Does bouncy equal happy? Comparing user's interpretations of emotions conveyed by one designed moving object based on the soma-semiotic framework

Deborah Fels [a,b,*], Alethea Blackler [b], Kristina Niedderer [c]

[a] Ted Rogers School of Information Technology Management, Ryerson University, Toronto, Ontario, Canada
[b] QUT Design Lab, Queensland University of Technology, Brisbane, Australia
[c] Manchester School of Art, Manchester Metropolitan University, Manchester, UK

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ABSTRACT

When designing objects, designers attempt to communicate the purpose and meaning of that object to users using various factors such as visual appearance (aesthetic), practical interaction elements (product semantics) and meanings beyond the practical product interaction (semiotics). This study sought to confirm the previous deductively-developed soma-semiotic framework, whose purpose was to understand and ultimately predict the emotional impact of different design elements on users, using one specifically designed object, Fruit Bowl (FB). The purpose of the study reported in this paper was to compare the theoretically derived emotional responses to FB from the soma-semiotic framework with empirically derived data from users in order to improve the framework. Sixty participants evaluated the meaning and emotion conveyed by FB as well as self-reported their own experienced emotions under two scenarios. The framework predicted that FB would convey joy in a first scenario, and amusement in a second scenario based on different movements. Using a weighted vector analysis based on Russell's two-dimensional Circumplex of emotions, users identified that the overall emotion of the first scenario to be similar to the predicted emotion. This was attributed mostly to the bouncy movement of the bowl and its visual aesthetic. However, in the second scenario the overall rating was calm/impressed; rather than humour. The abstract design did not favour users making the same associations as the designer. We recommend that the soma-semiotic framework be revised to include aesthetic, in addition to semiotic and semantic, elements as determinants of user interpretations and reactions to designed objects.

1. Introduction

The aim of the research reported in this paper is to evaluate the use of a soma-semiotic framework constructed previously by (Niedderer, 2012). The framework focuses on emotional expression and experience in relation to movement to support designers in interpreting and creating emotional impact within designed objects containing movement.

Designed objects are often intended to communicate purpose and meaning to users. Yet, they are also usually designed with an artistic or aesthetic purpose. Sometimes that aesthetic overlays, or is part of, the intended functionality, inherently impacting the user's experienced emotions (Gaver, 1999; Triberti et al., 2017). Hekkert and Cila (2015) stresses the importance of considering user's emotions in design. He suggests that there are two main considerations in understanding the emotional impact of a design on users: 1) to avoid unintended negative reactions; and 2) to achieve a positive or satisfactory experience of that design and its functionality. Triberti et al. (2017) and Chitturi (2009) also suggest that ultimately it is the user's positive and negative experiences with a particular design in matching their desired goals that will determine its success as a product. So (2019) found that emotions elicited by a design have a linear relationship to design preference. In understanding the implications of design on users in relation to emotions, there are three important factors to consider: 1) the functionality and/or meaning conveyed by an object; 2) the positive or negative emotional factors conveyed by that object and interpreted by the user; and 3) the positive or negative emotions experienced by the user as a result of interaction with the design.

* Corresponding author. Ted Rogers School of Information Technology Management, Ryerson University, Toronto, Ontario, Canada.
E-mail address: dfels@ryerson.ca (D. Fels).

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At this point, it is important to acknowledge that the field of emotion research is well populated and controversial. Even the definition of emotion, and differences between affective experiences and emotions, shifts depending on the field of study (Russell, 2015). For the purpose of this paper, we use what Russell (2015) terms "the folk concepts of emotion" (p. 433), where single "primitive" terms such as anger, joy, fear, etc. are used to label a complex process or concept. In addition, we consider emotions to be episodic and short lived (minutes) rather than having a longer lasting effect (moods).

Following a brief overview of theories of emotions, particularly in relation to aspects of movement, interpretation and meaning, the somasemiotic framework and the designed object (Fruitbowl: FB) are described, together with the interpretation of FB through this framework with respect to the expected emotional effect on the bowl's prospective users. Subsequently, we report and discuss the results of an empirical user study examining the meanings and emotions conveyed by FB, and emotions experienced by participants in response to FB. This includes a comparison between emotions intended by the designer and the conveyed emotions of FB identified by participants using a vector analysis in Russell's circumplex model of emotions as suggest by (Sugaya et al., 2018) as one way of quantifying comparisons. The comparison offers insights into the possibility of using the framework predictively for design as well as a possible methodology for future comparative analysis.

2. Background

2.1. General models of human emotion

In the English language there are many discrete words describing human emotions. For example (Mohammad and Turney, 2013), found 826 English terms representing discrete emotions and over 10,000 words that could be associated with emotion(s). Studying this vast emotional landscape of humans has been a field of scholarship in psychology and linguistics for many years, in an attempt to determine representational models that can be used to assess them in humans, and automatically construct and express appropriate human emotions in machines. In the classification of human emotions, there are two main camps, identification of foundational sets (taxonomies) of discrete emotions from which all other emotions are derived (e.g., Ekman, 1999; Izard, 1992; Plutchik, 1980; Plutchik, 1994), and abstract models of emotion (e.g., Ekman, 1992; Russell and Pratt, 1980).

One commonly used set of discrete or primary emotions was proposed by Ekman (1992) and consists of six basic emotions; joy, sadness, anger, fear, disgust and surprise, which were derived from studies of facial expressions. More complex emotions (sometimes referred to as secondary and tertiary emotions in the literature) are then derivatives or combinations of these primary emotions (Ekman, 1992, Association and others, 2006, and Parrott, 2001).

A second frequently used model of describing and identifying emotions is an abstract model that defines emotions as falling along a two dimensional continuous scale; valence and intensity (or arousal), with the most common proposed by Russell and Pratt (1980). In this model, the horizontal axis is the valence axis and labelled with positive/pleasant as the right-most positive coordinate, and negative/unpleasant as the left-most negative coordinate. The vertical axis is the intensity axis, labelled with arousal as the top-most label and sleepiness as the bottom-most label. Various emotions can then be located within the four quadrants outlined by these two axes. Yik and Russell (2004) suggest that the emotions can be divided into segments, where each segment begins at the intersection of the two axes (0,0) and rotates through a 90° angle in a counter clockwise direction; indicating that an emotion can be represented as a two-dimensional vector in the x,y planes of the Circumplex model. Scherer (2005) empirically determined the x,y coordinates of a variety of different emotional states (see Fig. 2). This abstract model is a commonly used model to represent and evaluate the emotions of human-computer interfaces (Mandryk et al., 2006), automated processing (Paltoglou and Thelwall, 2013) and measurement of mood in advertising (Batra and Ray, 1986).

While the debate on the existence and quantity of basic/primary human emotion categories and models is on-going, what is evident is that people can identify emotions in words/phrases, faces and objects as well as from movements and can label those emotions, regardless of the model of emotions applied. It is thus feasible to ask participants about the emotions they interpret from designed objects as well as for them to identify and report on their own emotions.

2.2. Human interpretation of emotions

People are able to interpret and understand an emotion independent of whether or not they have any particular emotional reaction (Moors et al., 2013). For example, humans can appraise the emotional component of an object or event separately from their own subjective feelings experienced as a result of that object or event (Scherer, 1982, 2005). There can also be a difference between the interpretation of emotion an object conveys that the user identifies and understands, and the impact on a user's own emotional state. Thus, people can have multiple, diverging emotional experiences from the same event (Russell, 2015). When examining the emotional interpretation of a designed object, it is therefore important to distinguish between a user's expressed interpretation of the object's emotion and their own emotional state as a result of their experience with that object, in order to understand how one might influence the other.

2.3. Movement and emotion

Emotions can be expressed through a static image, however, movement can add another layer of possibility for communicating meaning and emotion of an object (Giraud et al., 2015). The field of robotics provides ample examples of how movement implemented as gestures and facial expressions can be used to express emotions (Wang et al., 2016). Animation of visual objects such as the "lamp" animation designed by Pixar™ can have strong emotional overtones communicated by its visual design and movement (Neupert, 2014). Our study explores how aesthetics and movement can be used as mechanisms to communicate a design's meaning and emotions and to compare this with the emotional impact that the designed object has on its users.

The expression and interpretation of emotions through human or human-like movement and gestures have been long been acknowledged, studied and applied in dance (e.g., Camurri et al., 2003; Rust-D'Eye, 2013; Sawada et al., 2003; Sparshott, 1997; Van Dyck et al., 2013), animation (e.g., Ali and Marcus, 2016; Courgeon and Clavel, 2013; Giraud et al., 2015), and robotics (e.g., Saraiva et al., 2019; Wang et al., 2016). In all of this work, velocity, directionality, intensity, shape, flow and size are common dimensions used to manipulate emotional expression. In particular, arousal is affected by velocity, intensity, shape, energy and directionality, with speed and intensity/energy being the strongest factor (Giraud et al., 2015). However, there have been few studies, which examine which specific properties best map to specific factors in either arousal/valence or discrete emotion models.

In one experiment, mapping human movement characteristics to affective responses, Tan et al. (2016) used biological movement parameters to generate emotions in a shape changing interface. They designed a bellows-like object that could move up and down to various heights, and tilt forward and backward at various angles. These motions could occur at various levels of smoothness, force and speed. They found that human movement characteristics can be used to generate movement in non-human interfaces to impart emotions to that interface, as modeled using Russel's Circumplex model of emotions of valence, arousal and dominance axes (Russell and Pratt, 1980). In particular, the speed at which the interface changes shape has an impact on all emotional dimensions, particularly arousal; faster speeds are interpreted

as increased arousal. Directionality (moving up or down) and orientation (forward/backwards) has a strong effect on valence; moving up conveys positive valence, moving down is interpreted as negative, and a flat orientation is more positive than one tilted away from or towards a user.

What seems to be consistent in research from many diverse fields is that objects can convey emotions through visual means relating to appearance as well as movement, and that those means can be concrete (e.g. emoticons) or abstract (e.g. gestures, vibration, direction). In terms of movement, various factors/properties of movement contribute different emotional properties: commonly, velocity and energy are associated with an arousal dimension; and shape, directionality and smoothness affect the valence or positive/negative dimension. However, there is little research on how user interactions with an object that cause it to move affect their interpretation of emotions conveyed by the object; about the relationship of abstract and concrete signs in affecting emotions; and about designing for complex emotions.

2.4. Design for meaning

Emotions communicated by objects and those experienced by users are only part of the story. Since the nascent beginnings of design research, researchers have been exploring the concept of design as a means of mediating communication between a designer's intentions for a design, an object's messages, and a user's interpretation of that design upon seeing/hearing/touching or using it (e.g., Sim, Hudson, O'Hare, Armstrong, Baker and Hayes, 2001; Waller, 1979). Crilly et al. (2008) argue that the model of mediated communication consists of designers, who are influenced by their values, attitudes, sensibility, feelings, experience and insight, and a created artefact whose form and user interface are designed to communicate its function and/or meaning. Users interact with that artefact and judge the intended functionality/-meaning of it as influenced by their own values, attitudes, sensibilities, feelings, experience and insight. Buchanan (1992), Crozier (1994), Taylor et al. (1999), and Urquhart and Wodehouse (2018) concur about the ability of a product to have the effect of altering a person's perceptions and attitudes. Turkle (1980) states: "… man has always been shaped by his artefacts. Man makes them but they in turn make him" (p.24) and she suggests that how a person responds to artefacts is a "window onto his deeper concerns" (p.19). King (2000) and Krippendorff (1989) agree that meaning is not inherent in things but is cognitively constructed by consumers of those things. People do not perceive objects as simply forms but as meanings; objects are seen in the context of other things, situations, and users (King, 2000). Buchanan (1985) also argues that designed objects have character because in some way they reflect their makers.

The relationship between meaning, characteristics and emotion is mitigated through the mediated communication process (Crilly et al., 2008). Desmet and Hekkert (2007) show that emotions experienced by users follow from the interpretation and understanding of a design's meaning. Using Desmet and Hekkert's model of the relationship between design intentions, a designed artefact, the interpretation of meaning by the users and emotions (Subjective Impressions in Human-Product Interaction or SIHPI), Agost and Vergara (2014) found that there was a significant relationship between the meaning of a product and the emotions of the participant. (Niedderer, 2012) investigated the relationship of complex emotions, movement and product meanings to develop a framework that could provide guidance to designers. The author used semiotic and behavioural analyses of a specific design object to systematically explore and abstract complex emotions associated with the movement of that object.

What is often missing from these types of studies is the difference between identification of the designer's intended emotion and/or meaning for the design, the ability of users to identify those designed emotions as well as the design's meaning, and any impact it has on the user's own experienced emotions. Often only the former or the latter is reported. In this paper, we examine the possible relationship(s) between these three elements in relation to concrete and abstract aspects of conveying primary as well as complex emotions. To do so, we have used the framework and object by (Niedderer, 2012) as the basis for evaluation for the current study.

2.5. Summary of literature review

In summary, research into the relationship of design and emotions is well established. Much of the research focuses on user experience, and does so most successfully where primary emotions and semantic or semiotic static visual images or appearances are used. Through studies into human behaviour and gestures, more recently, an interest in the relationship of dynamic forms of expression has emerged, particularly relating to emotions and movement. Work in this area has been able to show the relationship of movement with primary emotions, but the interpretation of complex emotions remains difficult and under researched. In the following, we report on our evaluation of the soma-semiotic framework (Niedderer, 2012) through user testing with the object FB, to ascertain whether the framework can assist designers in predicting and making explicit user experience.

2.6. The soma-semiotic framework and Fruit Bowl (FB)

The development of the soma-semiotic framework emerged from a dual theoretical and practice-based deductive investigation into the relationship of emotions and movement as a basis for creating and interpreting complex emotions in design (Niedderer, 2012). The framework development was built on a purposive review of selected theories and approaches of emotional design, emotional psychology, soma-aesthetics and the analysis of relevant design examples. The aim of the framework was to provide designers with a tool for interpreting and understanding their own designs in the design process, and ultimately to help designers to better determine or predict the emotional affect and perceived meaning of their designs. The soma-semiotic framework distinguished three areas of meaning making, including aesthetic, semiotic and behavioural, but only builds on the latter two to avoid the appraisal-based character of aesthetics in favour of the content-based aspects of semiotics and behaviour:

- Semiotic reading, which relates to the visual reading of an object. This can relate either to an object's function, often called product semantics, e.g. Krippendorff (1989); or to the story it tells (Kälviäinen, 2005) in that it refers to some meaning that is external to the object.;
- The behavioural aspects of movement (abstract, somatic meaning) with which users can identify through empathy and have a relationship with emotional affect (Shusterman, 2011; Weerdesteijn et al., 2005).

The framework development was paralleled by a well-defined but open-ended design exploration, used to allow for the creative leap as a characteristic strength of designing to generate novel solutions. It was conducted to better understand the complexities of embodying emotions through designing, and of reading and interpreting artefacts, to aid developing the framework. It resulted in the creation of FB. FB consists of 16 looped silver strips arranged in a 2-layered star to create a flattish ball shape, which is flexible and transforms into a doughnut shape when laden with fruit, visualising the weight of the fruit (see Fig. 1).

Table 1 provides the original interpretation of the Fruit Bowl by <the author> using the soma-semiotic framework (Niedderer, 2012). It also offers an illustration of how to use the framework to identify individual indicators and meanings for analysis. While the framework was developed based on rigorous concept development triangulated with creative exploration (Durling and Niedderer, 2007) and later used by designers (Dean and Niedderer, 2016) to test its usefulness in the design process, it

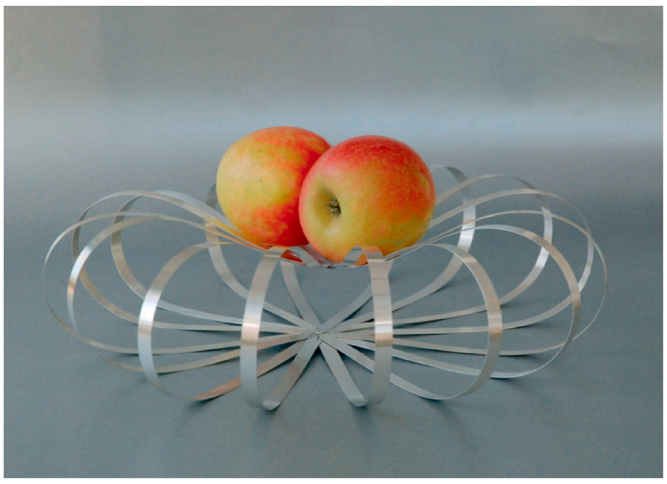

Fig. 1. The **Fruit Bowl** (Niedderer, 2012)**. Photo ©** (Niedderer, 2012) **. Used with permission.**

has not yet been evaluated with regard to its accuracy relating to user experiences. Therefore, this paper reports on a study undertaken to evaluate the framework, and compare predicted and actual user.

3. Method

3.1. Objectives

In our research, users were asked to identify their interpretation of the emotion(s) conveyed by a designed object (to enable comparison with the emotional interpretation through the framework) and also self-report their own subjectively experienced emotions. We used the same artefact as had been used during development of the soma-semiotic framework (FB) to test the framework as this was the first such test and it was important to be able to relate the results of the test directly to the framework development. The objectives of our study were thus to determine whether:

1) Any specific meaning(s) of the designed object, Fruit Bowl (FB) and its movement could be derived by target users;
2) FB conveyed any emotions with similarities/differences to the original interpretations made through the soma-semiotic framework (Niedderer, 2012); and
3) There was an impact on participants' experienced emotions as a result of interactions with FB.

In addition, we were interested in methodological aspects, such as whether:

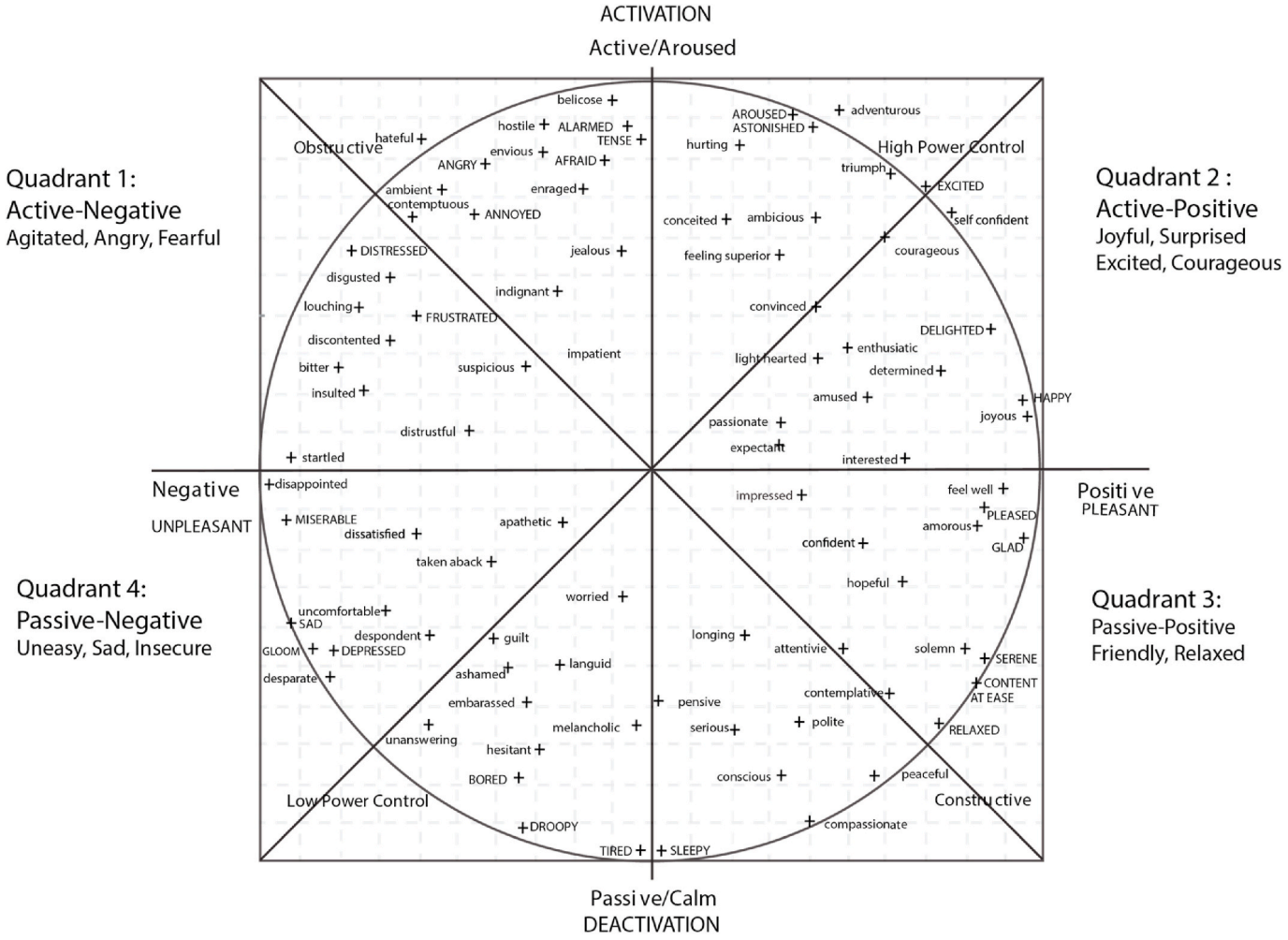

Fig. 2. Russell's Circumplex Model of Emotions labelled according to Scherer (2005) with the spontaneous emotion words and the emotion words from the prompt list presented to participants under Quadrant. The + sign indicates where each emotion word from the original model of emotions (Scherer, 2005) occurs in the two-dimensional space of the figure. Emotions in all uppercase letters are considered primary emotions and those in lower case are considered complex. Reproduced from Scherer (Scherer, 2005, p.720) with permission.

Table 1
Example of soma-semiotic framework completed for Fruit Bowl 1 (Niedderer, 2012) p.65–66).

Meaning Indicator	Description of movement/ image	Soma-semiotic interpretation of individual movement/image with regard to emotion	Soma-semiotic interpretation of combined movement/image with regard to emotion
Movement 1 – lightly laden, e.g., with one apple (expressive/ functional/ behavioural)	Bounce + high movement activity and dynamics	Elated joy	Put together, joy (bounce) and fear/ scariness (of spiders) are a contradiction of emotions, which leads to a humorous reading.
Movement 2 more heavily laden, e.g., with two apples (expressive/ functional/ behavioural)	Wobbly circular/ sideways 'rolling' movement	Unsteady, drunken, helpless	
Visual [semiotic] image 1	Visually heavy centre (fruit) + long silver strips emanating from the centre	Heavy centre and centrally emanating strips are read as body and legs, inferring the image of a spider because of the similarity of their relationship/ proportions. Spiders are widely perceived as 'scary' and associated with fear.	

I. There were gender differences in the interpretation of FB;
II. Using the bowl or watching a video of it affected the dependent variables; and
III. Equivalent data could be obtained from audio and video recordings of the sessions

Reasons for investigating these methodological issues included that video can be expensive, a barrier to participation and difficult to capture, whereas audio is less expensive and more flexible. Video can be more difficult analyse as specialised software such as Noldus Observer™ is required. It would be useful to know whether audio can be just as effective in gathering and analysing robust data on user experiences with designed objects. Also, being able to present a video rather than having live interaction with a designed object may open up more possibilities for remote data collection.

As a result, there were three independent variables: 1) gender (male or female); 2) method of bowl interaction (watching video of bowl or interaction with physical bowl); and 3) recording of the sessions (video or audio). There was a 50:50 ratio for each category within each variable.

3.2. Participants

Sixty participants (40 female, 20 male, 0 other) were recruited over a three-month period to evaluate the meaning and emotion conveyed by FB and experienced by participants during the session. Recruitment criteria were general; participants needed to be adults who were physically and cognitively able to give voluntary consent, and able to see, hear, speak and, for the actual bowl condition, physically lift and place apples. Participants were recruited from a wide age range (18–75+), and diverse ethnic and educational backgrounds. All participants lived in the UK and were recruited from a wide geographical area covering the Midlands and Southern half of the country. Ethics approval for recruiting and involving human participants in this study was granted by the participating institutions (removed for blind review) as part of the European project (removed for blind review). All participants were informed of the study purpose, risks, privacy and confidentiality provisions, benefits and right to withdraw. All participants provided written consent for inclusion in this study.

3.3. Approach

Our study was designed as a $2 \times 2 \times 2$ factor within-subjects design, with one factor being interaction style (view video of bowl's behaviour or interact directly with physical bowl), one being recording method (audio only or video), and the last being scenario. Participants were asked to evaluate the two dependent variables of meaning and emotion conveyed by FB within two scenarios, with one apple and then two apples placed on it, and then they assessed their own experienced emotion, a third dependent variable. They were all exposed to the scenarios in the same order because seeing or experiencing scenario 2 depends on the conditions in scenario 1 – i.e. in order to move the bowl with apples on it (Scenario 2), the apples have to be placed on it (Scenario 1).

There are a number of acknowledged methods for evaluating user emotions, most prominently the PrEmo model by Desmet (Desmet, 2004; Laurans and Desmet, 2012). Both versions of the model are based on linking emotional responses to design to facial responses (stereotypical characters) to ascertain emotional evaluation. However, Laurans & Desmet (2012) found that although "these animations were … very successful in conveying valence [and] also clearly allowed participants to discriminate different type [s] of negative and positive affect", they did not allow for identifying "as many as hoped for" (p.11).

In addition, users find it difficult to assess their emotional state with Russell's Circumplex model (Paltoglou and Thelwall, 2013), and researchers have found previously that participants can struggle with placing their emotions onto the Circumplex, particularly with stating the strength of the emotions (Gomez et al., 2011). As a result, researchers have been combining the Circumplex model with the discrete model when collecting and analysing data from participants in order to allow the ability to judge/label emotional experiences (Russell, 2015).

Therefore, a different method was used over other existing methods such as the PrEmo model (Desmet, 2004; Laurans and Desmet, 2012), because, while the PrEmo model included complex emotions, it did not acknowledge that these can be based on two or more factors in the design. Our method offered a layered evaluation of the different aspects of emotions, allowing differentiation between concrete and abstract, static and dynamic (movement-based) expressions that may be perceived and experienced by the user.

3.4. Procedure

In the video condition, participants viewed a video of the two scenarios, and in the physical condition they placed real apples on the actual bowl. The video for the first scenario consisted of a looped 26-s video of one apple being placed on the bowl and the bowl bouncing up and down. For the second scenario, participants viewed a 14-s video of two apples being placed on the bowl and it then moving with more complex motion (up and down, and side to side). With the physical bowl condition, participants were asked to place the apple(s) on the bowl themselves (first one and then the other), and the researcher would ensure that the bowl was seen to move in the same way as in the videos by bouncing/moving the bowl if participants did not induce enough movement when placing the apples. When using real apples, care was taken to ensure that the apples used were visually similar to those in the videos, and the same colour, weight, size and shape for each participant.

After each scenario, participants were asked to discuss their interpretation of the bowl's meaning and any emotions that they thought the

bowl was communicating. These open-ended questions were asked first to encourage participants to respond using their own words. Once they had responded (or in some cases failed to respond for several seconds), participants were provided with a prompt list of 12 emotion prompts/labels and a "no emotion" option, and then asked to select which word(s) applied. After both scenarios were treated in this way, one additional question was asked about the impact of the bowl on the participant's own experienced emotions. Participants were first asked as an open-ended question and were then given the same list of emotion prompt words if needed. Finally, as the session concluded, participants were asked if there was anything else they would like to say about the bowl.

3.5. Apparatus and measures

The emotion prompts were selected and amalgamated from two schemes in order to have a balanced spectrum of positive and negative emotions (6 each) drawn from primary and complex emotions. The emotions were also selected to be appropriate for attribution to the bowl as opposed to human beings. Five primary and four complex emotions were selected from Parrott's emotion groups (Parrott, 2001) as seen in Table 2 **in bold**.

Since Parrott's emotion groups had more emphasis on negative emotions, we selected three more emotions from the Emotion Annotation and Representation Language (EARL) scheme (Association and others, 2006), which also follows the quadrant groups of Russell's Circumplex Model of Emotions, to create a balance between positive and negative emotions (seen in Table 2 in italics). It should be noted that these prompts were used only when and if participants were unable to express emotions in their own spontaneous words.

3.6. Data analysis

Audio and video recordings of the sessions were coded using Noldus Observer™ version 12 to identify major themes regarding the bowl's meaning as well as the emotions conveyed by the bowl and experienced by participants, using an open coding methodology. All emotion words expressed during the sessions were coded – those in the list of prompt words and those spontaneously used by participants themselves. Eleven main themes and twenty-nine subthemes were identified. In addition, two different modifier sets were allocated to eight of the themes: 1) sentiment (positive, negative, and neutral); and 2) intensity of the reported emotions or meaning (more, less, same). Table 3 provides an outline of the themes and sub-themes along with definitions and examples.

Two independent raters coded 20% of the data in order to ensure that the themes, definitions and modifiers could reliably be applied. Inter-rater reliability (Kappa statistic) between raters for all themes and subthemes was Kappa >0.6. According to Landis and Koch (1977), a Kappa value between 0.60 and 0.79 suggests substantial agreement between raters. The remaining data were then coded by a single rater. The large variety of spontaneous emotion words (over 50) from the audio/video recordings, most of which did not appear on the emotion prompt list presented to users, and those from the prompt list itself, were translated into Russell's Circumplex model of emotions using emotion labels outlined in (Gobron et al. (2010, and Paltoglou and Thelwall (2013). Fig. 2 shows the distribution of emotion words used in this study superimposed on the four quadrants of the Circumplex model by Scherer (2005). In this model the x-axis with positive and negative end-points is called the valence axis, and the y-axis is called the arousal axis. Given that emotions are plotted on an x-y axis, it is possible to quantify each emotion as a vector beginning at the centre of the model (Sugaya et al., 2018).

Shapiro-Wilkes tests for normality indicated that most of the data were not normally distributed and attempts at transformations did not lead to improvements. As a result, non-parametric statistics were used.

Table 2
12 emotions selected from Parrott (bold) and EARL (italics).

Primary	Complex
Angry	**agitated**
Sad	**insecure**
Fearful	**uneasy**
Joyful	**excited**
Surprised	courageous
	relaxed
	friendly

4. Results

A Wilcoxon rank test between all variables for Scenarios 1 and 2 was carried out to examine any learning effect. Kruskal-Wallace and related post hoc tests were used to examine differences between the emotion quadrants, meaning themes, and the grouping variables of interaction style and data recording method. A Spearman correlation statistic was used to examine relationships between the emotion and meaning variables. A Bonferroni correction was applied to the p-value to reduce the probability of Type I errors due to the number of tests applied to the data. Significance was thus determined to be $p < 0.025$.A Wilcoxon signed rank test was carried out to determine whether there were differences in conveyed and experienced emotions between Scenario 1 and 2, and there were no significant differences in emotions between Scenarios 1 and 2, suggesting that there was no order effect in the data. In addition, a bivariate correlation was carried out to determine any relationships between scenarios and emotion quadrant. There was no correlation for any of the emotion quadrants in Scenarios 1 and 2. As a result, all data were combined into a single data set. In addition, themes where there were fewer than ten entries were eliminated from this analysis.

In line with our objectives, the combined data were then analysed to determine: 1) differences in meaning categories for FB in order to find dominant themes, 2) differences in emotion categories for FB in order to find dominant themes; and 3) whether there were relationships between emotions and meaning findings from the experiment and intentions and predictions according to the soma-semiotic framework. In addition, we looked at whether i) gender, ii) the viewing of the video as opposed to use of the bowl, or iii) the use of video or audio for data collection had any impact on the dependent variables.

4.1. Independent variables

4.1.1. Gender

A Mann-Whitney test was carried out to determine whether there were any significant differences between male and female participants for all categories. There were no significant differences ($p > 0.025$) in FB conveyed emotion ratings, experienced emotion ratings or meaning categories.

Video of FB versus direct interaction with FB.

There were no significant differences for any of the emotion or meaning categories between watching the video of FB and direction interaction with it based on a Mann-Whitney test. Similarly, studies on the impact of the physical embodiment of a robot versus a virtual image/animation of one did not show significance (Lee et al., 2006; Powers et al., 2007). However, others, (e.g., Hwang et al. (2013) did find significant differences.

4.2. Video recording method versus audio recording method

Based on a Mann-Whitney test, there were no significant differences between video and audio recording methods for all categories.

Table 3
Definitions and examples of all themes and sub-themes.

Theme and definition	*Examples*
Meaning Themes	
Technical/functional – Aspects of the bowl or interactions involve practicality of object	**Pos –** Want to purchase one, "this is different" **Neg –** Not practical, attributing emotion of bowl to self
Use of Metaphor – Describes bowl or apples with human, animal, floral or other inanimate object characteristics	Has eyes or face, like slinky, like a spider, like Jello
Aesthetic, physical features – Describes shape, size, visual appeal as design or art object independent of practicality	**Pos** – Purity, symmetrical, novel, funky, geometric **Neg** – Does not look like a bowl
Movement/Kinematics – Discussion of bowl movement as being important or affecting emotion/person	**Pos** – Bouncy, has energy, rocking **Neg** – Bowl is unstable
Interactivity of Bowl – Characterisation of bowl's current or predicted behaviour	**Pos** – playful, strong, humourous, fun, or want to do something more with it, how would bowl react if do something else with it (e.g., place a banana on bowl). **Neg** – afraid apples will fall off, uses caution to place apples
Impact of Bowl Interaction on Self – Characterisation of how bowl or apples affect individual participant	**Pos** – "I like it", "I could watch it all day" **Neg** – "I want to protect apples", "I am concerned about apples"
No meaning assigned to bowl – Does not consider a bowl to have any meaning	"Bowls do not have meaning"
Emotion themes	
Conveyed Emotion of Bowl- stated emotion of bowl	
Sub-themes	
Active-Negative quadrant(FB_ActNeg) →	Angry, Afraid, Distressed, Agitated
Active-Positive quadrant (FB_ActPos) →	Aroused, Excited, Courageous, Happy (joyful)
Passive-Positive quadrant (FB_PasPos) →	Friendly, Relaxed
Passive-Negative quadrant (FB_PasNeg) →	Sad, Uncomfortable, Uneasy
No emotion →	"Bowls do not convey emotions"
Experienced Emotion – emotion induced in participant by bowl	
Sub-themes	
Active-Negative quadrant (Exp_ActNeg) →	Angry, Afraid, Distressed, Agitated
Active-Positive quadrant (Exp _ActPos) →	Aroused, Excited, Courageous, Happy (joyful)
Passive-Positive quadrant (Exp_PasPos) →	Friendly, Relaxed
Passive-Negative quadrant (Exp_PasNeg) →	Sad, Uncomfortable, Uneasy
No emotion →	"Bowls do not convey emotions"

4.3. Meaning

A Kruskal Wallace test was carried out to determine whether there were any differences between the meaning themes shown in Table 3. There was a significant difference between meaning themes [χ^2 (13, N = 432) = 55.45, p = 0.00]. Adjusted pair-wise comparisons resulted in six significantly different pairs (see Table 4). Table 5 shows the descriptive statistics for all meaning themes. Fig. 3 shows the frequency of occurrence of comments for all meaning categories.

Table 4
Significant post-hoc pair-wise comparisons for meaning variables.

Pair	p
Technical-neutral x Interactivity of Bowl-positive	0.012
Impact of Bowl Interactions on Self-negative x Interactivity of Bowl-positive	0.000
Impact of Bowl Interactions on Self-negative x Aesthetics-positive	0.018
Movement-neutral x Aesthestic-positive	0.000
Movement-negative x Aesthetic-positive	0.005
Technical-neutral x Aesthetic-positive	0.002

From Tables 4 and 5, and Fig. 3 we can see that the top four categories by mean comments are all coded as positive: interactivity of bowl, impact of bowl interaction on self, movement, and aesthetics. Participants stated that they enjoyed the interactivity of the bowl, its aesthetics and movement, as well as its impact on their own emotions. The fifth category is technical negative, where often participants, while appreciating the aesthetics and interaction of the bowl, would comment that it was not a very practical object – it would not hold much fruit, might bruise soft fruits, and could not hold some fruits at all (e.g. grapes). Table 5 and Fig. 3 also show that metaphor was not a large part of the way that people assigned meaning to the bowl. People often found it hard to assign a meaning to an object (this is something very familiar to designers but much more foreign to users). Meaning was thought to be more about what participants could see, feel and experience with the bowl (as per the top 5 categories focussed on interaction, aesthetics, movement, emotions and technical usability), rather than about exploring what the designer might be trying to communicate or what

Table 5
Mean and standard deviation for all meaning themes/sub-themes.

Category	N	Mean rank	Mean (# of comments made by participants)	SD
Technical-positive	25	218.74	1.88	1.20
Technical-negative	50	226.83	1.96	1.18
Technical-neutral	17	125.24	1.06	0.24
Interactivity of bowl-positive	47	246.64	2.23	1.58
Interactivity of bowl-negative	30	215.53	1.80	1.10
Impact of Bowl Interactions on Self-positive	39	230.78	2.10	1.50
Impact of Bowl Interactions on Self-negative	21	137.26	1.24	0.89
Movement-positive	54	230.12	1.98	1.25
Movement-negative	30	165.45	1.40	0.81
Movement-neutral	20	154.90	1.35	0.93
Aesthetics-positive	47	275.82	2.98	2.34
Aesthetics-negative	26	187.98	1.50	0.71
Use of metaphor	20	189.60	1.55	0.89

metaphors might be relevant.

Table 4 reveals that those who made positive comments about the aesthetics or interactivity of the bowl were less likely to see it as having a negative impact on themselves, or to make negative comments about its movement.

4.4. Emotions

4.4.1. Emotion prompt words

Examining the emotion responses from the listed emotion prompts, the Wilcoxon sign rank test showed that there were no significant differences between Scenarios 1 and 2 for the 12 listed emotion prompt words ($p > 0.025$). As a result, for all following analyses, the listed emotion prompt words were combined with the over 50 spontaneous emotion words arising from the interview data in the applicable emotion quadrants (Fig. 2).

4.4.2. Emotions conveyed by FB

A Kruskal-Wallace test was carried out to determine whether there were significant differences between the emotion quadrants, including No emotion, for FB. There was a significant difference between the emotion quadrants and the No emotion theme for FB [χ^2 (4, N = 156) = 24.36, p = 0.000]. Pair-wise comparisons were carried out with adjusted significance. There was a significant difference in the mean number of comments between Conveyed_active-positive (FB_ActPos) and Conveyed-active-positive (FB_ActNeg), and Conveyed_passive-positive (FB_PasPos) and No emotion ($p < 0.025$). Table 6 and Fig. 4 provide the descriptive statistics for all Quadrants and the No emotion categories.

4.5. Emotions experienced by participants

A Kruskal-Wallace test was carried out to determine differences between the emotion quadrants and No emotion for the emotion experienced by each participant. As there were only nine entries in Experienced_active-negative (Exp_ActNeg) and the no emotion categories, they were eliminated from the analysis. There were no significant differences ($p > 0.025$) between the other three experienced emotion categories. Table 7 provides the descriptive data.

Fig. 5 shows the frequency of emotions words in each experienced emotion quadrant.

While there were no significant differences between the three experienced emotion categories with sufficient numbers to analyse, Exp_ActPos elicited the highest mean number of comments per participant (M = 2.20, SD = 1.65 – see Table 7). As seen in Fig. 5, the majority (41%) reported their own feelings about the bowl as an Active-Positive emotion (happy/joyful) followed by 27% of participants reporting a Passive-Positive (relaxed/calm) emotional reaction to the bowl. Thus, 68% of participants had a positive feeling about the bowl.

4.5.1. Weighted vector analysis

A resultant vector of the emotions for the two experimental scenarios was calculated by adding the x,y coordinate (X_{total}, Y_{total}) of each

Table 6
Mean rankings for all FB conveyed emotion categories.

Category	N	Mean Rank	Mean (# of comments)	SD
Conveyed_active-negative (FB_ActNeg)	20	59.43	1.5	0.89
Conveyed_active-positive (FB_ActPos)	55	101.65	3.0	1.73
Conveyed_passive-positive (FB_PasPos)	30	63.08	1.57	0.86
Conveyed_passive-negative (FB_PasNeg)	30	75.45	2.03	1.45
No emotion	21	62.40	1.67	1.15

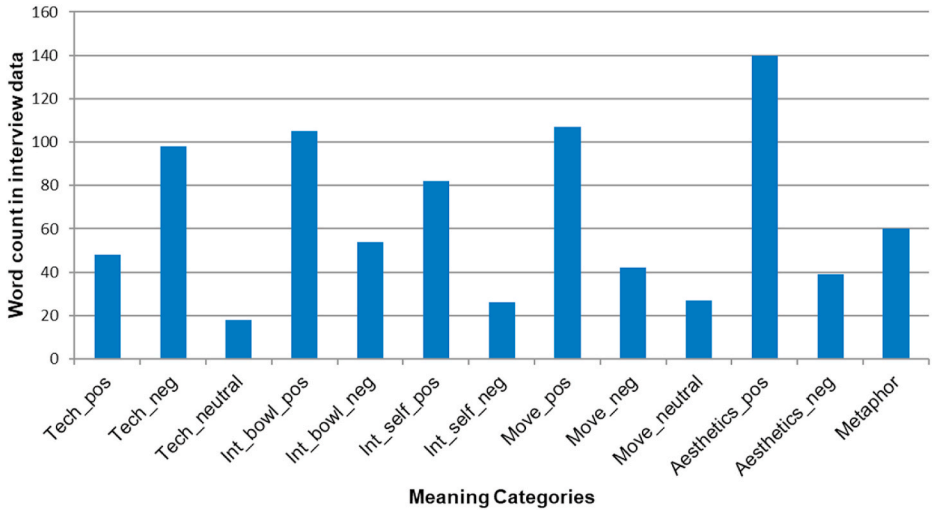

Fig. 3. Overall total of number of comments produced by participants for each Meaning theme/subtheme.

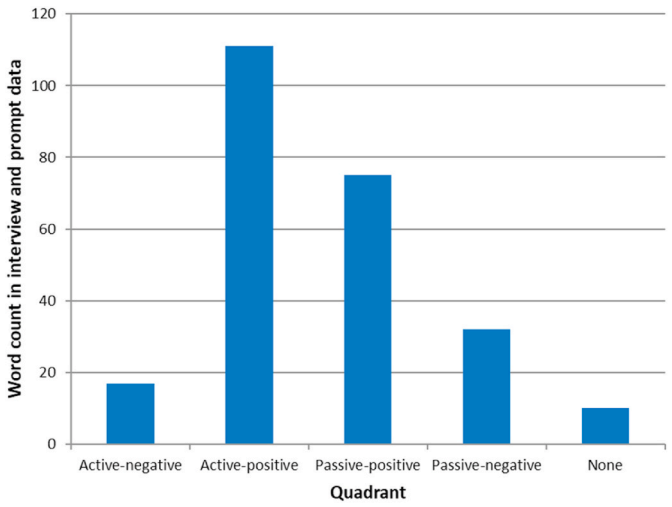

Fig. 4. Frequency of conveyed emotion words for each quadrant and for the no emotion category.

Table 7
Mean and standard deviation for all experienced emotion ratings.

Category of Emotion	N	Mean rank	Mean (# of comments for all participants)	SD
Experienced_active-negative (Exp_ActNeg)	9		1.78	1.64
Experienced_active-positive (Exp_ActPos)	51	63.03	2.20	1.65
Experienced_passive-positive (Exp_PasPos)	41	55.89	1.81	1.10
Experienced_passive-negative (Exp_PasNeg)	21	44.52	1.52	1.40
I am experiencing no emotion	9		1.11	0.60

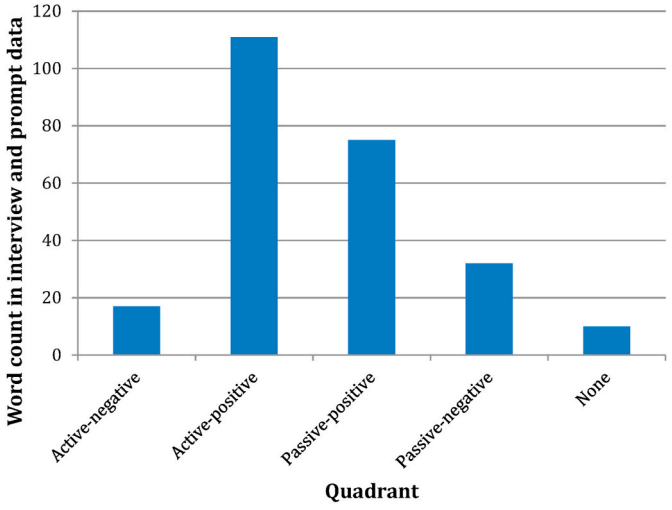

Fig. 5. Total count of emotion words in each quadrant of Russell's Circumplex for self-reported experienced emotional reaction to bowl. Experienced_active-negative and No Emotion categories were removed from the analysis due to low n.

emotion for each task weighted by the percent contribution of each emotion (see Equations (1) and (2)). Table 8 provides the resultant vectors for Scenario 1 and Scenario 2 respectively.

$$X_{total} = \sum_{q=1}^{4} x_q * W_q \quad (1)$$

$$y_{total} = \sum_{q=1}^{4} y_q * W_q \quad (2)$$

where: W = Percent contribution of emotion in task.

q = most commonly reported emotion for quadrants 1–4 (FB_ActNeg = Agitated; FB-Q2 = Joyful; FB-Q3 = Relaxed; FB_ Q4 = Uneasy).

The overall coordinate for the emotion of Scenario 1 is (4.2, 2.1) and for Scenario 2 (2.6,-0.8) (see Fig. 6, Emp_1 and Emp_2 respectively, for a graphical representation of these coordinates). Combining the resultant vectors from Scenario 1 and Scenario 2, the overall empirically derived emotion vector for FB is (6.8, 1.3) which falls in the Active-Position quadrant (dotted blue line in Fig. 6).

4.6. Comparison with the soma-semiotic framework

Although there were no significant differences or correlations between Scenarios 1 and 2, examining the frequency of occurrence of the various emotion types provide some useful insights into the theoretically derived or designed emotions (see Fig. 6). The majority of emotions conveyed by FB in Scenario 1 (the single apple that bounced up and down) were in the Active-Positive quadrant which contains happy, joyful-type emotions (111 of the 220 emotion words, 50%, used by participants) as predicted by Author (2012). The second most frequent word set occurred in Quadrant 3 (50 of 220, 23% of emotion words), containing words such as relaxed or calm.

For Scenario 2 (two apples which added the side-to-side movement), the majority of conveyed emotions were in the Passive-Positive quadrant or calm/relaxed (57 of 170 emotion words, 34%, emotion labels used by participants) followed by words occurred for Active-Positive quadrant (48 of 170, 28%) and then words in the Passive-Negative quadrant (40 of 170, 24%). The soma-semiotic framework developed by the designer predicted the resultant emotion for Scenario 2 to be a combination of unsteady, fear and joy. Calm or relaxed did not factor into the original model yet it was the dominant emotion identified for Scenario 2 by participants.

4.6.1. Vector analysis

Assuming the three different emotions attributed by (Niedderer, 2012) for Scenario 2 (joy, fear and unsteadiness as seen in Table 1) would contribute equally (33%) to the overall emotion for Scenario 2 and using Equations (1) and (2), the resultant emotion would be close to passionate, which also falls into the Active-Positive quadrant of Russell's Circumplex (SS_2 in Fig. 6). When combined, such as when FB contained two apples, (Niedderer, 2012) predicted the conveyed emotion would be "humour" or "fun" because of the contradictory emotions produced by the different movements. Humour/fun (amused in Fig. 2) fits into the Active-Positive quadrant and occurs near the centre of the quadrant. However, the resultant vector of the three emotions for Scenario 2 is closer to 'passionate', which has a lower valence but similar arousal level as amused. Combining the predicted emotions as outlined from both scenarios using the weighted vector analysis would then produce an overall emotion conveyed by the bowl to be one with a high positive valence and a low arousal such as Delighted in Active-Positive quadrant (dashed red line in Fig. 6).

Table 8
Weighted coordinates for a representative emotion in each quadrant for Scenarios 1 and 2.

Vector	x	y	Weighted_x Task1	Weighted_y Task1	Weighted_x Task2	Weighted_y Task2
FB_ActNeg-Agitatied	−5	6	−0.36	0.44	−0.35	0.42
FB_ActPos-Excited	7	7.2	3.53	3.63	1.98	2.03
FB_PasPos-Relaxed	7.1	−6.8	1.61	−1.55	2.38	−2.28
FB_PasNeg-Uneasy	−6	−4.1	−0.57	−0.39	−1.41	−0.96

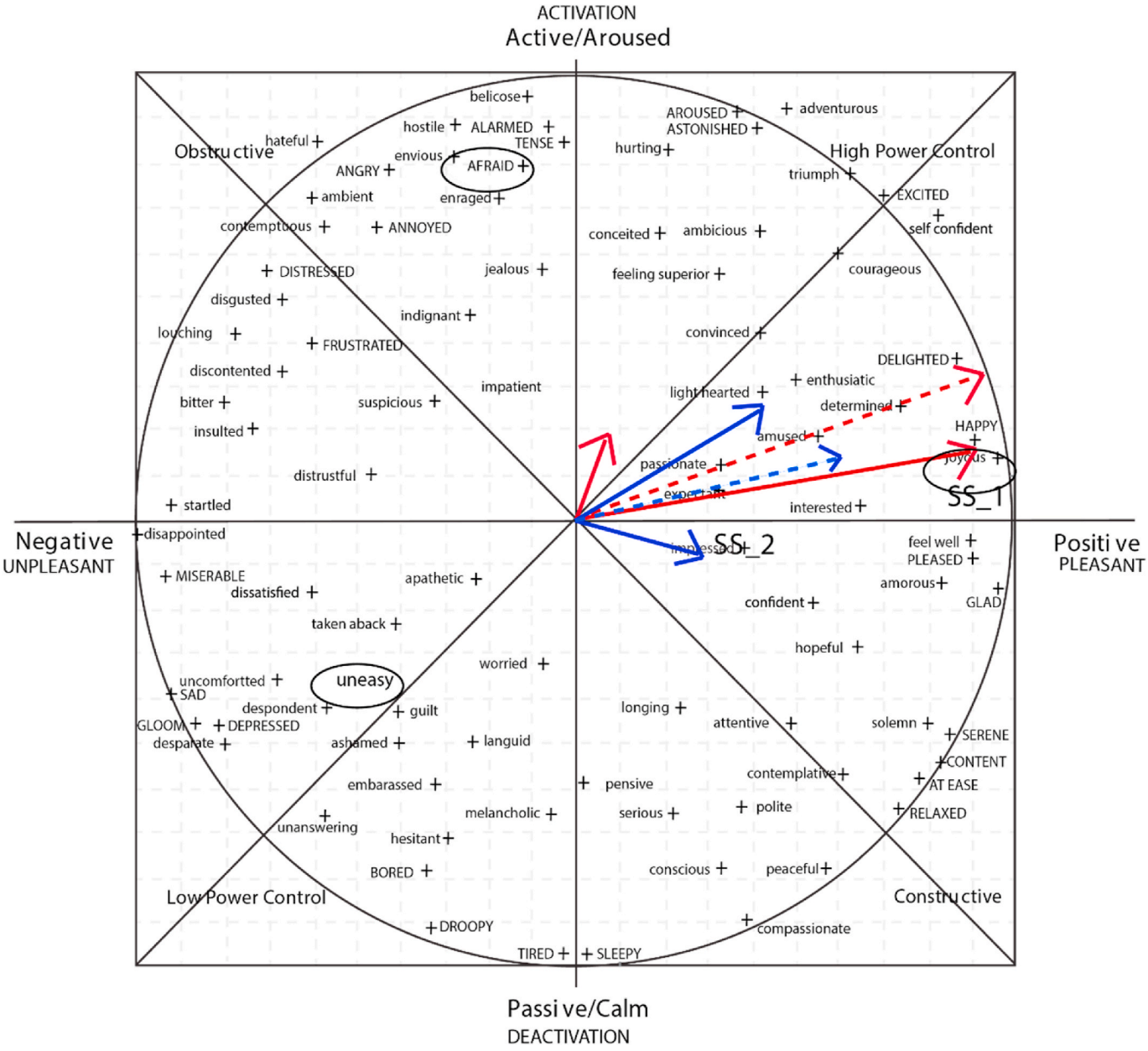

Fig. 6. Estimate of predicted resultant vector, shown as dashed red arrow, from addition of Joyful emotion vector of bouncy bowl from Scenario 1 and Fearful, Joyful, and Uneasy emotion vectors of wobbly bowl from Scenario 2 as described by bowl designer and assuming each contributed an equal value (33% for each emotion). The blue lines show the vectors from Scenarios 1 and 2 of the study as well as the resultant vector (dotted blue line). Note: each notch on the x, y axis is valued at 1 unit so that the highest x or y value is plus or minus 10 with the central point (0,0) designated at the x and y axis intersection. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

5. Discussion

We were interested in understanding; 1) any specific meaning(s) attributed to the FB, 2) whether FB conveyed any emotions with similarities/differences to the original interpretations made through the soma-semiotic framework, and whether 3) there was an impact on participants' experienced emotions as a result of interactions with FB. In addition, we were interested in methodological aspects, such as i) gender, ii) whether using the bowl or watching a video of it affected the dependent variables, and iii) whether equivalent data could be obtained from audio and video recordings of the sessions.

5.1. Overall meaning

Participants found it hard to explicitly state when asked what they thought FB might mean as this was largely a concept foreign to them. Results showed that they made many more comments about the aesthetics, movement and emotional impact of the bowl (most of them positive), and more about the technical usability and practicality of the bowl (many negative) than they did about metaphorical meaning. Therefore, expecting users to make metaphorical conclusions about the meaning of an object may be unrealistic and the inclusion of metaphor as a major function of the framework should be revised.

However, those who made positive comments about the aesthetics or interactivity of the bowl were less likely to see it as having a negative impact on themselves, or to make negative comments about its movement. These findings suggest that a positive interactive or aesthetic understanding of an object may be related to more positive emotions about it, as also found by Agost and Vergara (2014). Chitturi (2009, and Triberti et al. (2017) also suggest that a user's positive and negative experiences with a particular design will determine its success as a product. This is an issue worth exploring further in future research, as designing positive aesthetic and interactive experiences into objects could be a way to improve perceived ease of use (PEOU) and attitudes towards usage (ATU), and hence adoption or acceptance of technologies, as suggested by Technology Acceptance Model (TAM) research (e.g. Davis, 1993).

The effect of motion on the interpretation of the bowl's movement may best be explained with Tan et al.'s (2016) biological movement framework where the velocity of movement has the greatest effect on arousal (and less so on valence) and thus the correlation between the Positive-Active quadrant and Positive-Passive quadrant could have resulted from the change in velocity of the movement from fast in Scenario 1 to slower in Scenario 2. The change in directionality from up-and-down in Scenario 1 to side-to-side in Scenario 2 could have also played a role, as Tan et al. (2016) found that directionality (up versus down) and orientation (forward/backwards movement) affects valence ratings. In our study, the orientation in Scenario 2 was flat with smaller up/down movements compared with Scenario 1. According to Tan, this would then convey a positive valence but low arousal (Positive-Passive quadrant) which was confirmed by the empirical results of our study. Taken together, these movements suggested calm rather than fear or uncertainty.

5.2. Overall emotion

Similar to the propositions of Norman (2005), Russell (2015) and Russell and Pratt (1980), designed objects can convey emotions and those emotions can be interpreted by users. Examining the overall emotion profile regardless of scenario and according to the post hoc results, the Active-Positive quadrant contains the majority of the emotion words from the 50+ spontaneous words plus 12 listed prompt words (159 of 390 emotion labels in total, or 41%). It is significantly greater than the Active-Negative emotions, Passive-Positive emotions, and the No Emotion category. As a result of the vector and statistical analyses, we would suggest that the overall user experience for FB is a Positive-Active emotion between the regions labelled "interested", "amused" and "determined" in Fig. 6 that we are labelling "fun."

Although there was a variety of emotions reported by participants, the most prominent ones were in the positive valence quadrants of Russell's Circumplex model. The conveyed emotion of FB predicted by a theoretical assessment performed by (Author removed for blind review, 2012) was in the Active-Positive quadrant as an equally balanced combination of Fear (Active_Negative quadrant), Uneasiness (Passive-Negative), and Joy (Active-Positive quadrant). The empirically derived emotion conveyed by FB was also in the Active-Positive quadrant, however, less positive and arousing due to the frequency of emotions allocated in Passive-Positive (as opposed to the Active-Negative and Passive-Negative quadrant in the theoretical assessment).

5.3. Methodological findings

In this particular study, these results did not depend on whether or not a participant could interact with the bowl physically or watch its behaviour on video, or whether the data were collected through video or audio. There were also no differences between male and female participants in their assessment of meaning and emotion of the bowl, and its impact on their experienced emotion. We suggest then that the recording method of data collection (audio or video), and whether the user can interact with a designed object or watch a video of the interaction may not have an impact on a participant's ability to identify, report and discuss the emotion and meaning conveyed by that object, and experience emotions themselves as a result. Thus, it is possible to use a virtual method that uses video demonstrations rather than physical interaction with designed objects for assessing the interpretation of emotions conveyed by those objects. In addition, capturing only the audio of these interactions, rather than video recordings, produces acceptable and similar results. This may allow studies to be conducted with participants from international locations, to be more cost effective, and be possible in situations where face-to-face interactions are limited, such as those experienced with COVID-19. Whether or not this finding could apply in other situations such as gathering and analysing other types of data would need to be confirmed.

5.4. Proposed changes to soma-semiotic framework

We suggest that the biological movement framework proposed by Tan et al. (2016), that links the arousal and valence of emotions to speed, direction and orientation of objects, could be integrated into the soma-semiotic framework to describe emotional outcomes for moving designs. In addition, we recommend that aesthetic value be incorporated into the soma-semiotic framework to account for the impact of aesthetics on emotional outcomes. Further, it has become apparent that the use of metaphor in the interpretation of abstract visual appearance is

Table 9
Revised soma-semiotic framework for Fruit Bowl based on empirical results and Russell's Circumplex quadrant model of emotions.

	Meaning indicators	Weighted vector analysis in Russell's Circumplex model of emotion
Scenario 1 (expressive/ functional/ behavioural/ **aesthetic)**	Movement: Up/down/ bounce + high speed Interaction behaviour: Positive Aesthetic: Positive	Empirical: Active-Positive emotion with low positive arousal, medium valence (e.g., amused)
Scenario 2 (expressive/ functional/ behavioural/ **aesthetic**)	Movement: Wobbly circular/sideways 'rolling' movement + slow speed Interaction behaviour: Positive Aesthetic: Positive	Empirical: Passive-Positive Emotion with low negative arousal, low valence (e.g., impressed)

problematic, and not much considered by participants (see Fig. 5). Metaphor requires consideration of form, sound, interaction, materials, and other properties to convey it and proper use of metaphor to carry out design or describe it requires a mutual cultural and social understanding of the metaphorical premise between the designer and the user (Hekkert and Cila, 2015). Therefore, the use of metaphor may be more (or perhaps only) appropriate where concrete/narrative visual imagery has been used that is not open to interpretation. Table 9 provides a revised framework to that shown in Table 1, based on the results of this experiment.

To apply this revised framework to the assessment of designed objects that move, designers must consider three elements of the design; 1. movement structure and properties such as direction, speed and orientation, 2. the aesthetic intentions/value of the work (Ferrarello et al., 2018), and resultant emotional impact on users, and 3. the potential valence of the interaction behaviour on users. The emotional intention and impact, which are often complex and multi-faceted, can be assessed quantitatively by plotting vectors of the various emotional elements on Russell's Circumplex model of emotions. Equations (1) and (2) can then be used to determine the resultant vector. This vector then may not necessarily equate to one specific emotion in the model but will provide designers with the emotional quadrant that applies to their design.

5.5. Contributions of this research

This research set out to discover whether 1) any specific meaning(s) of FB and its movement could be derived; 2) FB conveyed any emotions with similarities/differences to the original interpretations made through the soma-semiotic framework, and 3) there was an impact on participants' experienced emotions as a result of interactions with FB.

We found that FB did indeed convey emotions and also elicit emotions in participants. A novel aspect of this research was to use vector analysis to plot the emotional intentions of a designed object on Russell's Circumplex model, which can illuminate the resulting quantitative, summative relationships of the individual emotional elements ascribed to a designed object by the soma-semiotic framework. It may be possible to use this vector analysis method for other word-based emotion models.

Combining the soma-semiotic and movement frameworks, and representing predicted individual emotive elements as vectors on the Russell's Circumplex may provide unique insights for practitioners into the emotions of designed objects being communicated to users as well as the potential user experience of the objects. This is an important consideration because research has shown that pleasurable emotions enhance aesthetic and interaction experiences with designed objects, which relates to user satisfaction (Hekkert and Cila, 2015), one of the three major components of usability.

In addition, designing for pleasure, or hedonomics, beyond usability, has been acknowledged for over 20 years as an important component in Human Factors (Jordan, 2002). As a hedonomic exercise (Oron-Gilad and Hancock, 2017) of creating pleasurable and satisfying interactions with a designed object, practitioners may be able to manipulate the individual emotive elements using these frameworks to express desired positive outcomes and avoid negative user experiences from their designed objects. This may then, in turn, affect a user's judgement about their satisfaction with using an object or their decision to acquire it (Davis, 1993; Jeon, 2017). Novice designers may also be able to use these models to better understand their own intuition and the outcomes of their work, in order to produce desirable objects and positive user experiences.

We were also interested in methodological aspects, i) whether there were gender differences in the interpretation of FB, ii) whether using the bowl or watching a video of it affected the dependent variables, and iii) whether equivalent data could be obtained from audio and video recordings of the sessions. Our findings that none of these variables had any significant impact should encourage researchers in similar fields to explore more flexible methods of data collection. Based on our findings, we would recommend that designers carefully apply the revised soma-semiotic framework (Table 9) when designing to elicit emotions in users, and also consider carefully whether metaphors that seem obvious to them will be easily interpreted by users. We also recommend that researchers more confidently employ cheaper and easier audio rather than video recording when they are interested in discovering participant's feelings and interpretations of a designed object rather than their interactions with it, and to use more affordable and flexible data collection instruments such as Zoom™ and/or video/photographic demonstrations rather than face-to-face demonstrations or in-person interactions.

5.6. Limitations

There was a number of limitations in this study that should be addressed in future work. The emotion prompt list used was not balanced according to any common emotion model, although Scherer (1982) suggests that using lists of emotion labels in this way is a very common procedure in emotion studies. Because users find it difficult to assess their emotional state based on these two axes (Paltoglou and Thelwall, 2013), it is common practice for researchers to combine the Circumplex model with the discrete model when collecting and analysing data from participants (Crozier, 1994). As a result, the number of emotion prompt words in the list that applied to each quadrant of Russell's Circumplex model was not equal. However, participants were asked first in an open-ended manner about the emotions conveyed by the bowl and that they themselves were experiencing without being limited to the words on the list. In fact, all participants used many spontaneous emotion words not listed on the prompt list during the discussions about the bowl, and more than 50 of these were coded and mapped onto the Circumplex along with the prompt words. However, future studies should ensure that there is a balanced list that adheres to a particular theoretical model of emotions.

A second issue was that the order of the two scenarios was not randomised; Scenario 1 always occurred before Scenario 2 because of the way that one led into the other. This could have affected the meaning and emotion words used in Scenario 2 due to the influence of participants seeing the emotion prompts during Scenario 1, or having more experience with the concept of FB. The Wilcoxon rank test showed that there was no learning effect between the two scenarios and any of the dependent variables. However, from the descriptive data, it seems that Scenario 1 and 2 did elicit different emotions; Scenario 1 tended to have more emotions in the Active-Positive quadrant and Scenario 2 in the Passive-Positive quadrant. It could be that there were an insufficient number of participants to show significance, or that the two scenarios were really not different enough to show statistically significant differences. Future research should ensure that unrelated tasks for within-subjects designs are randomised or counter balanced.

Another limitation is that only one designed object/designer pair was evaluated and thus generalisations of either the soma-semiotic framework, the vector analysis method of emotion summarisation and the empirical evidence cannot be made. However, this paper provides some initial evidence that this method of assessing the emotions conveyed by designed objects to users shows promise. Further research using other design objects and designers is required to evaluate the soma-semiotic framework in other contexts and the fidelity and efficacy of this method for general use.

Finally, the participant pool was limited to a population of one specific country. Reaction to aesthetics, and emotion identification and impact are affected by cultural values (Mesquita and Frijda, 1992; Russell, 2015). Although there was some cultural diversity, the dominant cultural group was white, Anglo-Saxons from the UK. The interpretation of the results must thus be limited by this caveat. Other demographics such as age, life experience, and attitudes towards designed objects may have influenced an individual's reactions to FB or

their assessment of the meaning and emotion of it. In fact, two participants stated that "objects do not convey emotions or meaning as they are inanimate," and did not attribute any emotions or meaning to FB. A future study could replicate this existing study and add cultural diversity, age, art appreciation and life experience as independent variables to ensure that any conclusions about the emotion and meaning of a particular designed object account for different cultural perspectives and demographic differences.

6. Conclusion

In conclusion, participants were able to interpret FB's meaning and emotion in two different scenarios with some degree of agreement, although all emotion quadrants of Russell's Circumplex were represented. In Scenario 1, one apple produced an active, bouncy up and down movement. Using a weighted vector analysis, the emotion of FB in Scenario 1 was a Positive-Active emotion in the area of amused, labelled fun. This was similar to the predicted emotional outcome for FB from the soma-semiotic design framework. In Scenario 2, two apples were placed on the bowl, which resulted in a change to complex movement involving a slow back and forth motion with some bounce. This was predicted to introduce uneasiness and fear as the movement and look of the bowl were metaphorically related to that of a spider. While some users used metaphorical references to describe the meaning of the bowl, there was little consensus. Rather, most people described the bowl's meaning using aesthetic and movement language, equating those to emotional assessments. This indicated that participants were able to distinguish different features (semiotic, semantic, aesthetic, behavioural) that led to the overall reading of complex emotions. It also demonstrated, however, that abstract imagery could be easily read in different ways, leading to different interpretations and readings of complex emotions.

As a result, the soma-semiotic framework has been adjusted to include a movement framework that relates properties of movement such as speed and directionality to the two emotion axes of Russell's Circumplex model of emotions. In addition, aesthetic judgement has also been added to the model where positive aesthetic judgement influences a positive emotional user assessment. The difficulty of using metaphor to interpret abstract visual appearance is acknowledged. The use of concrete/figurative visual imagery, which is less open to individual interpretation, in the context with movement will require further study.

In terms of the evaluation method used, it facilitated the elicitation of users' layered perceptions of different and sometimes diverse emotions as well as visual associations and metaphors conveyed by the bowl. While predictably primary emotions, such as joy, were perceived more consistently, the method allowed the richness of associations and emotions users have with objects to be revealed. Beyond improving the framework, this offers a rich source for designers to understand and extract users' perceptions and reactions.

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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