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# Theory of constructed emotion meets RE: An industrial case study☆

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ABSTRACT

Emotional requirements should be treated as first-class citizens rather than subsumed under "non-functional" requirements. This follows already from three primary elements of persuasion by Aristotle, being *logos*, *ethos* and *pathos*, which respectively stand for function, quality and emotion. Eliciting and representing emotional requirements should be based on up-to-date emotion theories, which are backed by cognitive psychology and neuroscience. The most promising among them is the theory of constructed emotion. Accordingly, this paper aims to find out what are the advantages of grounding requirements engineering in the theory of constructed emotion. We also aim to explore the possible methods or techniques that support the construction of emotions in the requirements engineering process for building emotion aware systems and how they could be utilised by stakeholders of a sociotechnical system with different backgrounds. By utilising the action design research method, we first formulate an appropriate methodology and then apply it for building and evaluating an artefact, which in our case study consists of the animations shown on the Media Wall. The main contribution of our paper is an original repeatable methodology for eliciting and representing requirements for interdisciplinary design projects aimed at designing software-intensive emotive artefacts. The methodology is rooted in the theory of constructed emotion. Although the proposed methodology can in principle be used for designing and developing any sociotechnical systems, a particular variation of the methodology proposed in this paper is geared towards designing and developing emotive artefacts that have the purpose to co-construct certain emotions among the stakeholders and the audience with the goal to further particular societal issues.



## 1. Introduction

Rosalind Picard pioneered affective computing in 1995 as "computing that relates to, arises from, or influences emotions" (Picard, 2000). This research field bridges the gap between humans and machines and primarily focuses on human emotions. Affective computing has gained attention from various domains, including neuroscience, psychology, education, medicine, sociology, and computer science. In software engineering, emotions have been studied in different phases of the software lifecycle. For example, emotions and sentiment analysis support the user requirements prioritisation process in the requirements engineering phase. The study Ferrari et al. (2021) analyzes the biometric data complementing the interviews to prioritise requirements for product improvement and steer the interviews based on the users' engagement. The user feedback obtained from the app stores and social media such as Twitter and Facebook has also been analysed for the sentiments by the users expressed in textual review formats for improving software applications (Williams and Mahmoud, 2017; Guzman and Maalej, 2014; Iqbal et al., 2019, 2021). Another research direction in the software engineering domain focuses on developers emotions and impact of emotion on their productivity (Fountaine and Sharif, 2017; Müller and Fritz, 2015).

Several methods are used to measure a person's emotional state based on the existing psychological theories. One method is to analyse words and sentences and assigns weights to emotional words, such as love, shame, and hate. For this method, multiple tools can be used for deducting the emotional state like SentiStrength,[1] Stanford NLP sentiment analyzer,[2] and NLTK.[3] Another method is to utilise biometric data such as eye gaze,

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[1] http://sentistrength.wlv.ac.uk/
[2] https://stanfordnlp.github.io/stanfordnlp/
[3] https://www.nltk.org/

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0164-1212/

heart rate, and galvanic skin response for deducting a subject's emotional state (Ferrari et al., 2021; Fountaine and Sharif, 2017). The current research also focuses on using emoticons and emojis for emotional awareness and understanding (Brants et al., 2019).

The research results presented in the exciting studies (Mendoza et al., 2013; Ramos and Berry, 2005; Pedell et al., 2013; Miller et al., 2015, 2012) have revealed that software engineers fail to give fair consideration to the emotional needs of users when designing systems and point out that emotional needs have not been successfully addressed in the software engineering field.

Several researchers have claimed that emotional requirements should be treated as first-class citizens, in addition to functional and non-functional requirements (Miller et al. (2015), Mooses and Taveter (2021), Taveter et al. (2019), Mooses et al. (2022)). Considering this, we propose to employ an existing well-known theory—*theory of constructed emotion* Barrett (2017a) in the requirements engineering (RE) process, which was first proposed in Taveter and Iqbal (2021) and was elaborated for the domain of design in Marshall (2021). To the best of the authors' knowledge, this is the first study of its kind that uses the theory of constructed emotion to elicit and integrate emotional requirements at the early stage of the software development process. This is done in the context of sociotechnical systems (Mumford, 2000), which clearly distinguishes between social or human and technical aspects of a software intensive system. The main goal of this study is to understand how the theory of constructed emotion facilitates the requirements engineering process, and to achieve this goal, we investigate the following research questions:

> RQ1: What are the advantages of applying the theory of constructed emotion in the requirements engineering process?
> RQ2: What are the possible methods or techniques that support the application of the theory of constructed emotion in the requirements engineering process for developing an emotion aware sociotechnical system?
> RQ3: How is the proposed methodology helpful for stakeholders of a sociotechnical system with different backgrounds?

For answering the research questions RQ1, RQ2 and RQ3, we employ the research method of action design research (Sein et al., 2011). According to the action design research method, the initial stage of problem formulation is followed by building an artefact, using the artefact, evaluation, reflection and learning, and generalisation of the learning outcomes. The last stage results in the design principles that are articulated for the chosen class of systems. In this paper, the artefact to be built is the Collins Street 644 Media Wall in Melbourne, Australia. The artefact is iteratively evaluated by the stakeholders of the 644 Media Wall project. The design principles are embodied in the resulting methodology for designing the emotion-aware sociotechnical system that is put forward in this paper.

This paper is structured as follows: Section 2 introduces various existing theories of emotion as a background and elaborates on three different aspects of the theory of constructed emotion. In Section 3, we discuss our case study project and its related details. Section 4 discusses the requirements elicitation process for our case study and outlines our proposed methodology pipeline. In Section 5, we illustrate two examples of our proposed methodology's application and report the results. Section 6 presents the discussion and analyzes threats to validity, and Section 7 concludes the paper.

## 2. Background

Theories of emotion can be divided into theories of basic emotion, appraisal theories of emotion, and theory of constructed emotion. In the subsequent Sections 2.1–2.3, we will provide an overview of each group of emotion theories.

### 2.1. Basic emotion theories

According to basic emotion theories, there exists a set of innate discrete emotions shared among different organisms that appear to be similar and comparable across different cultures and societies (Panksepp, 2000). According to Barrett (2017b), basic emotion theories claim that emotions are natural types whose instances share a physical fingerprint, such as a set of facial movements (an expression) and a pattern of autonomic nervous system activity. A well-known proponent of the theories of basic emotion Ekman (1992) claims that the six basic emotions are anger, disgust, fear, happiness, sadness, and surprise. However, scientists have not been able to agree on which emotions are basic or natural types (Ortony and Turner, 1990).

### 2.2. Appraisal emotion theories

In appraisal[4] emotion theories, emotions are viewed as judgments by an individual concerning the relationships between life events and situations on the one hand and the individual's environment on the other (Lazarus and Lazarus, 1991; Frijda et al., 1986; Ortony and Turner, 1990). For example, a person may appraise or evaluate a particular situation as dangerous, which triggers the corresponding emotion of fear. The third author of this paper remembers a situation of this kind from Kruger National Park in South Africa where it was easy to imagine that the mane of a lion could be seen behind the bush. According to the appraisal emotion theories, appraising this situation triggered the emotion of fear.

### 2.3. Theory of constructed emotion

Our paper is concerned with a particular theory of emotion—the theory of constructed emotion Barrett (2017b,a). The theory of constructed emotion is backed by findings in neuroscience (Barrett, 2017b). According to the theory of constructed emotion, instances of emotion concepts are constructed by the brain to help us to achieve our goals in social situations by changing the body balance in the service of allostasis—managing and allocating the energy levels in the body. For example, the brain constructs an instance of the emotion concept happiness with reference to a particular goal in the situation, such as spending time with friends, enjoying a meal, or accomplishing a task, in the service of allostasis (Barrett, 2017b). This implies that the emotion concept happiness has a generic meaning, but its specific meaning changes from one emotion instance to the next (Barrett, 2017b). Different emotions may be constructed to support the attainment of different goals. For example, if the goal is romantic love, the emotions *passionate*, *longing* and *lustful* may be constructed which make this goal more attainable. Differently, if the goal to be attained is tough love or brotherly love, respective instances of the emotions *disciplined* and *bonded* may be constructed (Barrett, 2017a).

Theory of constructed emotion declares that emotions are produced by combinations of the same elementary components (Posner et al., 2005), the most agreed ones among them being the type of valence and extent of arousal (Hamann, 2012). Valence and arousal determine core affects, which are not emotions but much simpler feelings (Russell, 2003). Valence characterises how pleasant or unpleasant one feels, while the feature of arousal is concerned with how calm or excited one feels. According to Russell (2003), examples of core affects are excited (high pleasure, high arousal), calm (high pleasure, low arousal), tired (low pleasure and low arousal), and tense (low pleasure and

[4] Not to be confused with appraisals treated in Section 4.3.

**Table 1**
Comparison of emotion theories.

| Question | Basic | Appraisal | Theory of constructed emotion |
|---|---|---|---|
| Are emotions unique mental states? | Yes | Yes | No |
| Are emotions caused by special mechanism? | Yes | Varies by model | No |
| Do emotions have unique manifestations? | Yes | Varies by model | No |
| Does each emotion have unique response tendency? | Yes | Varies by model | No |
| Is experience a necessary feature of emotions? | Varies by model | Yes | Yes |
| What is universal? | Emotions | Appraisal | Affects and social situations |

high arousal). Unlike an emotion, a core affect is not a cognitive concept (Zajonc, 2000) and is an inherently nonlinguistic entity like felt body temperature (Russell, 2003). The immediacy of core affects and the subsequent bodily responses make them easier to be automatically detected using physiological measures, such as detecting excitement with a heart rate measurement. Within a sociotechnical system, such reactions are often quantifiable after a single engagement with the technology in question for purposes such as evaluating the effects of (techno) stress or pleasure during online trading.

In Table 1, we summarise and compare basic emotion theories, appraisal emotion theories and theory of constructed emotion. We do this in terms of six interrelated questions and responses to them, adapted from Gross and Feldman Barrett (2011). The comparison shows that according to the theory of constructed emotion, our emotions are *not* unique mental states with unique manifestations and unique response tendencies. Our emotions are rather our *experiences* constructed by ourselves in terms of core affects and social situations. According to Barrett (2017a), these characteristics enable us to architect the emotions to be felt, which we take advantage of in the case study described in Sections 3 and 5.

In the following Sections 2.4–2.6, we will be looking at the three particular aspects of the theory of constructed emotion: emotional granularity, emotion co-construction, and collective intentionality.

### 2.4. Emotional granularity

A person develops emotion concepts through contextualised social interactions in which language plays a significant role (Hoemann et al., 2019). Words are also the key instruments in instantiating emotion concepts—i.e. constructing emotions (Gendron and Barrett, 2018).

*Emotional granularity* refers to having more nuanced descriptions of emotions. For example, the feeling *sadness* is a general description of one's valence and arousal, whereas the feeling *quandary* is more specific (Marshall, 2014). Emotional granularity refers to the amount of specific emotions that fall within the same level of valence and arousal, that a person can distinguish between and name. It has been shown that people with high levels of emotional granularity experience many benefits, including being generally healthier (Barrett, 2017a).

As an example of a highly specific emotion is the Japanese emotion concept of *mono no aware* which describes the despair felt at the impermanence and transience of life, especially in its most satisfying moments when our love for others, and their need for us, feel so unexpectedly overwhelming – and life so very fragile and temporary – that we become very sad (Wells, 2018). This is a good example of a complex emotion that involves feeling love, sadness, and overwhelmedness at the same time. One of the advantages of the theory of constructed emotion in requirements engineering is its capability to support the representation of complex emotions, such as *mono no aware*, and real-life situations to which these emotions relate.

### 2.5. Emotion co-construction

Since other people can perceive emotions constructed in one person's mind via sensory input like facial actions, utterances, and body movements, emotions usually involve *emotion co-construction*. For example, an utterance, such as "you look sad", impacts the next state of the conversation partner. From this perspective, emotions are episodes or situations that are socially constructed or co-constructed between individuals (Gendron and Barrett, 2018). We can accordingly elaborate the definition of emotions by stating that emotions experienced by us are co-constructed in three embedded contexts: in-the-moment interactions, relationships, and cultural contexts (Boiger and Mesquita, 2012).

Emotion co-construction is also rooted in the theory of predictive mind (Clark, 2013; Hohwy, 2013; Clark, 2015; Friston et al., 2017), according to which the brain runs a generative model of the world, using past situations to anticipate and respond to future sensory events, and correcting those representations with the incoming sensory information that was not predicted. The extent to which the incoming sensory input disagreed with prediction signals is called *prediction error* (Barrett, 2017b; Hohwy, 2013; Clark, 2015). In this account, emotion co-construction can be reframed as synchronised conceptualisation – prediction and correction – between two or more people (Gendron and Barrett, 2018). Emotion co-construction can also occur through an artefact, such as a goal model or an animation.

### 2.6. Collective intentionality

As explained above, emotions are abstract and potentially complex concepts that may be defined and instantiated into existence through emotion co-construction using language. This implies that emotion concepts may be designed, and the construction of the respective emotions may be engineered. For defining new emotion concepts, theory of constructed emotion employs the notion of *collective intentionality* by John R. Searle, which forms a part of the theory of constructed social reality (Searle, 2006). As Feldman Barrett describes, to define a concept, first you need a group of people to agree that a concept exists, such as flower or cash or happiness. This shared and agreed knowledge is called collective intentionality (Barrett, 2017a, p. 134–135). Searle argues in Searle (2006) that collective intentionality is an entirely separate human mental state from individual intentionality. While individual intentionality (Searle, 2006) is described in the first-person singular forms, such as "I desire", "I believe", "I intend", collective intentionality is described in the forms like "we believe", "we desire", "we intend".

When applied to emotions, which are goal-based concepts (Barrett, 2017a, p. 144), the conclusion is that you cannot feel the emotion unless you know the concept, which is usually associated with a word. In other words, emotions like *fear*, *anger*, *cool*, *fun* and *happiness* are not in-built; they are learned and constructed.

**Table 2**
664 Collins Street Media Wall—stakeholder roles.

| Stakeholders | Roles | Description | Quantity | Time |
|---|---|---|---|---|
| Mirvac | Project manager, Building manager, Marketing officer | Primary client. Builder and Manager of 664 Collins Street | 3 | 200 |
| Grimshaw architects | Senior architect, Junior architect, Graphic designer, Industry liaison | Architects of the Southern Cross Precinct and suppliers of the design brief | 4 | 400 |
| Swinburne design manager | Executive producer | Creating and communicating the design intention and client liaison. | 1 | 600 |
| Swinburne lecturers | Manager and administrator, Max 7 programmer, Unity programmer, Motion graphics designer, Film producer, Information technologist | Production, art direction, teaching, expert critique, peer review content creation | 6 | 1200 |
| Swinburne students, 2017/18 | Designer/Developer | Content creation, peer review. | 50 Students 47 Produced, 26 Published | 47 × 75 = 3525 h |
| Swinburne students, 2018/19 | Designer/Developer | Content creation, Peer review | 30 Students, 28 Produced, 18 Published | 28 × 300 = 8400 h |
| Technical advisors | Video engineer, Data processing specialist | Advising on rendering and programming | 4 | 200 |
| Corporate initiatives | Project manager, Specialists from the Videro company, LED installers | Installers of the LED screen. Integration with screen drivers and scheduling software. | 10 | 200 |
| **Totals** | | | **108** | **14,725 h** |

## 3. Case study

This section describes the case study of developing software for the 664 Collins Street (664) Media Wall. The case study illustrates how the theory of constructed emotion may be applied in the requirements engineering process to construct emotions and develop aesthetic experiences through real-world software applications. The 664 Media Wall is a particularly well-suited example for our paper, as the primary functional goal of the project was to produce an *emotive* "cultural artefact".

### 3.1. What is 664 Collins?

The 664 Collins Media Wall (or 664 for short) is a massive public artwork and a principal design element of the Southern Cross Railway Station in Melbourne, Australia. The station took thirteen years to build and won the prestigious Lubetkin Prize for the most outstanding building. The Southern Cross Station serves approximately 280,000 people per day and includes a retail plaza and a major office building. The office building straddles the station, with its lobby located on Melbourne's iconic Collins Street. The 664 Collins Street office block is designed by Grimshaw Architects and built and managed by the large Australian property development company Mirvac. As per the government requirement, new commercial property developments must contribute to producing Australia's social capital. Grimshaw and Mirvac dedicated the foyer of 664 Collins to championing the arts to fulfil this government requirement. A large LED video screen was envisaged for the foyer with 7.5 by 8.5 meters and a pixel pitch of 3.2 mm, making it Australia's largest indoor LED screen. The foyer of 664 Collins Street is at the street level, next to the entrance of Southern Cross station, giving the 664 Media Wall a high level of public exposure to daily commuters. The Media Wall enables the presentation of a wider variety of artwork rather than static exhibits and provides opportunities for creating dynamic and responsive content. The Media Wall encourages the presentation of abstract ideas and employs new modes of representation to a diverse audience, considering its effects as a tool for cross-disciplinary communication.

### 3.2. Project requirements

The 644 Collins Media Wall aims to create new forms of urban storytelling by displaying them on the screen for a diverse audience. In addition to the goal of producing a cultural artefact, Mirvac and Grimshaw demanded that the project should be "data driven", enabling both real-time and pre-recorded asynchronous data feeds. Mirvac wanted the data to be collected, processed and presented as ever-evolving real-time generative artwork. Additional restrictions were that the outcomes could not use sound, display text, or enable people to interact directly with the screen.

This high-level project goal of being data driven had a significant effect on the subsequent project requirements and how emotions were constructed. The vision by Mirvac was that the content being displayed on the screen should be drawn from real data sources. There are numerous Media Walls around the globe with beautiful and engaging content that do this, such as "Wind of Boston" created by the artist Refik Anadol.[5] However, these data feeds are not live; rather, the Wind of Boston and other similar digital paintings are pre-rendered linear movies that run on a seamless loop. In contrast, Mirvac wanted the data to be collected and processed in real-time.

### 3.3. Stakeholders

The main stakeholders of the project were the two companies Mirvac and Grimshaw and the design team from the Swinburne University of Technology (see Table 2). The Swinburne design team working on the 664 Media Wall included senior academics and students from Swinburne Design, Architecture, Astrophysics and Supercomputing, Data Science, and Smart Cities Research Institutes and Swinburne Interaction Design curriculum. Other contributors included the City of Melbourne Data Centre and the German-based software company Videro. Please note that each participating student performed both the roles of designer and developer, which is typical in digital media design projects such as Collins 664 Media Wall.

## 4. Methodology

This section describes how the overall project requirements for the 664 Collins Media Wall were elicited and represented

[5] https://refikanadol.com/

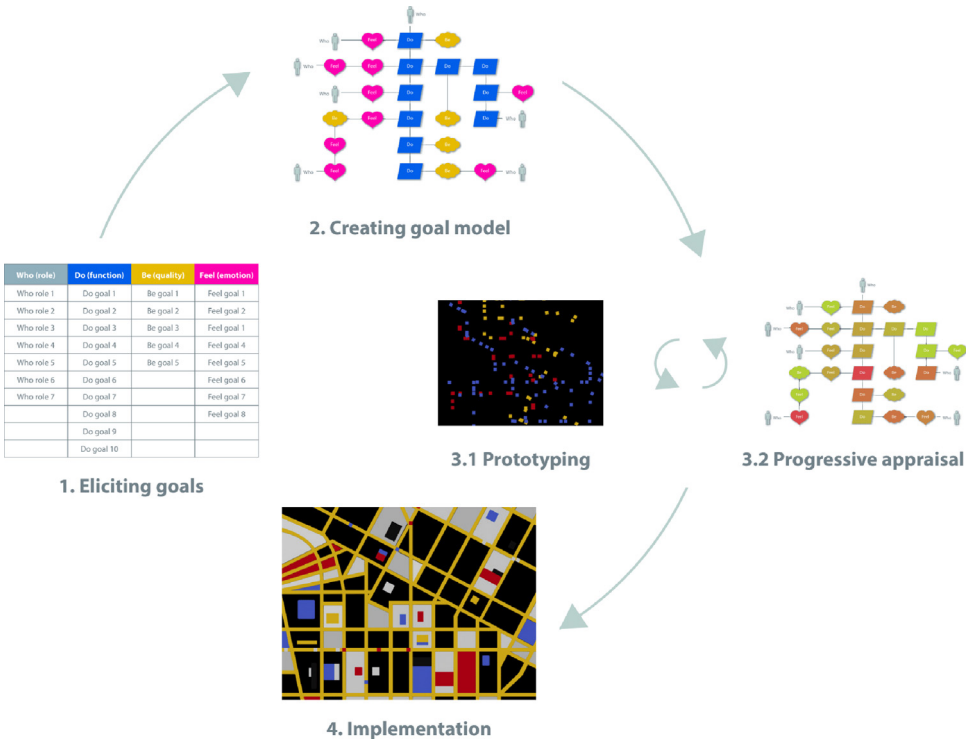


**Fig. 1.** Methodology.

with the focus on addressing the emotional aspects of the project. For doing that, we proposed and applied the methodology represented in Fig. 1 that is consistent with the theory of constructed emotion. Our case study demonstrates how the project's high-level emotional requirements were elicited from the primary stakeholders and communicated to the designers and developers of the Media Wall. In response, the designers and developers articulated their design intentions, specifying the emotions they aimed to achieve.

The requirements engineering method to be used in the project was driven by the need to consider the social context of the Media Wall, in addition to the technical requirements. In other words, we were looking for a method originating in a requirements engineering methodology appropriate for sociotechnical systems. The candidate methodologies of this kind were Tropos (Bresciani et al., 2004) and agent-oriented modelling (Sterling and Taveter, 2009; Miller et al., 2014, 2015; Sulis and Taveter, 2022).

An advantage of the methodology of agent-oriented modelling is that it explicitly includes the notion of emotional goals, whereas in Tropos human concerns, including emotions, are regarded as a subset of soft goals. Another advantage of agent-oriented modelling is that it is paired with the do/be/feel method of requirements elicitation and co-design (Lorca et al., 2018).

Consequently, we decided to elicit and represent the requirements, including the requirements about the emotions to be constructed, using agent-oriented modelling presented by Sterling and Taveter (2009) and Miller et al. (2014, 2015) and recently updated by Sulis and Taveter (2022). The method of motivational goal modelling included by agent-oriented modelling is highly compatible with the theory of constructed emotion for the following three reasons: (i) it uses the concept of an emotional goal supporting the attainment of some functional goal: (ii) it explicitly and systematically uses emotion words in the elicitation and representation of emotional requirements; (iii) it employs collective intentionality to design and instantiate new emotion concepts and engineer them into artefacts.

Agent-oriented models allowed us to represent both human activities and software system behaviour. As was mentioned above, one of the principal methods in agent-oriented modelling is motivational goal modelling, which is used to depict business objectives and system requirements, both functional and non-functional, and the relationships between them. Furthermore, the goal models proposed by Sterling and Taveter (2009) explicitly include emotional goals (Miller et al., 2015), which capture the desired feelings of stakeholders in a sociotechnical system and their relation to the system and each other. This goal modelling technique supported engineering our project requirements by enabling us to produce emotive cultural artefacts. Additionally, our project had stakeholders from different backgrounds, and motivational goal modelling facilitates communication and achieving mutual understanding between them.

In the longer run, the choice of agent-oriented modelling led to the methodology of principle-led design (Marshall, 2014, 2021), which adapts the methodology of engineering sociotechnical systems by Sterling and Taveter (2009) to the domain of design.

The methodology shown in Fig. 1 consists of four steps: eliciting goals, creating goal model, appraisal and prototyping, and implementation. Our proposed methodology is repeatable and can be used as it is in similar future projects. In the following Sections 4.1–4.4, we will discuss the steps of the methodology in detail.

### 4.1. Eliciting goals

This section discusses the process and techniques to elicit the early requirements for the Media Wall project in terms of three kinds of goals and the roles needed for the attainment of the goals. We will first describe how we defined the project scope and will later explain the requirements elicitation process.

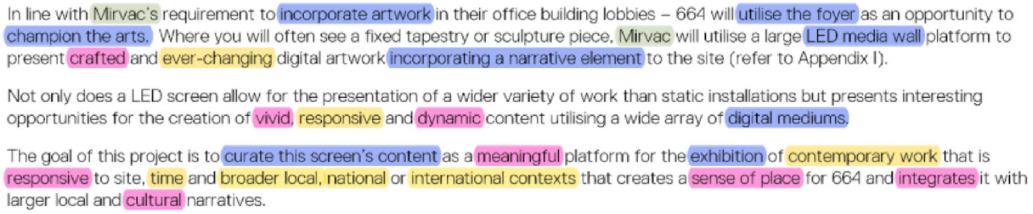


**Fig. 2.** Eliciting roles and goals from the client brief.

**Table 3**
Media Wall do/be/feel list.

| Roles — who | Function — do | Quality — be | Emotion — feel |
|---|---|---|---|
| Mirvac | Create cultural artefact | Data driven | Emotive |
| Grimshaw architects | Visualise data | Ever-changing | Meaningful |
| Swinburne lecturers | Build community | Responsive | Vivid |
| Swinburne students | Champion the arts | Contemporary | Dynamic |
| Intelligent designer | Incorporate narrative | Timely | Inspirational |
| Professional tenants | Curate content | Contextual | Unique |
| 644 management | Reflect theme (In)Visible | Sustainable | Situated |
| External pedestrians | Consider disabilities | Energy efficient | Integrated |
| Australian government | Minimise energy consumption | Explicitly distinct | Reflective |
| Disabled people | Accumulate meaning | Innocuous | Sustainable |
| | Regard viewpoints | Viewable | Considerate |
| | | Real-data | |
| | | Real-time | |

#### 4.1.1. Project scope

At the beginning of the project, its initial scope was vast and subjective to the extent that the project can be described as a "blue sky project". The crucial requirements were that the content must constitute a "cultural artefact" that should be 'emotive' and 'data driven' as is stated in Section 3.2.

Since the execution of the contract began, the core team consisting of the Mirvac project manager, Swinburne executive producer, and the lead architect from Grimshaw met weekly for approximately one hour for the duration of the project, which concluded at the start of 2019. In addition to the quorum of the three team members mentioned, other stakeholders attended the weekly meetings, including but not limited to those listed in Table 2, with the number of attendees usually ranging from 6 to 10 people. These regular team meetings helped to build conceptual synchrony, minimise prediction error, and propagate collective intentionality towards achieving the project's emotional goals. Over the course of several months of weekly meetings, the core project team developed a comprehensive *project brief* of 16 pages. The contents of the brief included information organised under the following headings: Introduction and background, partnerships, key information (summary), intention of the project, timeline, quality, site, audience and content considerations, time (as a design element), energy consumption, project team, appendix i: design images, appendix ii: screen dimensions and technical specifications, appendix iii: precedent projects.

#### 4.1.2. Early requirements elicitation process

The requirements elicitation process for the Media Wall consisted of analysing the brief and creation of the do/be/feel list. We will describe them below.

- **Analysing the brief**
  The project brief was analysed at the first sub-step of the requirements elicitation process, highlighting the roles and goals. A specific set of colours represented the roles and goals, depicting roles as green, functional goals as blue, quality goals as yellow, and emotional goals as red. Fig. 2 shows a short extract from the project brief illustrating how the roles and goals were highlighted.

- **Creation of the do/be/feel list**
  At the second sub-step of the requirements elicitation process, the do/be/feel list (Lorca et al., 2018) was created and the list is shown in Table 3. The do/be/feel approach is used to elicit requirements that explicitly include the functions, qualities and emotions important for all involved stakeholders. In part, this was done based on the roles and three types of goals highlighted and transcribed in the project brief at the first sub-step. However, additional requirements were elicited from the meetings, interactions with other stakeholders, experiences shared by experts, or support received from them for pursuing a specific design intention. The do/be/feel list combines, categorises, and refines the requirements. Therefore, the complete list may contain many repetitions, including the client's name and the primary project goals, but these are still included as the repetition helps in the process of refinement and categorisation by identifying essential items. The aim of the categorisation is to group similar requirements so that each of them may be represented by a single high-level functional, quality or emotional goal. Additional requirements to be included in the do/be/feel list may be elicited through a real-time co-design method (Lorca et al., 2018). The resulting do/be/feel table – Table 3 – has three columns. The role ('who') column comprises the list of stakeholders such as lecturers, Swinburne students, and 664 management. The function ('do') column lists the high-level functional requirements as functional goals, and the quality ('be') column presents the non-functional requirements as quality goals. Finally, the emotion ('feel') column is particularly significant in the scope of this paper because it describes the emotions associated with the functional and quality (non-functional) requirements. For example, as is shown in Table 3, the stakeholder Mirvac has the high-level functional goal "create cultural artefact", which is associated with the quality goal 'data driven', and emotional goal 'emotive'. The do/be/feel list serves as an input for building the goal model at the second step of the methodology described in Section 4.2.

### 4.2. Creating goal model

At this step, we created a high-level motivational goal model based on the do/be/feel list shown in Table 3. The goal model organises the goals comprised by the do/be/feel list into a hierarchy of goals and elaborates their categorisation in addition to the do/be/feel list. In the goal model, do-goals or functional goals describe what the software-intensive artefact to be designed should do, be-goals or quality goals describe how the artefact should be, i.e., the quality aspects of the artefact, and feel-goals or emotional goals describe what emotions should be constructed by the brains of the stakeholders to support the attainment of the functional goals with the required quality. Constructing emotions in support of the attainment of functional goals is in line with the theory of constructed emotion (Barrett, 2017b). The overall purpose of the goal model is to promote communication, discussion, agreement and synchrony between stakeholders through a shared modelling artefact. Therefore the goal model should be easily interpretable by means of naming the do-, be- and feel-goals included by the goal model and distinguishing the type and purpose for each of them. The goal model should evolve based on discussions between the stakeholders, with each iteration honestly reflecting a progression towards the project goals, which in this case had an emphasis on the emotional goals. The method that was used for modelling emotional goals by itself instantiates and constructs emotions via iterative appraisal, feedback and agreement, forming collective intentionality as is explained in Section 2.6.

In the process of organising the goals comprised by the do/be/feel list into a hierarchical goal model, functional, quality and emotional goals are rendered by the corresponding icons. Functional goals are rendered by tilted rectangles, quality goals by clouds and emotional goals by hearts. Functional goals are spatially located into similar categories, across the *x*-axis and hierarchically on the *y*-axis. Solid and dashed lines may be used to indicate relationships between goals, such as the relationship between a sub-goal and its parent goal. However, the purpose is not to describe hard ontological relationships. If the use of lines compromises the immediate interpretability by non-cognate stakeholders, they should be discarded. The roles that are most concerned with pursuing the functional goals are placed adjacent to them. Quality and emotional goals are likewise attached or placed adjacent to functional goals. For quality goals, this attachment or placement represents that the related functional goals should be achieved with the indicated quality. For emotional goals, it represents that they support the attainment of the corresponding functional goals, in compliance with the theory of constructed emotion (Barrett, 2017b). In many cases, the functional goals are binary, and the quality and emotional goals determine to what degree the functional goal has been achieved.

The motivational goal model featured in Fig. 3 illustrates the high-level goals of the 664 Collins project. In total, 10 roles and 45 goals are described, 11 of the goals being emotional goals. The model exemplifies the relationships between functional, quality and emotional goals and their relative importance. The top level goal, to ‘design 664 Collins Street Media Wall’ is binary; the stakeholders either did or did not achieve this goal. Similarly, the achievement of the functional goal to “create a cultural artefact”, which involves revealing valuable meanings about society, depends on the attached quality of being ‘data driven’. Again, the goal of being data driven is somewhat binary, where being more data driven has a limited effect on creating a cultural artefact. However, the overall successful design of the 644 Media Wall is almost entirely dependent on the primary emotional goal, which in this case is to feel ‘emotive’. In this way, the high-level goal models may be created with the emotional goals as the core elements, supported by the functional goals and quality goals, which is a clear innovative difference from the original motivational goal modelling approach (Sterling and Taveter, 2009).

### 4.3. Appraisal and prototyping

The crucial step after creating the high-level motivational goal model was to communicate the model and receive approval from relevant stakeholders that this accurately reflects their motivations. Our methodology includes a series of iterative and formal progressive appraisals that occur on a fortnightly basis throughout the production timeline. The fortnightly appraisal included a dialectic discussion between the designer and the primary stakeholders where the level of attainment for each goal was ranked, and a new goal model was generated and distributed. Based on each progressive appraisal, the overall model was reviewed with the addition or removal of goals or restructuring of the goal hierarchy to reflect the collective agreement. Co-design methods were employed by, for example, working with stakeholders in a shared virtual space such as a Miro board to jointly elaborate the goal model. In emotion co-construction, which was explained in Section 2.5, collective intentionality was built by purposeful instantiation and placement of emotional goals, in agreement with others. It is worthwhile to note here that in our approach, according to the theory of constructed emotion Barrett (2017b), emotional goals are considered as predictions rather than hard requirements, where the stakeholders instantiate the emotion concepts with the help of the goal model.

Another measure of success of the progressive appraisal process is whether a stakeholder voluntarily prints the resulting goal model and pins it on their office wall. In some cases, stakeholders indeed had the final goal models professionally printed and framed. To this end, the goal model should also be shareable, printable and readable on a single A4 page or US letter page. For interpretability and shareability, we suggest limiting the total number of roles and goals in the high-level model to less than 50.

As a part of the appraisal process, stakeholders not only articulated their reviews to developers but also maintained some high-level comments for themselves. For this, they used the traffic light concept by highlighting their comments and assigning scores between 1–3.

Based on the results of the fortnightly appraisal meetings, animation prototypes were developed and updated iteratively according to the changes suggested in the appraisal goal models and traffic light evaluations.

### 4.4. Implementation

This step generated the final piece of software, i.e., animations for the 664 Collins Media Wall based on their selected topics and data. This step mainly inspected all changes and updates asked for in the previous steps of the methodology, and it was then decided if the final piece was ready and selected for the Media Wall.

## 5. Experiment

This section discusses the application of our methodology with the help of two examples[6] from the industrial case study conducted by us. We demonstrate the application of our methodology proposed in Section 4.

In the first phase of the project, 50 students participated taking on the designer role. They developed 47 videos, out of which 26 pieces were accepted by the stakeholders and published on the Media Wall. In the second half of the project, 30 students participated and 28 pieces of animation videos were developed,

[6] Case study files are published online here: https://figshare.com/articles/journal_contribution/Theory_of_constructed_emotion_meets_RE_An_industrial_case_study/20391423.

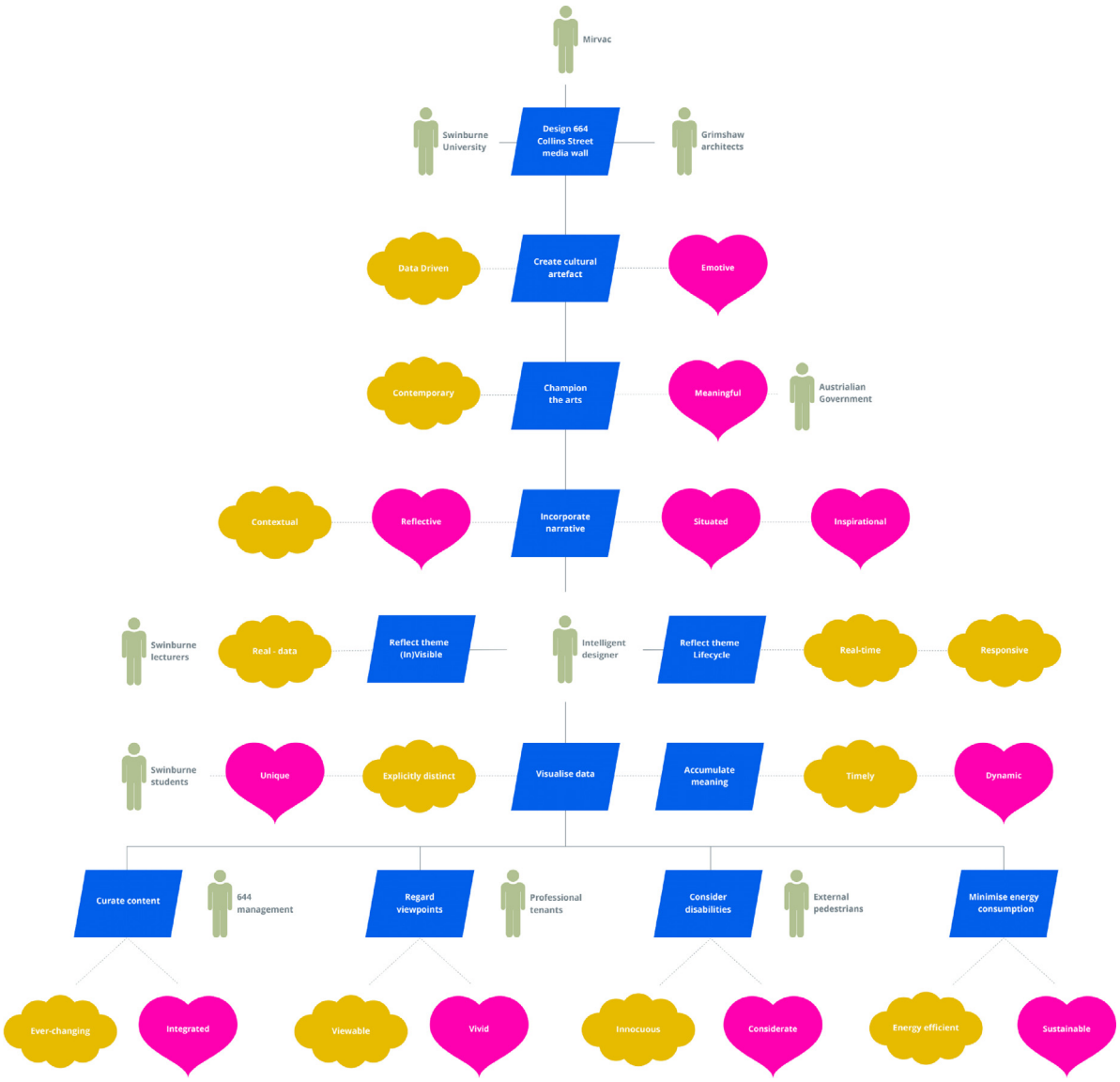


**Fig. 3.** High level goal model for the Media Wall.

out of which 18 pieces were accepted by the stakeholders. Our experiment included 80 students, a.k.a. designers in our case, from two different academic batches, which is illustrated by Table 2. In both phases, videos were data driven, but the second phase incorporated live data feeds—data collection and processing in real time. Students were asked to follow the proposed steps in Section 4 after deciding their topic for the piece of software, i.e., an animation for the Media Wall. In Sections 5.1 and 5.2, we are respectively demonstrating one example from each project phase.

### 5.1. Example 1: Happiness

The first example is called "Happiness". This work was developed and designed by Renu Gudlawar. This student work entitled "Holistic Embodiment of Happiness" was built using information sourced from the World Happiness Report.[7] After extracting the data, seven variables were used: GDP per capita, social support, healthy life expectancy, freedom to make life choices, generosity, perceptions of corruption, and dystopia. While this data played an essential role in connecting the Happiness student work to real-world happenings, simply showing the data does not construct the emotion of happiness. Furthermore, happiness is a broad emotion concept, of which the designer aimed to construct numerous nuanced instances.

The first step of the student task was to elicit the overall high-level project requirements after analysing the brief; for all developers the initial requirements were the same as shown in Section 4.1.2. Additionally, the designer researched and defined the topic of happiness. The aim was to construct the emotion of happiness when the stakeholders see the animation. The student expressed happiness for the project as follows:

"Representing happiness as a number takes away from the humanity of the emotion. Happiness is unity, love, strength, family, friends, and passion. There are also a lot of things that the World Happiness Report does not look at. My goal is to produce a piece of work that represents all the immeasurable things that happiness is, to feel joyous and delightful, and to show happiness as a collective state of being."

At the next step of applying the methodology, the high-level requirements were elicited as the do/be/feel list shown in Table 4.

7 https://worldhappiness.report/

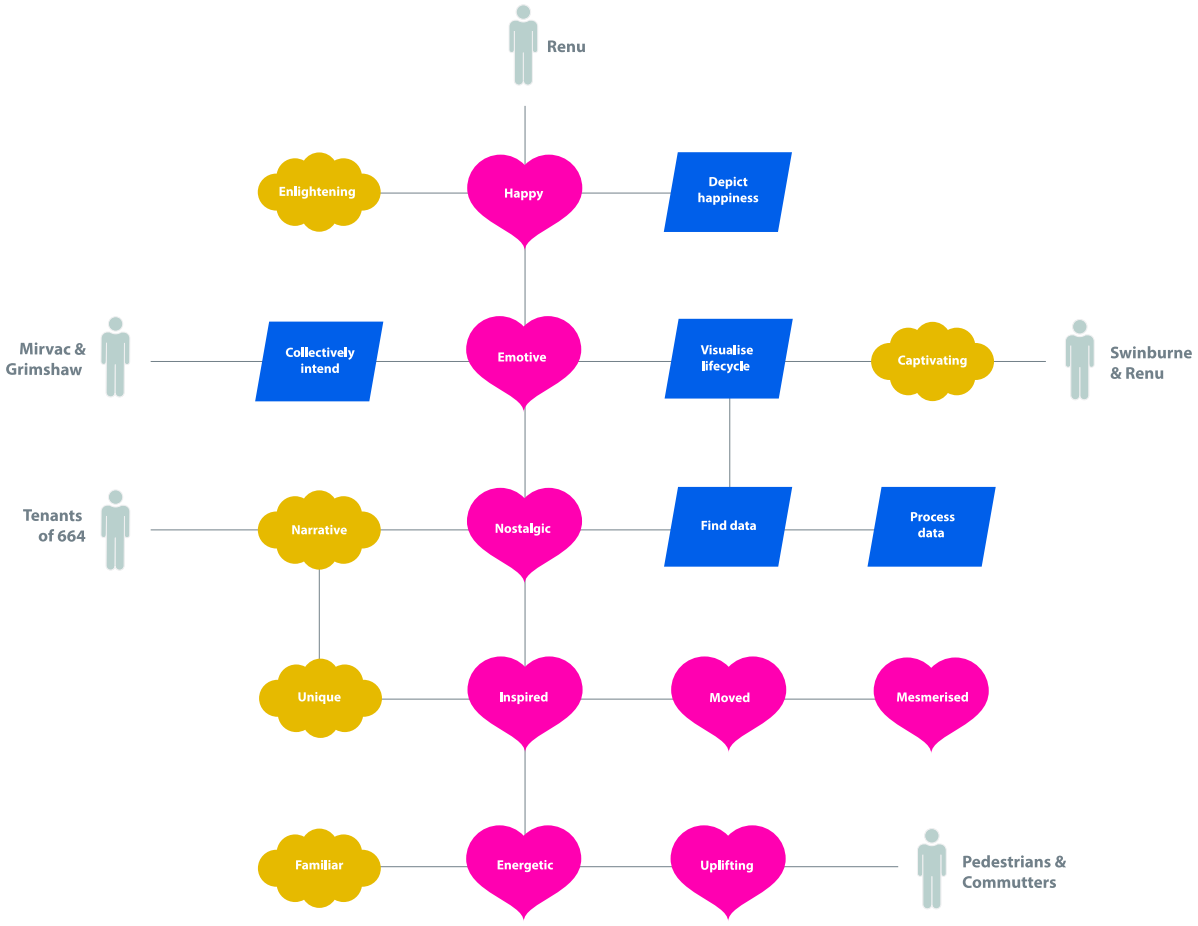


**Fig. 4.** Happiness goal model by Renu.

**Table 4**
The do/be/feel list of the Happiness work.

| Roles — who | Function — do | Quality — be | Emotion — feel |
|---|---|---|---|
| Renu (designer) | Depict happiness | Enlightening | Happy |
| Mirvac + Grimshaw | Visualise lifecycle | Familiar | Emotive |
| Tenants of 664 Collins | Collectively intend | Captivating | Nostalgic |
| Pedestrians + Commuters | Find data | Unique | Inspired |
| Swinburne | Process data | Narrative | Moved |
| | | | Mesmerised |
| | | | Energetic |
| | | | Uplifting |

According to the list, the main stakeholders are designer, Mirvac, Grimshaw, Collins 664 tenants, and the Swinburne University of Technology. In addition, the stakeholder list includes pedestrians and commuters because they will see the final animation. The do/be/feel list presents the functional and quality goals and emotional goals associated with them. The emotion (feel) column contains the emotional goals 'happy', 'emotive', 'nostalgic', 'inspired', 'moved', 'mesmerized', 'energetic', and 'uplifting'.

At the next step, the goal model was created to refine the requirements for the student work, mainly focusing on emotional requirements. In the resulting goal model depicted in Fig. 4, some parts of the emotive language can be seen as translated from the do/be/feel list of the student work shown in Table 4. In total, eight emotional goals were identified in the do/be/feel list, and all of them were successfully transformed into the final goal model. The goal model depicted in Fig. 4 elaborates the do/be/feel list by bringing more clearly out that feeling 'emotive', 'nostalgic', 'inspired', 'moved', 'mesmerized', 'energetic', and/or 'uplifting' represent different interrelated aspects of feeling happy.

As the next step, an iterative progressive appraisal was performed on the goal model. This step also included developing the animation prototype and updating it iteratively based on the changes suggested in the appraisal model. At the start of the project, the goal model is coloured grey as is shown in Fig. 5. As a result of an appraisal meeting, each goal is ranked with the grade between 1 and 10. These results are averaged, and a new goal model is generated and distributed, with the ranking being indicated by a 10-step colour gradation from 1 (red) to 10 (green). Based on each progressive appraisal, the overall model is reviewed with the addition or removal of goals or restructuring of the hierarchy to reflect the collective agreement. During the

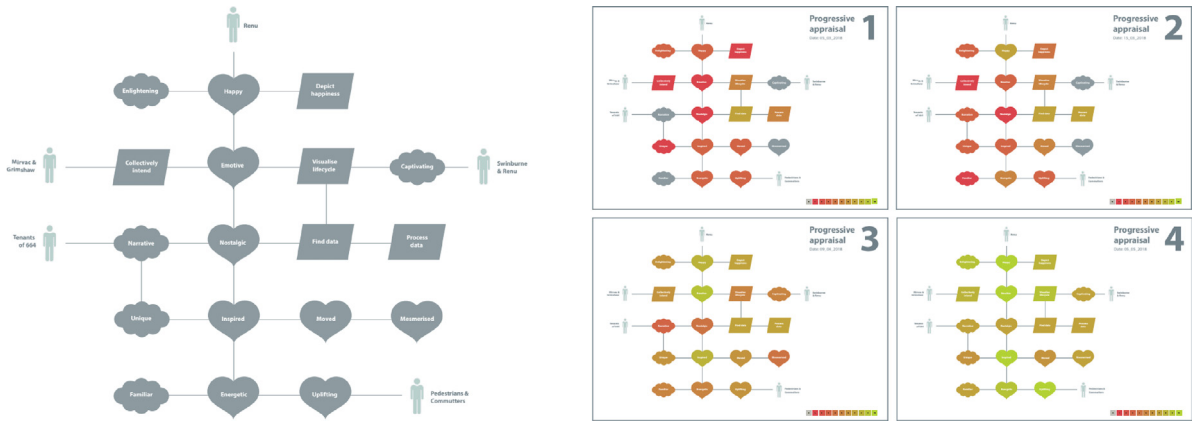


**Fig. 5.** Happiness appraisal model. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

**Table 5**
Traffic light evaluation of the Happiness work.

| Reviewer | Traffic light evaluation 1 | Traffic light evaluation 2 | Traffic light evaluation 3 |
|---|---|---|---|
| Reviewer 1 | One of my favourite submissions as it is unique and dynamic. | Great — would like to see this ready. | Would like to learn how they did this! |
| Score | 2 | 2 | 3 |
| Reviewer 2 | More in focus. | It is naturalistic and personal and I think pretty compelling to watch. | No changes required. |
| Score | 1 | 3 | 3 |
| Reviewer 3 | Change skybox. Review start shape. | If the image is more crisp I think it would be worth including. As it stands it needs some cutting. | Simple concept but effective. Great ideas in this one, visually artistic. |
| Score | 1 | 2 | 3 |
| Reviewer 4 | Yes, potential to cut into separate videos to avoid monotony? | Generate various duration of pre-rendered content so that this can be mixed and rotated. | Definitely has potential, I think its worth including. Maybe breaking each of the shots separate. |
| Score | 1 | 3 | 2 |
| Reviewer 5 | The particle effects here are quite nice. | I'm not sure there is much worth extracting from this as removing any one element would destroy the narrative. | The blooming rose bit is great. Less rotation especially with some of the overlayed flowers, which I fear may be nauseating. |
| Score | 1 | 2 | 2 |
| Reviewer 6 | Speed could be increased slightly, however, can see merit in leaving as is. | I like the sense of depth. | One of my favourites. |
| Score | 2 | 3 | 3 |
| Totals | **8** | **14** | **16** |

fortnightly appraisal process in the 664 Media Wall project, stakeholders expressed their rankings, which the developers reported as helpful. As shown in Fig. 5 most goals turned into green and brown shades, and nothing is in the red zone. Hence, this indicates that the goals mostly achieved collective intentionality.

On the other hand, stakeholders maintained their personal reviews in a table. They used the traffic light concept by highlighting their comments by red, yellow and green colours, and assigned to the student works the scores between 1–3. An example of applying the traffic light concept for the Happiness work is represented in Table 5.

In the real world, the overall goal models presented in Figs. 4 and 5 were readable and printable to the wall size due to their high quality. The final progressive appraisal model is shown in Fig. 6. The final output of the Happiness work based on the final goal model is demonstrated in Fig. 7.

### 5.2. Example 2: Crumple

The second example is called "Crumple". The example was designed and developed by Nicole Brimblecomb. Each iteration of this student's work was generated from real-time traffic accident data providing a unique emotional and aesthetic experience. The designer explained and defined her work as follows:

"I am trying to convey the emotional experience of an accident where through trauma, we learn real strength, seeing beauty amidst the irony. I demonstrate the shock waves sent when a family member or a loved one is involved in an accident. The

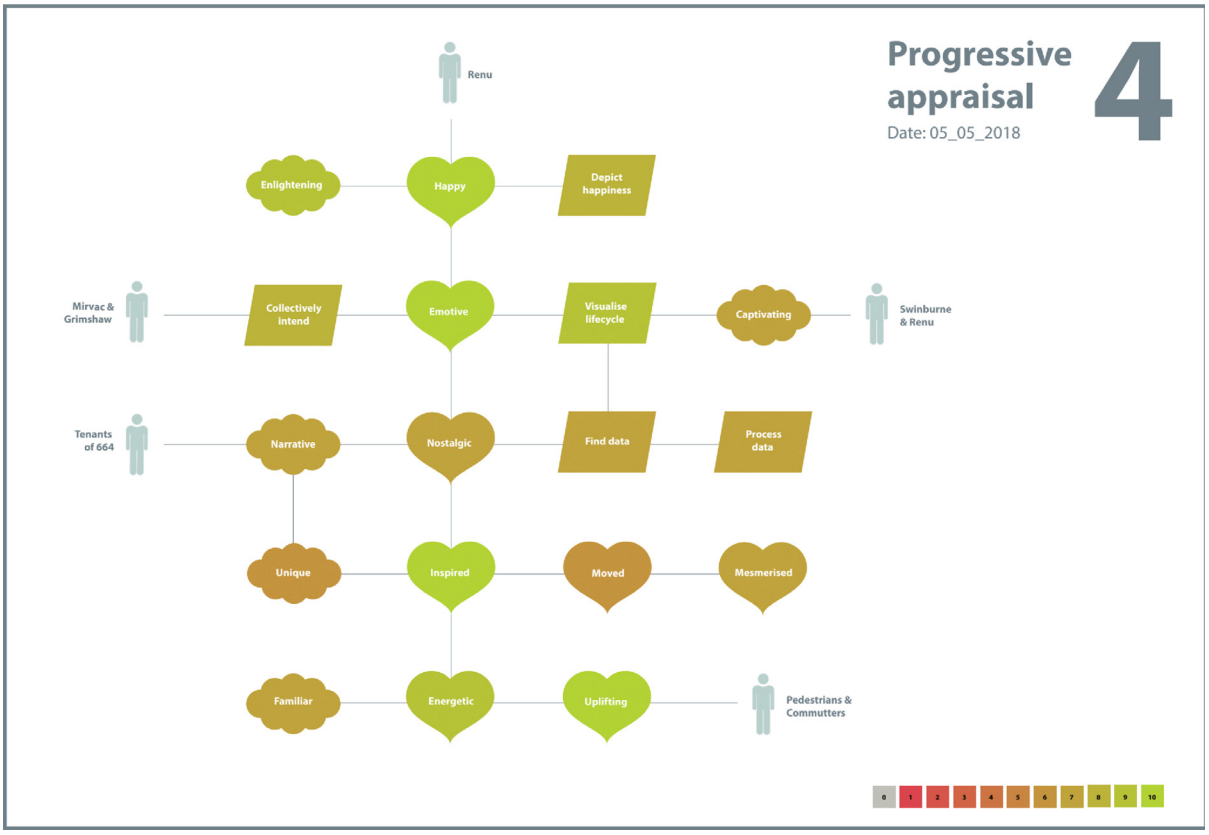


**Fig. 6.** Happiness final progressive appraisal model.

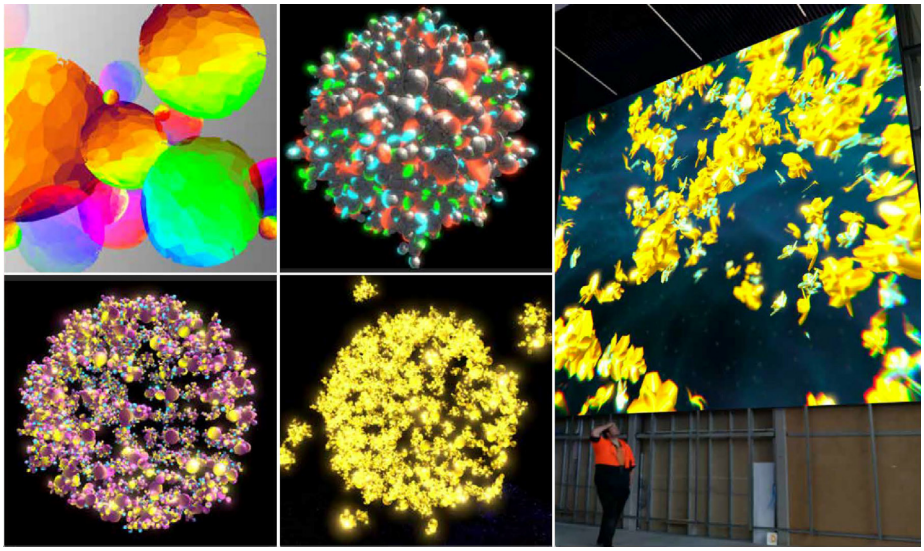

**Fig. 7.** Final design of the Happiness work by Renu.

pulsation and constant colour change within the piece relate to the wrinkles and dents a vehicle gets when making contact. Drawing line connections based on the number of cars involved, varying in frequency as lines connect to one another, signifying speed zones of these accidents. These lines then disperse and fade, resembling pain from the crash wearing off, replicating the lifecycle of devastation where the victims courageously move forward in the aftermath".

The example of Crumple also followed the same steps of applying the methodology as the example of Happiness. However,

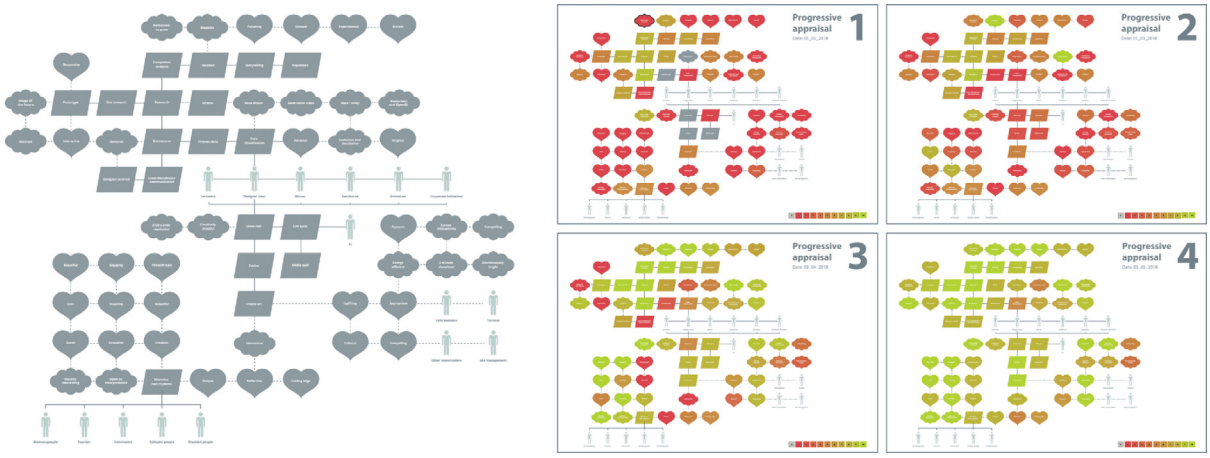


**Fig. 8.** Crumple appraisal model.

**Table 6**
The do/be/feel list of the Crumple work.

| Roles — who | Function — do | Quality — be | Emotion — feel |
|---|---|---|---|
| Designer | Data visualisation | Data driven | Unique |
| 664 management | Brainstorm | Abstract | Abstract |
| Mirvac | Competitor analysis | Biophilic | Appropriate |
| AI | Cross disciplinary communication | Compelling | Beautiful |
| Businesspeople | Designer centred | Creatively mindful | Compelling |
| Cafe business | Evolve | Energy efficient | Cool |
| Commuters | Ideation | Evolution and devolution | Creative |
| Corporate Initiatives | Inform | Generative video | Cultural |
| Disabled people | Life cycle | Harnessed to grow | Cutting edge Dynamic |
| Epileptic people | Minimise fast rhythms | Image of the future | Dynamic |
| Grimshaw | Media wall | Immersive | Engaging |
| Lecturers | Process data | Iterative | Evocative |
| Other stakeholders | Prototype | Max /Unity | Experimental |
| Swinburne | Repetition | Non-linear | Inspiring |
| Tenants | Research | Open to interpretation | Interactive |
| Tourists | Show reel | Rasterised and OpenGL | Original |
| | Site research | Screen interactivity | Philanthropic |
| | Storytelling | Discretionally bright | Pulsating |
| | | Visually interesting | Personal |
| | | 2720 × 2400 resolution | Reflective |
| | | 3-minute durations | Responsive |
| | | | Sensual |
| | | | Social |
| | | | Uplifting |

this example resulted in a more extensive do/be/feel list, which is shown in Table 6. The goal model reflects the controversial personal emotional experiences of being involved in a car crash. The progressive appraisal goal model is shown in Fig. 8 and the final artefact is demonstrated by Fig. 9. All the other related files, such as the Crumple goal model, final appraisal model, and traffic light review table can be found in Annex and online.[8]

## 6. Discussion

The research work reported in this paper was concerned with systematic engineering of requirements representing emotions to be created by emotive media artefacts. We rooted the requirements engineering process for emotive media artefacts in the theory of constructed emotion. In short, the theory of constructed emotion claims, based on the recent findings in neuroscience, that instances of emotion concepts are constructed by the brain to help us to achieve our goals in social situations by changing the body balance in the service of allostasis—managing and allocating the energy levels in the body. In Section 1, we posed three research questions (RQs) that we answer in summary as follows:

RQ1: The advantages of applying the theory of constructed emotion in the requirements engineering process are creating among the stakeholders collective intentionality about the desired emotional requirements and explicit usage of emotion words for constructing and instantiating emotion concepts.
RQ2: A possible method supporting the application of the theory of constructed emotion in the requirements engineering process for developing an emotion aware sociotechnical system is motivational goal modelling.
RQ3: The proposed methodology is helpful for stakeholders of a sociotechnical system with different backgrounds because motivational modelling can achieve both the level of aesthetics that is acceptable for the diverse set of stakeholders and constructive discussions between them on acute topics.

In the following, we will discuss the answers to the RQs in more detail.

Our first research question RQ1 investigated the advantages of applying the theory of constructed emotion in the requirements engineering process. In our case study, we performed an iterative process of building and evaluating a software-intensive

8 https://tinyurl.com/yecw2xdz

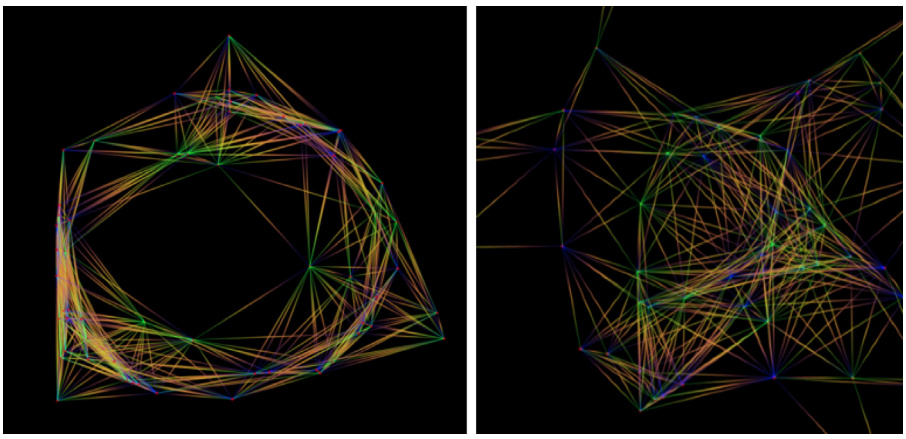

**Fig. 9.** Final design of the Crumple work by Nicole.

artefact, consisting of the animations to be shown on the Collins 664 Media Wall. At the end of each iteration, the artefact was evaluated by the stakeholders of the project. In compliance with the theory of constructed emotion, the purpose of the evaluation sessions a.k.a. appraisal meetings was to create among the stakeholders collective intentionality about the desired emotional requirements for the project, along with the functional and quality requirements. The emotional requirements represented new emotion concepts about which the stakeholders agreed. Consequently, the first advantage of applying the theory of constructed emotion in the requirements engineering process is that employing collective intentionality enables to design and instantiate new emotion concepts and engineer them into artefacts such as pieces of art, music, and literature but also software like in the case study treated in this paper. The second advantage of applying the theory of constructed emotion in the requirements engineering process is explicit usage of emotion words for constructing and instantiating emotion concepts, which can be easily grasped by most stakeholders. In compliance with the same theory, we represented emotion concepts by emotion words, starting from highlighting emotion words in the project brief and creating the do/be/feel lists and goal models thereafter. This worked well, resulting in the team of stakeholders agreeing about the emotion concepts such as 'uplifting' and 'nostalgic' for the animation of Happiness and 'sensual' and 'philanthropic' for the Crumple animation.

The second research question RQ2 explored the methods or techniques that support the application of the theory of constructed emotion in the requirements engineering process for developing an emotion aware sociotechnical system. Dedicated methods are required for that purpose. We found that the goal models proposed by Sterling and Taveter (2009) and Miller et al. (2014, 2015) that had been adapted to the domain of design by Marshall (2014) were promising, providing rigour and repeatability, being based on a structured logical ontology, and providing shared artefacts to promote communication between multiple stakeholders. By applying the method of motivational goal modelling to co-construct emotions among the stakeholders, various ideation methods, including interactions with the clients, identified and instantiated emotion concepts, by representing them as words. The emotion concepts denoted by words were then arranged into a hierarchical framework created by goal models that placed the emotion concepts in a particular context, being distinctly identifiable as discrete emotional goals that support the attainment of binary functional goals. The meaning of these emotional goals was built through verbal and visual language to achieve conceptual synchrony between the instantiating designer and other stakeholders.

For the reasons explained, the methodology proposed by us in Section 4 is centered on motivational goal modelling. The methodology comprises an agile process, which includes progressive appraisals, that focuses on giving feedback by the stakeholders. Based on each progressive appraisal, the overall goal model was reviewed with the addition or removal of goals or restructuring of the goal hierarchy to reflect the collective agreement. The level of collective intentionally towards the emotional goals on which both the stakeholders and developers honestly agreed was evidenced by the evaluations of the final progressive appraisal goal models, such as the traffic light evaluation of the Happiness work shown in Table 5. The developer working on the Happiness animation has commented the appraisal process as follows:

"Consulting my design goal model has allowed me to focus on the aspects of the projects I need to work towards. My previous model was not pushing my project towards a fully realised concept that was going to work for the client or their parameters. My redesigned goal model focuses more on the visual aspects of the project and how it is perceived by the audience. For example, my new direction should emphasise the importance of abstract visual design as well as how the addition of data creates unique patterns that could have only been made through the combination of these elements".

Another advantage of applying motivational goal modelling is that it enables to elicit and represent requirements for both social or human and technical aspects of a sociotechnical system. Typically, social or human aspects of a sociotechnical system are rendered by emotional goals, while the aspects that can be addressed primarily by means of technology are captured by quality goals. The primary quality goal of the project mandated that the resulting artefact – Collins 688 Media Wall – should be data driven. This goal was also achieved, especially because the second phase of the project incorporated live data feeds—data collection and processing in real time. For example, each iteration of the Crumple animation described in Section 5.2 was generated from real-time traffic accident data. Some other animations like the Happiness animation treated in Section 5.1 are based on statistical data sourced from different reports.

The methodology proposed in this paper stands out because common requirements modelling approaches fail to adequately represent important elements of design projects. Hard functional goals dominate, while other subjective qualities of the system such as its efficiency, security and durability are considered as soft and less measurable (Paay et al., 2009). The latter is important because the mantra, "If you can't measure it, you can't make it" is common in requirements engineering (Gregory, 2019). Such claims are still made in the requirements engineering community now and then, although they have the contrary meaning to the

original quote by the American Engineer William Edward Deming "It is wrong to suppose that if you can't measure it, you can't manage it — a costly myth" (Deming, 2018). Furthermore, human concerns, such as usability and emotions, are often further deprioritised as a subset of soft goals. Against this background, the case study of 664 Collins Media Wall clearly demonstrated that emotional requirements should be treated as first-class citizens, providing an example where the emotional goals were the core elements, supported by the functional goals and non-functional (quality) goals.

With our final research question RQ3, we were trying to find out to what extent the proposed and applied methodology was helpful for stakeholders of a sociotechnical system with different backgrounds. In commercial projects like ours that involve developing products and services for people, stakeholders come from diverse knowledge domains including finance, management, design, production, marketing, distribution and advertising. The design of the goal model as a shared artefact is audience dependent, which is a fundamental consideration not only for interpretability and understandability but more importantly for aesthetic qualities. Aesthetics includes the design of icons, colour, typography, visual hierarchy and reproduction, where the overall quality of design is judged by the worst rather than the best of what is seen. For an audience with a high visual literacy, a poorly designed goal model or another similar artefact presented will significantly reduce both credibility and collective intentionality towards emotional goals. It cannot be underestimated that emotional goals will not be met unless aesthetics are prioritised above all other concerns. Additionally, an important aspect of the project was to confront and promote discussion amongst the tenants of the building on various topics, without overtly offending them. The topics of such communication were wars, pollution, climate change, coral bleaching, and so forth that were dealt with many of the artworks included by the animation. The project achieved both the level of aesthetics that was acceptable for the diverse set of stakeholders and constructive discussions between them on acute topics.

Although the theory of constructed emotion has been earlier applied for analysing *in retrospect* design artefacts, such as animated films (Wells, 2018), this paper is the first publication that puts forward a systematic methodology employing the theory of constructed emotion for engineering software-intensive design artefacts. The proposed methodology is not complete and requires further elaboration because the artefact – Collins 688 Media Wall – resulting from the project did not involve interactions between the artefact and its audience or users, which is a normal feature of most software products.

We cannot compare the methodology put forward in the current paper directly with other similar methodologies because to the best of our knowledge, no other requirements engineering methodology claims to be rooted in the theory of constructed emotion. The theory of basic emotions is applied by Brown et al. (2020) for exploring methods of capturing players' emotions during an interactive story with the purpose to improve user interfaces in interactive media. In a similar problem domain, Shirvani and Ware (2020) apply an appraisal emotion theory to constrain possible actions and add variety to possible plots in interactive digital narratives. In the domain of software engineering, Lin et al. (2022) and Girardi et al. (2020) explore identifying the emotions by developers in a software engineering process through determining the valence and arousal values of core affects.

### 6.1. Threats to validity

The work reported in this paper is characterised by three main threats to validity, which will be explained below.

A threat to construct validity is that the scope of our study is limited to the elicitation and representation of requirements and the emotions constructed by the developers and stakeholders. This threat was mitigated by collecting feedback from the stakeholders from diverse knowledge domains including finance, management, design, production, marketing, distribution and advertising, who were included in regular iterative progressive appraisal meetings. Another related limitation we had in our project was that the goal model was supposed to be shareable, printable, and readable on a single A4 page or US letter page. Therefore, we set the limit of less than 50 roles and goals for the high-level model to improve the interpretability and shareability. Also, due to copyrights and privacy issues, we could not show or upload to online repositories all the materials from the project, such as the project's final report consisting of about 500 pages, meeting minutes, extensive reviews, etc.

A threat to external validity is that the feedback was not collected from end consumers of the Media Wall, such as pedestrians and commuters and tenants and people working in the building. This threat to validity is mitigated by the fact that the feedback was collected at different stages of the project during regular and iterative progressive appraisals from a significant number of diverse stakeholders of the project to make sure that instances of particular emotion concepts were co-constructed among them. The results obtained from this emotion co-construction can be expanded to end consumers of the Media Wall. Moreover, the mentioned threat to external validity was further mitigated by minimising the prediction error by the viewers of the screen by means of distributing among the tenants pamphlets about the intended meanings of the animations shown on the Media Wall, and assigning appropriate explanations next to the Media Wall. Finally, to mitigate this threat, the Collins 664 Media Wall was validated by successfully designing and implementing meaningful animations, which is vividly demonstrated by the fact that the Media Wall won the Silver Award in the prestigious International Design Awards competition, which involves a peer-reviewed evaluation process. For example, an anonymous member of the International Design Awards Jury commented the Media Wall as follows: "Excellent real-world experience initiative. The fact that the developers gain public exposure for their work and have collaboratively built this with expert support is an inspiring step forward for education".

A threat to internal validity is related to the fact that emotional design is by definition subjective and temporal, especially because the people who do the design are "artists". However, this threat to validity is well known because it is concerned with macro effects of sociology – how groups of people behave, being impacted by emotions? – which cannot be easily measured (Collins, 1988). Moreover, although design is artistic and thereby subjective by nature, applying the theory of constructed emotion reduces subjectivity by explicitly co-constructing the emotions to be felt by the users or audience to support the goals to be achieved by the artefact being designed.

## 7. Conclusions

Designers and artists have long been concerned with the design and development of emotive artefacts. Works of painting, dance, music and film clearly affect the emotions of both participants and their audience, but this has often been achieved through tacit knowledge. Rather than aiming to trigger emotional reactions, the 664 Collins Media Wall project employed the state of the art affective neuroscience to purposefully and systematically *construct* rather than trigger emotions. To find out how this could be done we formulated in Section 1 the research questions RQ1, RQ2 and RQ3. We applied the research method of action

design research for answering the research questions because it treats information technology artefacts as sociotechnical systems that are shaped by the organisational context during their development, which was precisely the case with the Media Wall.

The main contribution of this paper is proposing an original repeatable methodology for eliciting and representing requirements for interdisciplinary design projects aimed at designing software-intensive digital media artefacts. The methodology is geared towards designing and developing emotive artefacts that have the purpose to co-construct certain emotions among the stakeholders and eventually in the audience with the goal to further the issues, such as wars, pollution, climate change, and coral bleaching. The methodology is compatible with the theory of constructed emotion because it is based on the goal model as the shared modelling artefact, where emotional goals are represented by means of emotion words and are attached to the functional goals, the achievement of which they support. We applied the methodology to an extensive case study of designing the 664 Collins Media Wall in Melbourne, Australia, where 108 stakeholders of 8 different kinds participated. The Media Wall was validated by the stakeholders during the design and implementation process, which was carried out iteratively by following the action design research method. The validation confirmed that the primary functional goal of the project to create a cultural artefact was achieved, along with the primary emotional goal 'emotive' and the primary quality goal 'data driven'. After the Media Wall was live and running, an essential accent to the validation was added by the fact that the Media Wall won the Silver Award in the prestigious International Design Awards competition, which involved a peer-reviewed evaluation process. Last but not least, the methodology proposed by us and its application to the case study enabled us to answer the three research questions that were posed at the beginning of the paper.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Annex

See Figs. 10, 11 and Table 7.

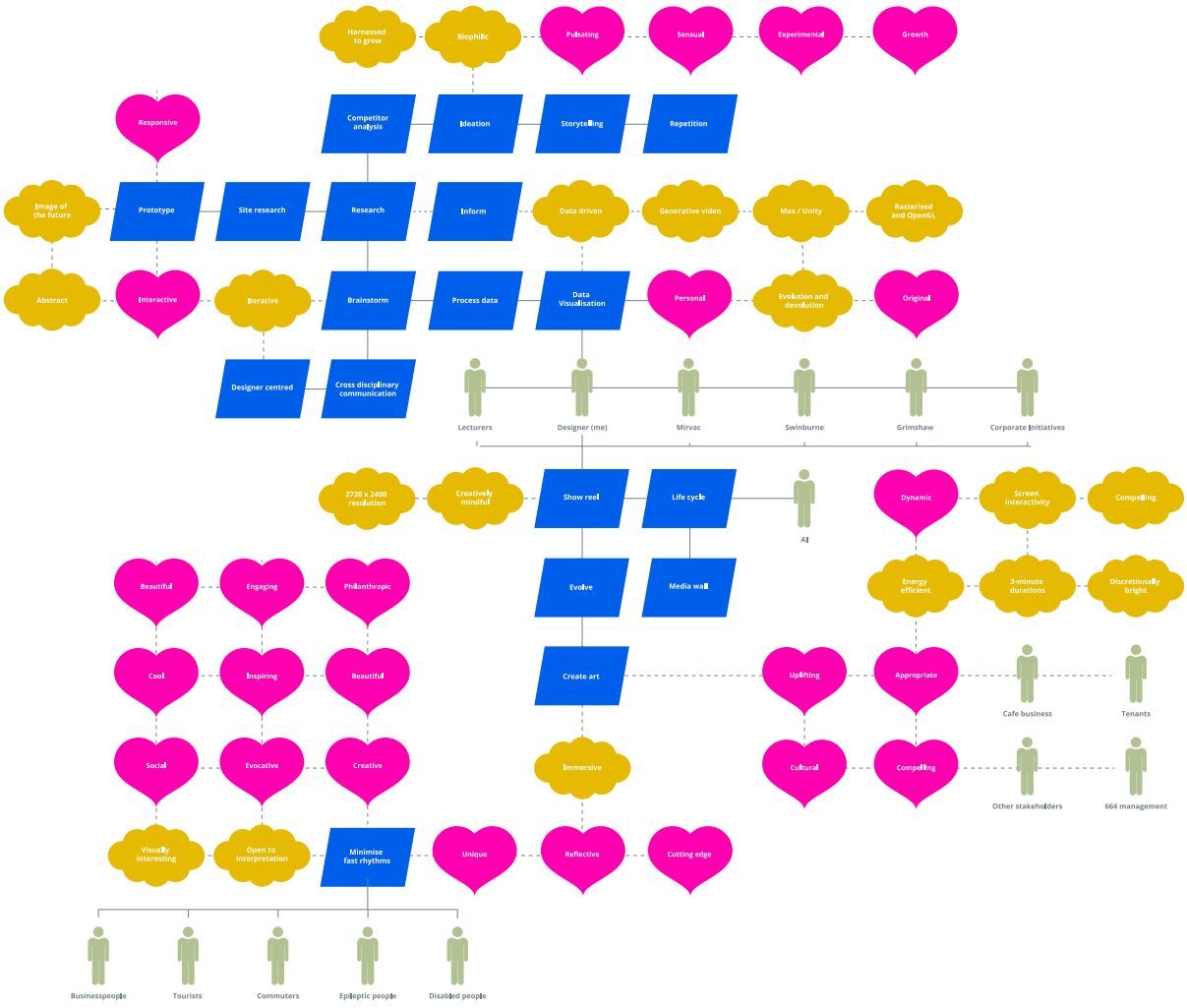


**Fig. 10.** Crumple goal model by Nicole.


**Fig. 11.** Crumple final progressive appraisal model.

**Table 7**
Traffic light evaluation of the Crumple work.

| Reviewer | Traffic light evaluation 1 | Traffic light evaluation 2 | Traffic light evaluation 3 |
|---|---|---|---|
| Reviewer 1 | Do some camera moves. | Needs some work, fix camera moves. | Review colours, remove shake. |
| Score | 2 | 3 | 2 |
| Reviewer 2 | Add depth and layers. Review colours and textures. | Colour palette? Slow down the camera movement. | There was no fadeout at the end. 3/3 |
| Score | 2 | 2 | 3 |
| Reviewer 3 | Drop to a set Y position rather than explosion. | Make smoother, improve quality. | Should be a fully rendered solution to provide smoother playback and higher quality. |
| Score | 1 | 1 | 2 |
| Reviewer 4 | I'm not in love with this one. Strobing needs to be removed. | Slow down the animations a bit. Fatten the white lines. | I'm open to its inclusion. |
| Score | 1 | 2 | 3 |
| Reviewer 5 | Concept has potential but needs to be completely re-done. | Too jittery. Investigate making it smoother. | Make the background black and slow the animations down. |
| Score | 1 | 1 | 2 |
| Reviewer 6 | I don't think this will hold up on the big screen as it currently stands. | A little heavy handed and repetitive. Needs visual work. | Would be nice if the camera moved in and out a bit. |
| Score | 1 | 1 | 2 |
| Totals | 7 | 10 | 14 |

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