WHY PRODUCT DESIGN SUPPORT FOR IMPROVED WORKER CONTENTEDNESS ?

Farrugia, Lawrence; Borg, Jonathan
University of Malta, Malta

Abstract

It is frequently unrealised that emotions elicited through human-product interactions are not limited to the use phase. Indeed human workers also interact with the evolving artefact throughout distinct life-cycle phases such as manufacturing, transport and disposal. This paper reports on the work carried out in researching the influence of product design on the emotions elicited from workers who interact with the artefact during the manufacturing phase. The research results indicate that product design has indeed a capacity to influence the emotions elicited from life-phase workers. In turn the elicited emotions have been demonstrated to impact the performance of life-phase workers. This may contribute to longer product development time and increased costs. The evidence presented in this paper therefore justifies the need for the development of a design means which puts product designers in a better position to foresee the influence of design commitments on the emotions and performance of life-phase workers. The paper contributes towards the development of this design support means by establishing a number high level requirements to be considered.

Keywords: Worker emotions, Emotional design, Design for X (DfX), design theory, life-cycle consequences

Contact:
Lawrence Farrugia
University of Malta
Concurrent Engineering Research Unit
Malta
lawrence.farrugia.07@um.edu.mt

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1 INTRODUCTION

For many years research into product design has provided a variety of tools, guidelines and other means in order to support product designers in foreseeing the consequences of the decisions made on the performance and functionality of the artefact. These consequences result from the interaction between the artefact and other life-phase systems such as: fabrication equipment, assembly systems and the user who is a natural system. Design support has been typically deployed in the form of guidelines and computer aided design (CAD) tools (Borg, 1999; Farrugia and Borg, 2013; Farrugia et al., 2008). For instance, the design for manufacturing and assembly guidelines (DfMA) (Boothroyd et al., 2010) enable the product design team to foresee how assembly time can vary as a direct consequence of the choice of product form and type of fasteners used. The notion of foreseeing consequences of design decisions at an early stage in the design process is very important, since addressing undesirable consequences throughout later stages can be very time consuming and costly (Nevins et al., 1989).

In recent years, product design research has broadened its purpose by considering not only the functional but also the supra-functional requirements of users. Research has shown a keen interest on how product design attributes such as form, colours and material texture can be exploited in order to elicit desirable emotions from human-product interactions which take place during the use phase. The elicited emotions are also considered to be a consequence of product design decisions.

However, it is frequently unrealised that human-product interactions are not limited to the use phase, but occur throughout the entire life-cycle of the artefact as shown in Figure 1.

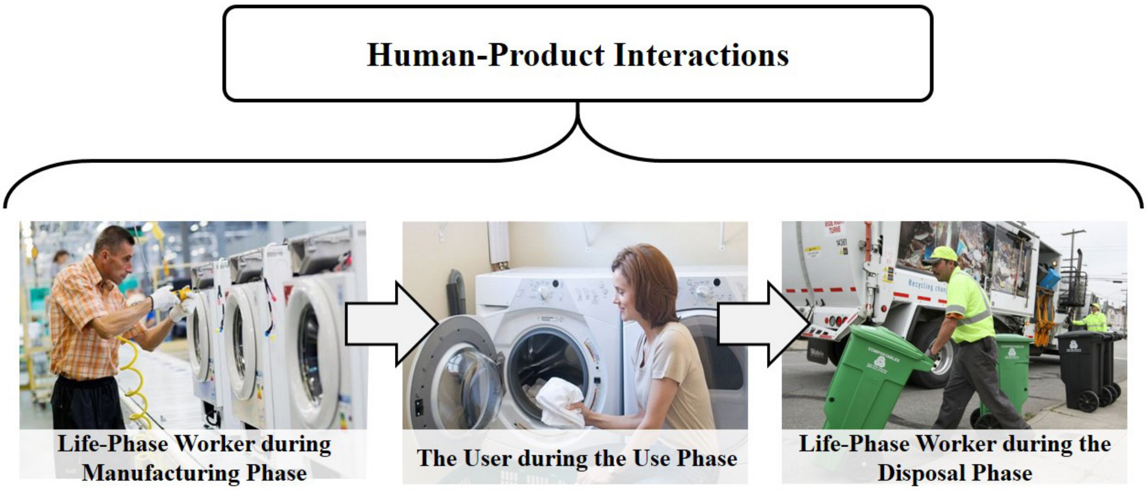

Figure 1. Human-product interactions across distinct life-phases

Human workers interact with the evolving artefact during various life-cycle phases, such as manufacturing, transport and disposal (Andreasen and Olesen, 1990). Like other human beings, life-phase workers also seek to be content and experience the elicitation of desirable emotions from these interactions.

The scope of this paper, is to outline *why* product design research should start to consider the influence of product design decisions on the emotions elicited from life-phase workers. The literature presented in the next section suggests that previous research has not devoted enough attention to the emotional impact which product design decisions have on life-phase workers. The interaction between the evolving artefact and life-phase workers occurs during the execution of tasks such as manual assembly, visual inspection, transport and disassembly of the artefact. These tasks are typically dictated by the way a product has been designed. Hence the first hypothesis of this research, is that design decisions can influence the emotions elicited from human life-phase workers who interact with the evolving artefact. The second hypothesis of this research is that the emotions elicited from life-phase workers can in turn influence their performance, which may contribute to increased product costs and longer development time. These hypotheses have been tested through an empirical study in which subjects were required to manually assembly an artefact. The results of this investigation are presented in section 3. In view of these results, section 4 contributes towards the development of a design support means for improved worker contentedness by outlining emerging high level requirements. The main conclusions derived from the research work are outlined in section 5.

2 BACKGROUND AND RELATED WORK

Research into product design and human emotions has had two salient themes: (i) capturing emotion knowledge by defining and measuring basic emotion prototypes and (ii) investigating how product design commitments, such as the selection of materials and product form, can elicit specific desirable emotions from users. An overview of the work carried out pertaining to these themes is presented in sub-section 2.1. A cognitive model which describes the process behind human emotion elicitation and its consequences on human behaviour is outlined in sub-section 2.2.

2.1 Challenges of research into product design and human emotion

The first research theme which is inherent to the study of product design and human emotions concerns the capture of emotion knowledge. An important challenge within this theme concerns the measurement of emotions which are elicited from human subjects. A review of different methods for the measurement of human emotions was presented by Caicedo and Beuzekom (Beuzekom and Caicedo, 2006). The authors classify the different methods of emotion measurement into 3 categories:

1. **Measurement of physiological arousal** which concerns the evaluation of changes in human physiology in response to emotion elicitation. The methods within this category typically rely on the use of thermometers and diodes in order to measure changes in blood pressure, skin conductance and heart beat rate.
2. **Measurement of motor expressions** which involves the assessment of changes in voice and facial expression as a result of emotion elicitation.
3. **Self-assessment measurement** methods in essence require for the subject to rate his/her feelings on a predefined scale. Two widely used methods within this category in the context of product design are the Product Emotion Measurement Instrument (Desmet, 2005) and the Geneva Emotion Wheel (Scherer, 2005).

In their analysis, the authors (Beuzekom and Caicedo, 2006) consider self-assessment methods to be ideal for measuring emotions elicited through consumer products. This is due to the inherent ease-of-use and the ability to gauge a wide spectrum of emotion concepts.

Another challenge which is associated with emotion knowledge pertains to the structuring of similar emotions such as amusement, joy, happiness and euphoria into basic emotion families. The motivation behind this challenge is to organize similar emotions into a manageable number of groups which can be utilized in practice by product design teams. Over the years numerous authors (Averill, 1975; Fehr and Russell, 1984) suggested emotion typologies in order to address this challenge. A shortcoming of the proposed emotions typologies was that these were too impractical to be utilised by product designers. Motivated by the lack of practical yet comprehensive emotion typologies, Desmet (Desmet, 2012) proposed a typology consisting of 25 positive emotions. However, a limitation of this research work is that it focuses exclusively on positive emotions elicited from individuals. Yet, negative emotions elicited within a specific context (Fokkinga and Desmet, 2013) can also contribute to create a rich user experience.

A second theme pertaining to research in product design and human emotions concerns how product design attributes, which are perceived through the human senses, can be exploited in order to elicit desirable user emotions. Ludden and Schifferestein (Ludden and Schifferstein, 2009) investigated how the olfactory sense can influence the evaluation of a product by customers. Similar research was carried out by Rahman (Rahman, 2012) who investigated the influence of tactile and visual stimuli on the evaluation of clothing articles. This study concluded that the perceived visual and tactile stimuli have a capacity to influence the customers' evaluation of the product. Fenech and Borg (Fenech and Borg, 2006) proposed a phenomena model of human emotion elicitation. This model was subsequently used in the development of an approach intended at providing emotion support to product designers. This approach was later adopted into a prototype design tool (Farrugia et al., 2008) which employs computer aided sketching in order to enable the conceptual synthesis of product form which elicits positive user emotions.

A severe limitation of the research work presented in this section, is that it focuses exclusively on the emotions elicited from users who interact with the product during the use phase. In view of this

limitation, the ongoing research work has proposed a framework (Borg and Farrugia, 2014) which introduced the notion that emotions are elicited as a consequence of the human-product interactions which occur throughout the entire life-cycle of the product. The framework suggests that human emotions are not elicited exclusively from users but also from life-phase workers.
There are two factors which can help to differentiate between life-phase workers and customers. The first factor is that life-phase workers interact with the artefact during phases which precede and follow the use phase such as manufacturing, transport and disposal. Another important distinction is related to the idea of that an artefact possesses internal and external properties(Hubka and Eder, 1996). Life-phase workers typically interact with both internal properties (e.g. type of manufacturing process, tolerances, arrangement of components etc.) as well as external properties (e.g. smell, ease of disassembly and operator safety). Unlike life-phase workers, users typically interact exclusively with the external properties of an artefact such as performance ratings, selling price and aesthetics.

2.2 The process behind human emotion elicitation and its consequences

Numerous models have been proposed in order to understand the underlying process behind human emotion elicitation. Two widely known contributors to the study of emotions are Richard Lazarus and Susan Folkman (Lazarus, 2006; Lazarus and Folkman, 1984) who proposed a model for the underlying appraisal process responsible for the elicitation of a human emotion, as shown in Figure 2.

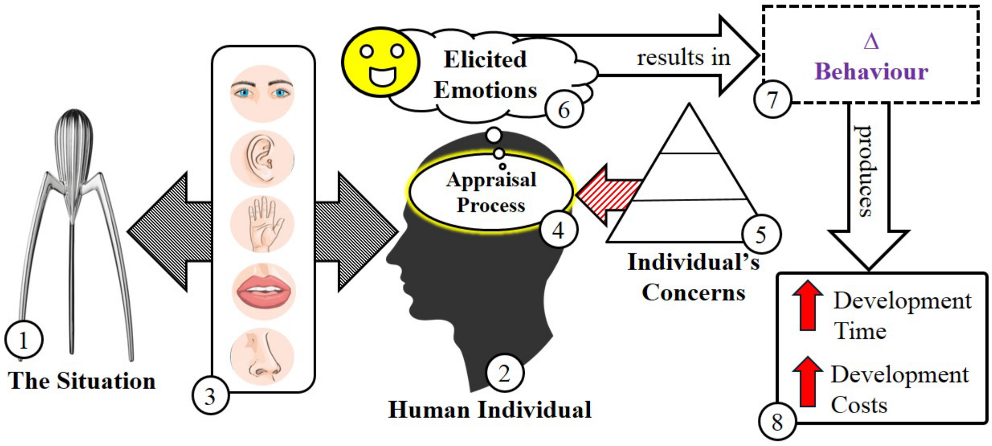

Figure 2. The appraisal process for human emotions

In the proposed appraisal process, a situation (1) which may be embodied by the product is perceived by the individual (2) via the human senses (3). The perceived situation is subsequently evaluated by the individual (4) with respect to subjective concerns (5). The individual's concerns are analogous to subjective criteria which determine whether the situation is appraised to be of relevance, a threat or a benefit. Part of the ongoing research, entailed an empirical study (Farrugia and Borg, 2014) with the objective to investigate what are the typical concerns of human life-phase workers. The results from this investigation suggest that human workers who interact with the evolving artefact across different life-phases share similar concerns.
The appraisal process also suggests that the elicitation of a human emotion is manifested through changes in the physiology, psychology and behaviour (7) of the individual. The change in behaviour is of particular interest to this research, as it may influence the performance of the life-phase worker which in turn may contribute to increased product development time and costs (8). The impact which elicited emotions have on human behaviour and performance has been demonstrated through several investigations. The study by Yang and Diefendorff (Yang and Diefendorff, 2009) suggests that negative emotions increase the tendency for individuals to engage in counterproductive work behaviour towards the organization and other workers. Other studies have demonstrated the impact of environmental stimuli such as ambient illumination (Akbari et al., 2013), temperature (Seppänen et al., 2006) and work overload (Cox et al., 2000) on the emotions elicited from human workers and their behaviour as a consequence.
A limitation common to these investigations is that these do not take into consideration how product design commitments such as: the choice of materials and form can influence the emotions elicited from life-phase workers. Instead the reviewed literature focuses on the impact of the perceived work

environment on the emotions elicited from workers. Motivated by this deficiency, an investigation on the influence of product design decisions on the emotions and performance of human workers was carried out. The description and results emerging from the investigation are presented in detail in the next section.

3 WHY SHOULD DESIGN RESEARCH CARE ABOUT WORKER EMOTIONS?

The scope of the experiment presented in this section was to investigate the influence of emotions elicited from human workers, on their performance while executing a manual assembly task. The experiment was intended to provide an answer to the following research questions:
Q1. To what extent can product design attributes influence the emotions elicited from subjects who interact with the artefact during manual assembly?
Q2. How does the elicitation of emotions relate to the performance of human life-phase workers during manual assembly?

3.1 The influence of product design on worker emotions and performance

The experiment consisted of a common manual assembly task in which the subjects were required to interact with the setup illustrated Figure 3. The subjects were required to manually orient and insert 9 pegs (A#, B#, C#) into the corresponding cavities (A, B, C).

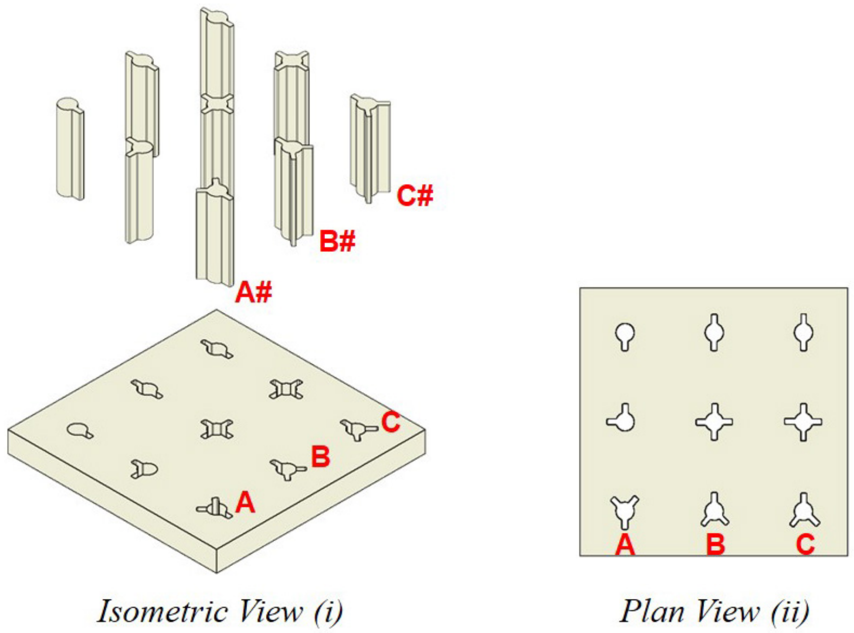

Figure 3. Isometric view (i) and plan view (ii) of the experimental setup

The shape and dimensions of the pegs and the corresponding cavities were designed in such a way so that only a specific peg (A#) can be inserted into its matching cavity (A), even though other cavities such as B and C have a similar shape. The experiment saw the participation of 10 subjects from different countries including Netherlands, Colombia and Denmark. Prior to the experiment, the task protocol was explained to the subjects who were also instructed to attempt to complete the assembly task within 2 minutes. This was done in order to emulate a realistic constraint where a human worker is expected to complete a particular task within the allotted time.
Throughout the experiment two sets of dependent variables were measured:

1. The performance of the subject which was measured in terms of: (i) total assembly time (seconds) and (ii) the total number of errors, defined as the frequency with which a peg was inserted in the wrong cavity. Both of these worker performance variables contribute to influence the cost and time of the product development process.
2. The emotional state of the subject was measured before and after the assembly task using the Geneva Emotion Wheel (Scherer, 2005). By measuring the emotional state before and after the

task, it was possible to determine the *change in the emotional state* of the subject as a consequence of the interaction with the artefact during manual assembly.

The Geneva Emotion wheel is a self-assessment emotion measurement tool which was chosen due to its inherent ability to represent a spectrum comprised of 20 emotion prototypes and employ a 5 point Likert scale to measure the intensity of each emotion prototype.

3.2 Key results

The first aim of this experiment was to understand to what extent a manual assembly task, as dictated by product design, can influence the emotional state of human life-phase workers. The horizontal axis of the plot in Figure 4 represents the 20 emotion concepts, while the vertical dashed line in the middle of the same axis discriminates between positively and negatively toned emotions. The vertical axis denotes the average change in the intensity of a particular emotion (average Δ emotion) which is calculated using equation (1). The term E_A represents the intensity of a particular emotion after the assembly task while E_B is the emotion intensity before the assembly task. Both E_A and E_B were measured on a 5 point Likert scale.

$$\text{Average } \Delta\text{Emotion} = E_A - E_B \qquad (1)$$

A positive value on the vertical axis therefore means that the subject experienced an increase in the intensity of the specific emotion concept on completing the assembly task. On the contrary, a negative value implies that the subject experienced a decrease in the intensity of the elicited emotion after completing the assembly task.

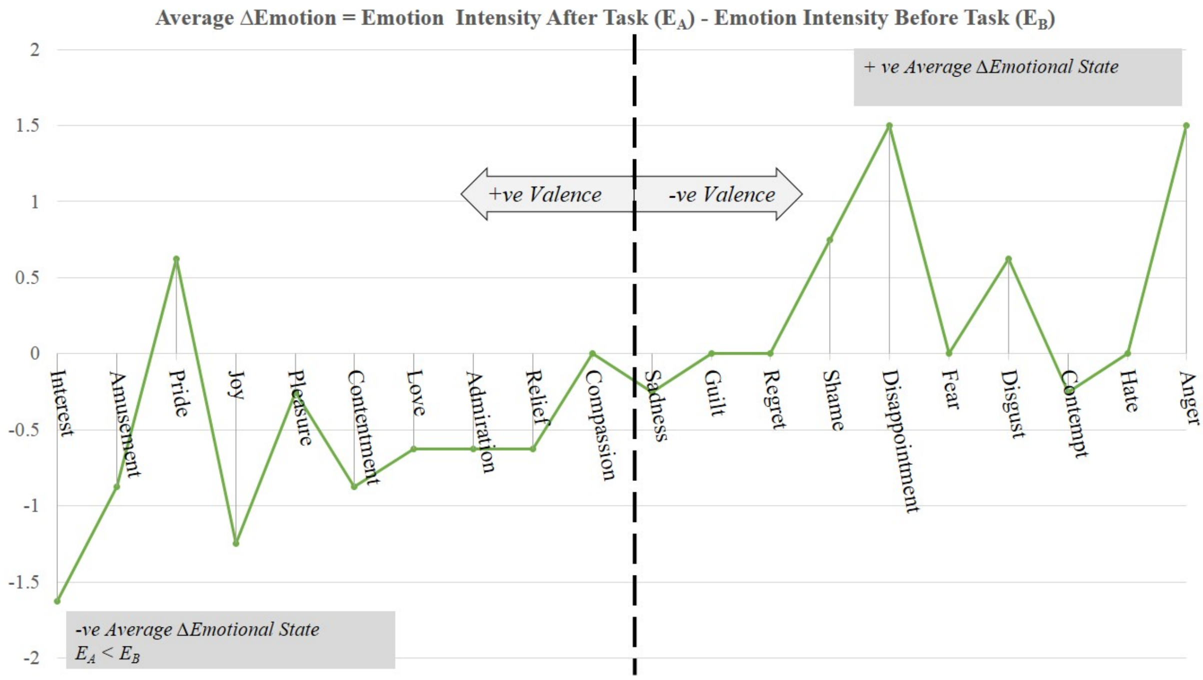

Figure 4. The change in the intensity of elicited emotions

The responses in Figure 4 indicate that the interaction with the evolving artefact during manual assembly can indeed influence the emotional state of the human subject. In fact the results show pronounced changes in emotion concepts such as amusement, pleasure, contentment, disappointment and anger.

Another interesting outcome from this result is that there is a general decrease in the intensity of emotions with a positive valence and an increase in the intensity of emotions with a negative valence. This implies, that in general the interaction between the interviewees and the artefact during manual assembly resulted in a decrease in elicitation of positive emotions. This was particularly evident in the case of emotions such as amusement, contentment and pleasure. On the contrary, the interaction with the artefact during manual assembly also resulted in an increase in the intensity of negatively toned emotions such as disappointment, anger and shame.

The second scope of this investigation was to determine if the change in the emotional state is related to the performance of the subject. The Pearson correlation coefficient (PEAR_CORR) was used in order to determine the type and strength of the relationship between the change in the emotional state and performance of the individual. This coefficient lies in the range of 1 and -1 both inclusive.
The plot in Figure 5 illustrates the correlation (PEAR_CORR) between the change in the intensity for a specific emotion (Δ Emotional State) with the total assembly time. The horizontal axis represents the 20 emotion prototypes which were correlated with the assembly time. The values on the vertical axis represent the Pearson correlation coefficient for each corresponding emotion prototype.

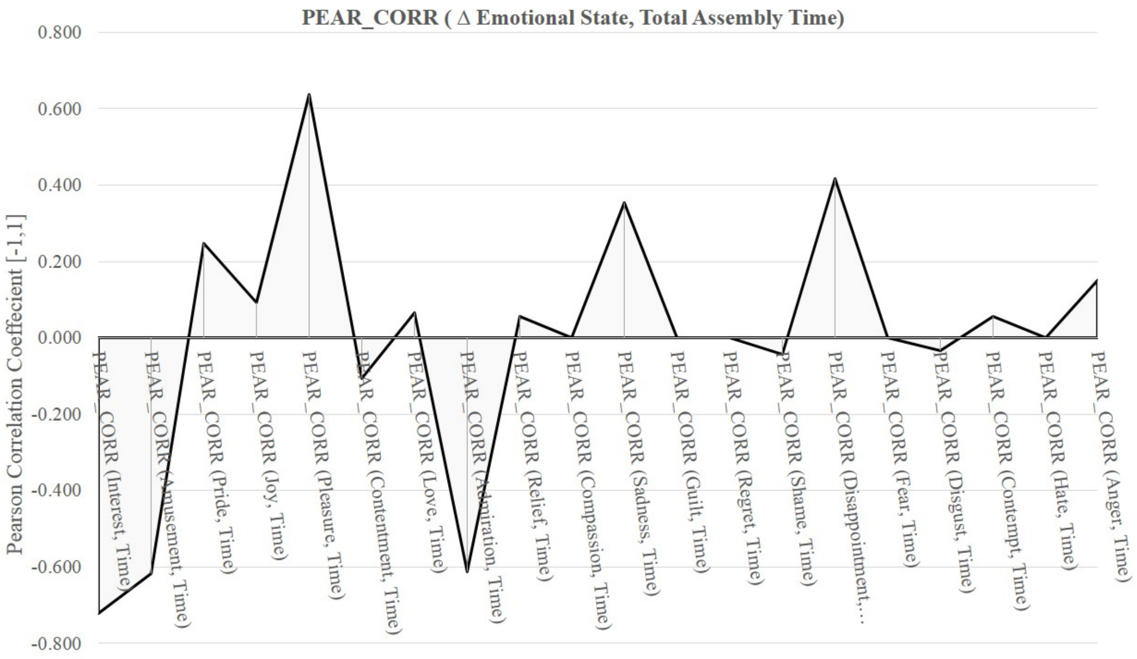

Figure 5. The relationship between Δ emotional state and assembly time

Positive values on the vertical axis indicate that as the intensity of a particular emotion increased there was also a corresponding increase in the assembly time. The magnitude of the Pearson correlation coefficient denotes the strength of the relationship between the two measured variables. A pronounced positive correlation was evident for the emotion prototype of disappointment. This implies that the increase in the elicitation of disappointment was an antecedent to an increase in the assembly time. However pleasure and pride were two positively toned emotions which were also positively correlated with the total assembly time. A possible explanation for this result is that subjects who completed the assembly task within the objective time would have actually experienced an increase in the intensity of positively toned emotions.
A negative correlation coefficient implies that an increase in total assembly time was related to a decrease in the in the intensity of the specific emotion. This was noticeable in case of numerous positively toned emotion prototypes such as amusement, interest and contentment. According to the appraisal process presented in the previous section, this indicates that a decrease in the intensity of positively toned emotions led to an increase in the total assembly time.
The second performance variable that was measured throughout the experiment was the total number of errors made by the worker throughout the assembly task. The relevance of this metric is denoted by the fact that a mistake during manual assembly may have ramifications on the performance and functionality of the artefact during later phases of its life-cycle. Addressing such mistakes during later phases may be costly and very time consuming. Throughout the experiment, an error was recorded every time the subject inserted a peg into the wrong cavity or made an error in judgement. The plot in Figure 6 illustrates the Pearson correlation coefficient between the change in the emotional state and the total number of errors for the 20 emotion prototypes.
The responses shown in Figure 6 indicate a very strong negative correlation between the number of mistakes and the change in the intensity of positively toned emotions. This is particularly true in the case of amusement and interest where the increase in the number of mistakes made was related to a

decrease in the intensity of these positively toned emotions. On the contrary, there was a strong positive correlation coefficient for the emotion prototypes of shame and anger. This implies that an increase in the elicitation of negatively toned emotions was related to an increase in the number of assembly errors made.

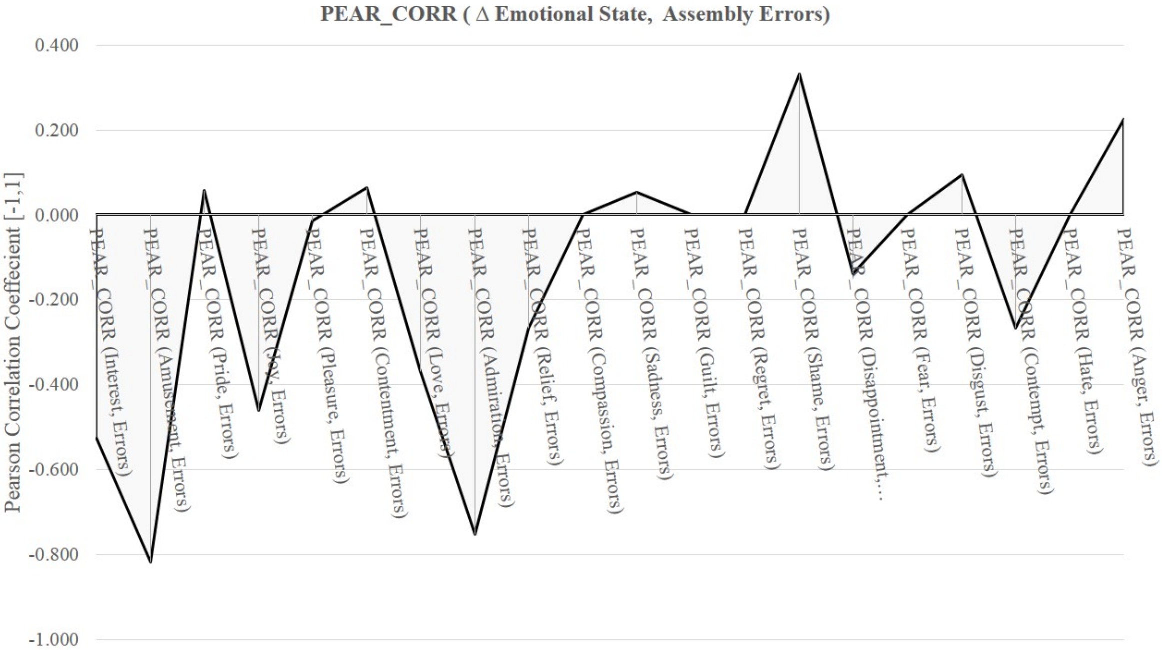

Figure 6. The relationship between Δ emotional state and manual assembly errors

The results presented in Figure 6 indicate very clearly that there is indeed a relationship between the change in the emotional state and the number of errors made by the subjects. In general it may be concluded that an increase in the elicitation of negatively toned emotions (and/or a decrease in positively toned emotions) renders the subject more prone to commit mistakes during the execution of a manual assembly task.

4 EMERGING REQUIREMENTS FOR PRODUCT DESIGN SUPPORT FOR IMPROVED WORKER CONTENTEDNESS

The results presented in the previous section indicate that product design commitments have indeed a capacity to influence the emotional state and as a consequence the performance of subjects during a manual assembly task. These results therefore justify the need for the development of a support means in order to enable product design teams to foresee how product design decisions can influence the emotions and performance of life-phase workers. To this extent this paper outlines a number of emerging high level requirements which should be considered in the development such support. The high level requirements are:

Requirement 1: The design support should enable the design team to foresee the consequences of design commitments in terms of: (i) emotional impact and (ii) performance of life-phase workers. This requirement emerges from the fact that the commitments made by the researcher in designing the setup used throughout the experiment have a capacity to influence the emotions and in turn the performance of workers.

Requirement 2: The term life-phase workers implies that the support means should not be limited to improve the contentedness of workers who are involved in the manufacturing phase.

Instead the support means should outline how design commitments are influencing workers who interact with the artefact across different phases in the life-cycle of the artefact such as transport and disposal.

Requirement 3: The design support should be required to make use of information which is output from other design tools/activities such as the quality function deployment. The notion behind this requirement is that the design support should take into account any existing constraints which are imposed on the design space. This would enable the design tool to provide feedback which is of use to the design team. For example: if the customer requires the use of a specific material, then the design means should consider this specification so that the feedback provided to the design team is not in conflict with this specification.

Requirement 4: The design support means should take into account the concerns of human workers. This is due to the fact that human emotions are a product of the evaluation of a stimulus with respect to the subjective concerns of the individual. The identification of worker concerns will enable the design team to identify if a design commitment e.g. the choice of a particular colour combination, poses a threat or benefit to the concerns of life-phase workers. The research work (Farrugia and Borg, 2014) has already carried out an investigation which identified a hierarchy of concerns which was shared among 60 life-phase workers.

Requirement 5: The support means would be required to differentiate between components which constitute the artefact, according to the following 3 categories:

Category A: Components in this category interact exclusively with the user. This means that these components are involved in human interactions which occur exclusively during the use phase. It follows that these components should be designed in order to exclusively fulfil functional and emotional needs of users.

Category B: Components in this category interact exclusively with the life-phase worker. Hence the components in this category will never be involved in interactions with the user. These components should therefore be designed in order to improve the contentedness and other emotional needs of life-phase workers.

Category C: Components within this category interact with both the users and some life-phase workers. The challenge associated with components within this category is to make design commitments which improve the contentedness of life-phase workers *without compromising* the fulfilment of the functional and emotional requirements of the users.

Requirement 6: Worker contentedness is not solely dependent on the product itself but also on the environment and the machine systems with which the worker is required to interact (Farrugia and Borg, 2014). The support to be provided should enable product designers to ameliorate worker contentedness not only by changing the product design attributes but also by proposing changes to the physical work environment and the machine systems which support the execution of the required tasks.

5 CONCLUSIONS

As evidenced by the title, the scope of this paper was to outline why design research should strive towards providing design support in order to elicit desirable emotions, such as contentedness, from life-phase workers. The literature presented in section 2 suggests that research into product design has so far focused exclusively on the emotions elicited from users who interact with the product during the use phase.

A first step towards the overall scope of the paper was to provide convincing evidence on the relevance and impact of emotions elicited from life-phase workers as a consequence of product design decisions. The investigation presented in section 3 was carried out in order to understand how design decisions can influence the emotions elicited from human life-phase workers. In addition the study investigated the influence of elicited emotions on the performance of subjects during manual assembly. The results presented in section 3 confirm the hypotheses that:

1. Product design decisions have a capacity to influence the emotional state of life-phase workers who interact with the artefact during manual assembly.
2. The emotions elicited during manual assembly have an impact on the performance of life-phase workers. The results indicate that an increase in the intensity of negatively toned emotions and a decrease in the intensity of positively toned emotions have negative ramifications on the performance human workers during a manual assembly task.

The evidence presented in this paper should therefore motivate research into product design to start considering the influence of design commitments on worker contentedness. This should be done not only for the sake of ameliorating the psychological health and well-being of life-phase workers but also because of the impact which elicited emotions have on performance metrics such as product development cost and assembly time.

The results presented in this paper therefore justify the need for the development of a support means for improving the emotional state of life-phase workers through the product design process. A first step towards the development of such design support has been the proposal of emerging requirements which the development of such means should consider.
The future short term objective of this research is to investigate the influence of product design on the emotions and performance of human workers who interact with the artefact throughout other life-cycle phases such as transport and disposal. The long term goal of this research is to develop a prototype tool which enables product designer to foresee the influence of the design commitments made on the emotions and performance of life-phase workers. The research work presented in this paper has set the first step towards this long term objective.

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