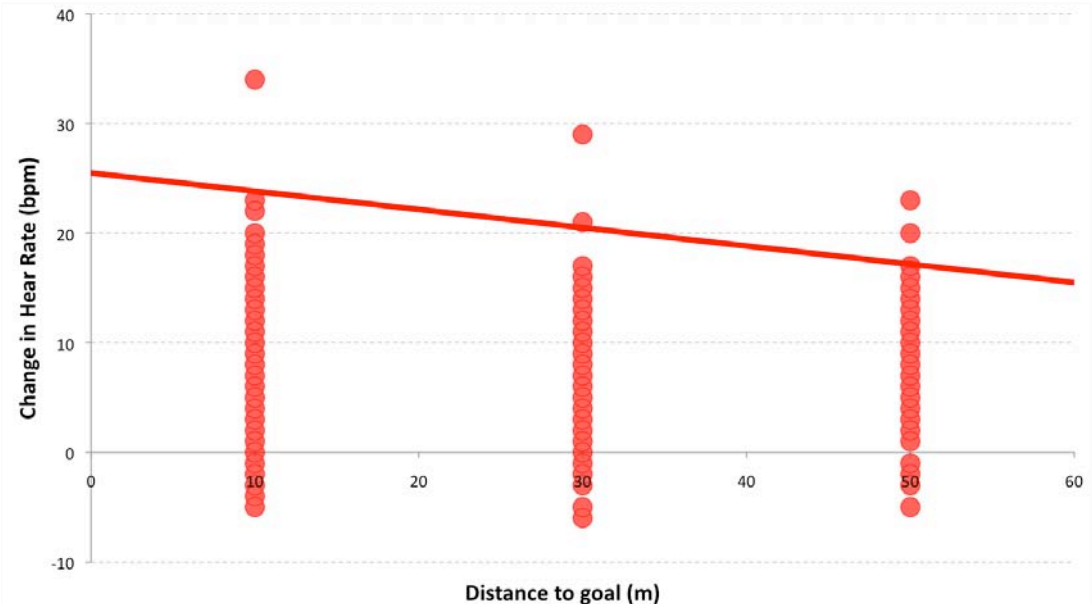


Figure 14: Graph of change in heart rate with distance to goal

Figure 15 below shows the change in heart rate with the speed of the action, i.e. how fast the ball is moving up and down the pitch.). The maximum change in heart rate increases from approximately 9bpm when the action is slow, i.e. speed equals

0m/s, to 19bpm when the action is faster, i.e. the speed is over 5m/s. Up to 5.33m/s, the relationship between the maximum change in heart rate and the speed of the action is fairly linear, therefore, the a simple linear relationship, with a gradient of (19-9)/5.33 = 1.88bpm/(m/s), can be applied here to approximate the increasing change in heart rate (HR_{INC}) with speed of action (s):

$$\mathbf{HR_{INC}\ (bpm) = 1.88*s}$$

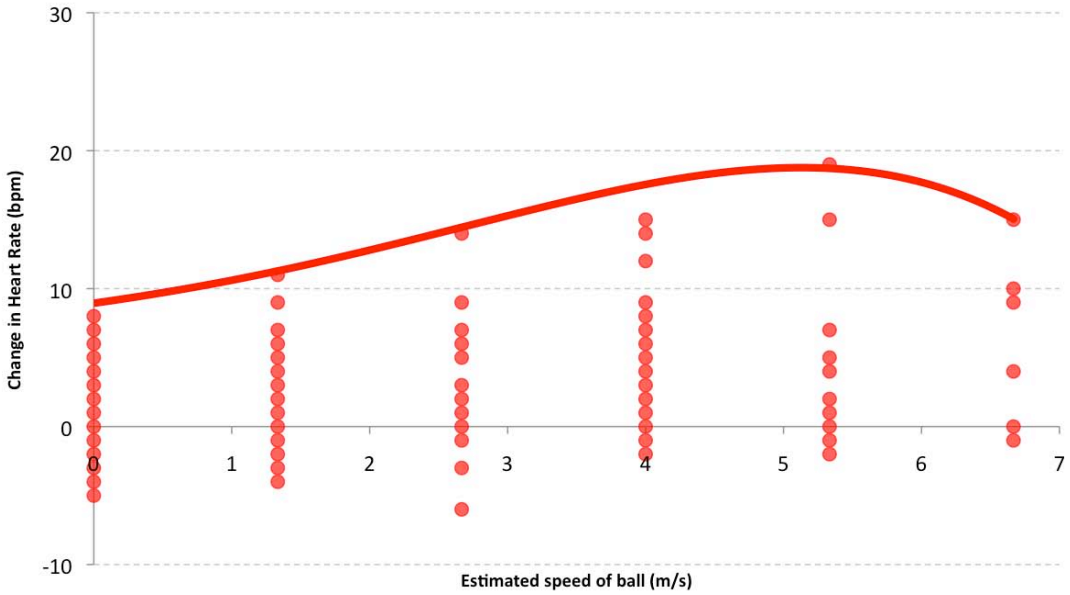


Figure 15: Graph of change in heart rate with estimated speed of the ball

Analysis of the increase in heart rate with different types of action is shown in Figure 16 below. Peaks in heart rate activity have been correlated to the type of action occurring in the match; passing, tackling, free kick, corner, and goal shot. For plain passing action, the change in heart rate ranged from -3bpm to 3bpm. For tackling actions, the change in heart rate ranged from 3bpm to 7bpm. For a free kick, the change in heart rate ranged from 7bpm to 17bpm. For a corner shot, the change in heart rate ranged from 17bpm to 22bpm. For a goal shot, the change in heart rate ranged from 22bpm to 35bpm. Considering the effect on the change in heart rate each of these types of action has, a set of scaling factors can be derived which will take into account the different emotional response of different situations in the action:

Passing scaling factor = 1
Tackling scaling factor = 1.5
Free kick scaling factor = 2
Corner scaling factor = 2.5
Goal shot scaling factor = 3

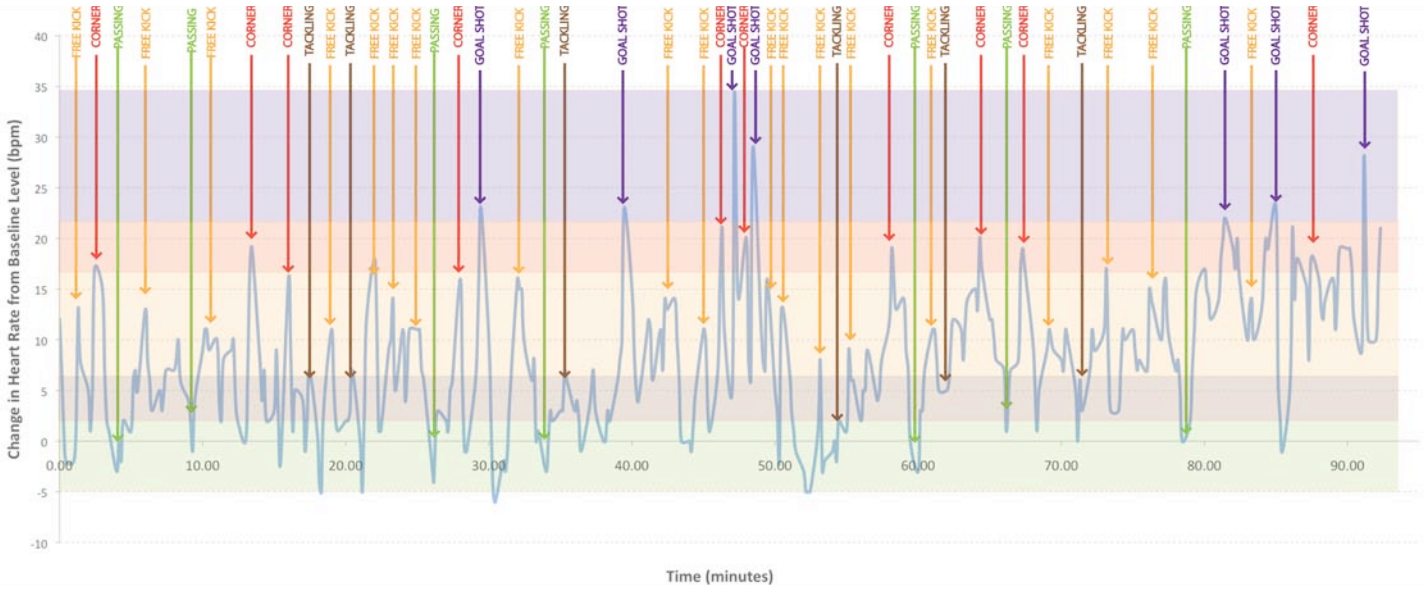


Figure 16: Analysis of change in heart rate or different types of action

Interviews of the expert spectator from whom the data was collected highlighted the importance of understanding the ranking of the skills of the individual players, and how that affected the emotional response while watching the action. Knowledge of the skills of a player added to the emotional response by increasing or decreasing the anticipation of a goal or exciting moment according to the known capabilities of the player in a certain situation. The skills of the players in one of the teams in each of the types of action analysed above were ranked from 1 to 5 (1 is very capable in that type of action, 5 is not as capable), and can be seen in Figure 17. Considering the effect the player's skill in a certain situation has on the emotional response, another set of scaling factors for the rank of the players were developed:

Player rank 1 scaling factor = 1
Player rank 2 scaling factor = 0.9
Player rank 3 scaling factor = 0.8
Player rank 4 scaling factor = 0.7
Player rank 5 scaling factor = 0.6

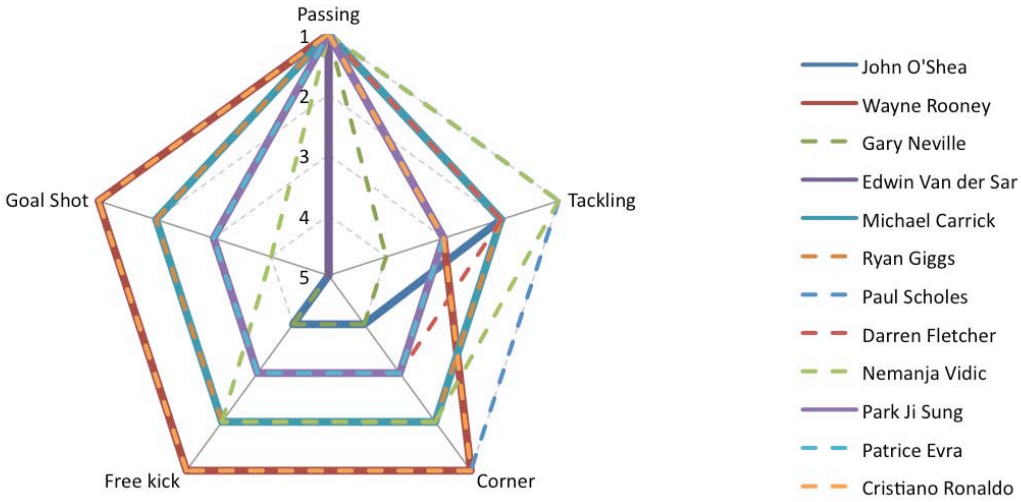


Figure 17: Player skills ranking

VI. INDUSTRIAL DESIGN

Figure 18: Colour analysis chart for range of sport events

VII. ENGINEERING DRAWINGS

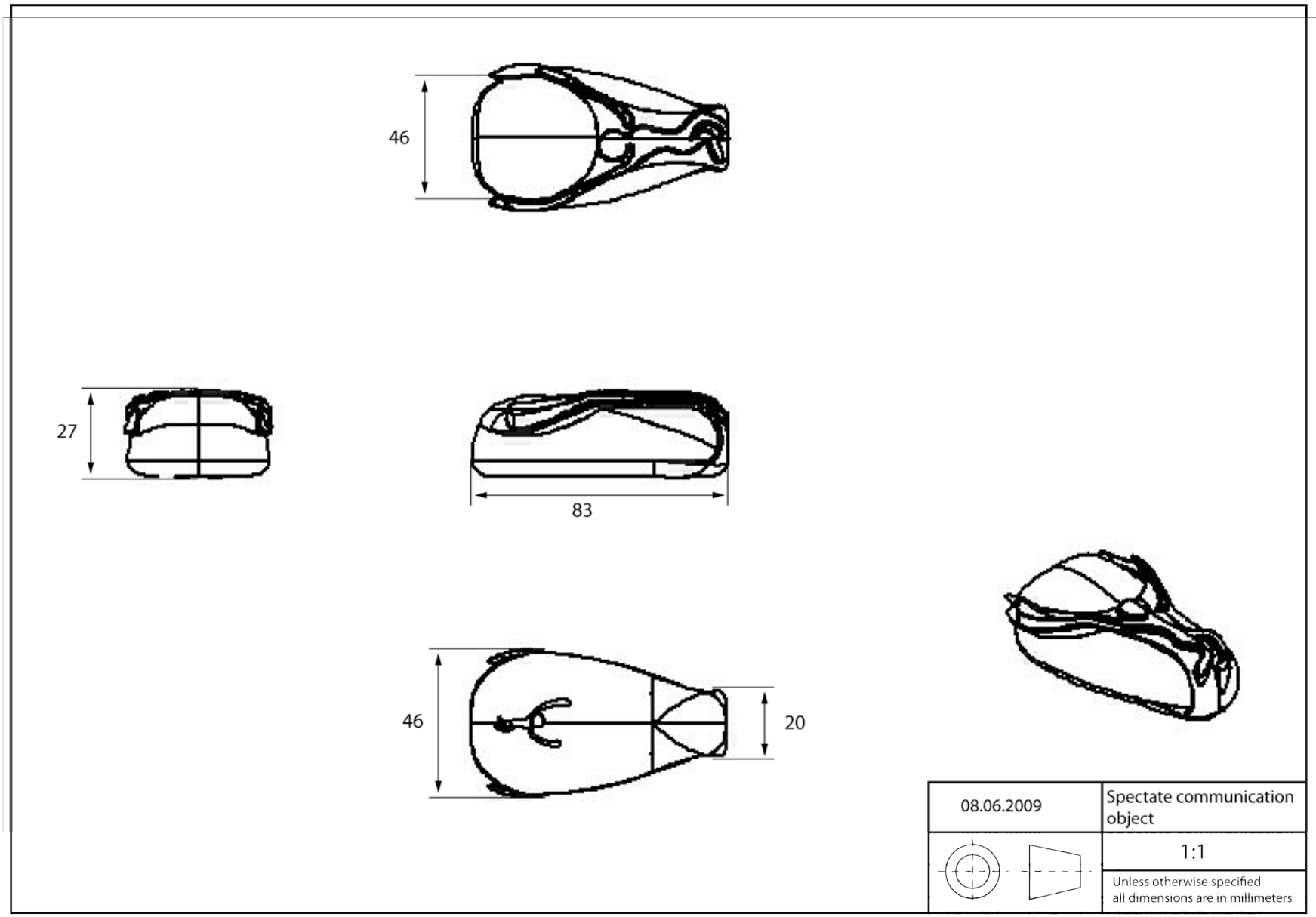


Figure 19: General assembly of product

VIII. BSI STANDARDS

- BS EN 62115:2005 Electric toys. Safety
- BS EN 61000-6-1:2007 Electromagnetic compatibility (EMC). Generic standards. Immunity for residential, commercial and light-industrial environments
- BS EN 62369-1:2009 BS EN 62369-1:2009. Evaluation of human exposure to electromagnetic fields from short range devices (SRDs) in various applications over the frequency range 0 GHz to 300 GHz. Fields produced by devices used for electronic article surveillance, radio frequency identification and similar systems
- PD ISO/IEC TR 24714-1:2008 PD ISO/IEC TR 24714-1:2008. Information technology. Biometrics. Jurisdictional and societal considerations for commercial applications. General guidance

IX. FINANCIAL PROJECTIONS

COMPONENT	2009	2010	2011	2011
MARKET PROJECTIONS				
NUMBER OF SCREENS	16	16	16	20
NUMBER OF EVENTS PER SCREEN	10	10	15	25
AVERAGE SPECTATORS PER EVENT	4000	4000	4000	6000
TOTAL NUMBER OF SPECTATORS	640000	640000	960000	3000000
EXPECTED MARKET	32000	32000	48000	150000
COSTS				
DEVELOPMENT	20000			
TOOLING	10000	10000	10000	30000
MANUFACTURE	0	216640	324960	1015500
DISTRIBUTION	0	8000	12000	25000
TOTAL	30000	234640	346960	1070500
REVENUE				
GROSS REVENUE	0	319680	479520	1498500
NET REVENUE	0	272068	408102	1275319
GROSS PROFIT	-30000	85040	132560	428000
NET PROFIT	-30000	37428	61142	204819

Table 11: Financial projections

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