Assessing Creativity: The importance of unexpected novelty

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Abstract

In this paper we experimentally study the contribution of the unexpectedness, unpredictability or surprising value of a novel product to its overall creative value. Accordingly, this creative value is computed within our approach through the use of a mathematical function that relies on the contribution not only of novelty but also of unexpectedness. Implemented in artificial agents "living" in a multi-agent environment comprising objects such as buildings, this function, called within this context Utility Function, provides agents with a model of its preferences when evaluating a product, and thus allowing them to prefer those products that elicit more surprise (elicited by unexpectedness) and curiosity (elicited by novelty and unexpectedness). We performed a series of experimental tests that involved an artificial agent and humans in order to take conclusions about the nature of that mathematical function, and also about the contribution of unexpectedness to it.

1 INTRODUCTION

Roughly speaking, agents accept percepts from the environment and generate actions. Selecting the "right" action is critical, because agents' performance depends heavily on that. This is one of the main concerns of Decision Theory. Resulting from the combination of Utility Theory and Probability Theory [28, 31], Decision Theory provides artificial agents with processes to make "right" decisions. One example of those processes may be briefly described as follows: given a set of possible actions that the agent may take, the agent computes their possible results and respective probabilities and then selects the action that maximizes a mathematical function, called Utility Function, that models its preferences.

In order to accomplish the task of building artificial agents that act and think like humans [28], we should be able to give an agent the capability of producing and evaluating creative products, in addition to other human features. Two main points of view, the creative process and the creative product, may be considered when modelling creativity in an artificial agent. Actually, creativity has been considered as a multifaceted phenomenon, and two more perspectives are commonly distinguished: the creative person and the creative environment [20, 33].

Although the assessment of creativity cannot be confined to the point of view of the product [27], it is certainly an important part. Actually, the evaluation of the output of an agent (or system) may give an idea of its creative talent. This evaluation usually consists of assessing whether the properties typically assigned to creative products are present in the products and in what degree they are present. Novelty, unpredictability, unexpectedness, originality, interestingness and appropriateness (also defined as usefulness, aesthetic value, rightness, etc.) have been referred to by most authors as the most important characteristics of a creative product [2, 3, 5, 6, 9, 10, 16, 21, 27, 29]. Furthermore, Boden argued that there is a distinction between mere novelty and creativity [3]. In her opinion, that distinction resides on the fact that creative products are not only novel but also unpredictable, unexpected and therefore surprising. According to Boden, unpredictability is the essence of creativity: creative products amaze us, shock us and delight us mainly because they are unexpected or unpredictable.

Taking into account the experiments carried out in psychology, evidencing that the intensity of felt surprise increases monotonically and is closely correlated with the degree of unexpectedness (see [26] for a review of these experiments), and also the basic definition of surprise ("to encounter suddenly or unexpectedly"; "to cause to feel wonder, astonishment, or amazement, as at something unanticipated"), there seems to be evidence that creative products, by being unpredictable, unanticipated or unexpected, cause emotional states of surprise in their viewers [2, 3, 9]. Actually, both creative artistic products and creative scientific products seem to agree with this finding: surprise apparently plays an important role both in the production and in the evaluation of creative products. Thus, guiding a creative process by surprise seems to be a promising line. This kind of approach has similarities with the ones taken in [8] and in [29], where the creative process is guided by interestingness. Schank [30] also outlined the role of expectation failure (a closer concept to surprise) in creativity. Authors like Peters [23], Williams [34], Ortony and Partridge [22], ourselves [11, 12, 13, 14, 15] and the research group of the Department of Psychology of the University of Bielefeld, in Germany, (e.g.: [19]) have addressed the subject of surprise in their works.

In this paper we take into account the importance of the presence not only of novelty but also of unexpectedness in a creative product. We propose and experimentally test a few variants of an Utility Function used by artificial agents. That Utility Function attempts to model the preferences of humans when evaluating products in terms of creativity, giving higher values to those products that are more unexpected and newer and therefore that elicit more surprise and curiosity. It is used by an agent not only to evaluate products produced by other agents, but also to evaluate products produced by itself, not only final products, but also products under construction, at intermediate steps of the creative process.

The next section introduces briefly the architecture that we have adopted for an artificial agent that makes use of a Utility Function based on both unexpectedness (unpredictability /

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surprise[3]) and novelty for the evaluation of creative products. Section 3 presents the experimental tests. Finally, a discussion and future work is presented.

2 AGENT'S ARCHITECTURE

We have developed a multi-agent environment in which, in addition to inanimate agents (objects, in this paper confined to buildings), there are two main kinds of animate agents interacting in a simple way: the "author-agents" or creators, whose main function is to create things (objects, events), and the "jury-agents" or explorers whose goal is to explore the environment, analysing, studding and evaluating it. Note that there are agents that may exhibit the two activities, exploration and creation. We have been using this social environment as a test bed, performing experiments related with models of creativity and emotions [11, 12, 13, 14, 15].

A possible architecture for an artificial agent, creator or explorer, that takes surprise and novelty into account in its reasoning/decision-making is depicted at a high level in Figure 1. It comprises the following modules (explained in more detail in the subsections below): *sensors / perception*; *memory*; *emotions, drives and other motivations*; and *reasoning/decision-making*. These last two modules are provided with information from the world obtained through *sensors/perception* and also recorded in *memory*. Then, the *reasoning/decision-making* module computes the current state of the world (external and internal). Afterwards, Probability Theory [31] is applied to predict possible future states of the world for the available actions (internal or external), and a Utility Function [28, 31] (which makes use, for instance, of the intensity of the generated emotions) is applied to each one of those states of the world. Finally, the action that maximizes that function is selected.

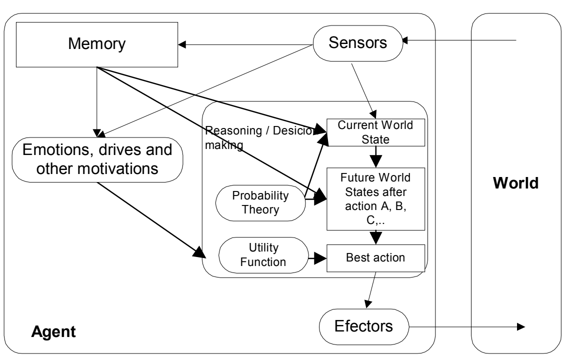


Figure 1. Agent's architecture. The ovals represent processing modules while the rectangles represent information modules.

2.1 Sensors/Perception

The information related to the *structure*, the *function*, the *behaviour* and the distance of the objects is collected from the environment through simulated sensors. There is an user definable parameter for the range of the visual field. Objects out of that range are not visible by the agent. The *function* of the objects is not accessible (i.e., cannot be inferred from visual information) unless the agent is at the same place as the object.

2.2 Action

The agents may present two main activities: the creation of products (present in creators) and its addition to the environment, and the exploration of the environment (a feature of the explorers) (see [11, 12, 14, 15] for more details about these activities). Each one of these activities involves other sub-actions such as the addition of pieces to the product that is under construction or the movements to certain locations of the environment.

2.3 Goals

The ultimate goals of the agent, namely the exploration of the environment and the creation and addition of products to the environment, result from the achievement of another goal: the maximization of positive feelings and the minimization of negative ones. Thus, we are considering emotions as action-goals [24].

2.4 Memory

The agent's knowledge base is of an episodic kind: each object is stored as an individual case in the episodic memory and associated with a number that expresses its absolute frequency (see Figure 2). In addition to this case-base, the agent also has a map of the environment in memory where it stores the location of the objects.

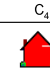
Field \ Case	C_1	C_2	C_3	C_4
Structure				
Function	House	House	Church	Hotel
Behavior	Static	Static	Static	Static
Abs. Freq.	50	40	5	5

Figure 2. Example of the episodic memory of an agent after exploring an environment.

2.5 Emotions, Drives and other Motivations

In this paper, this module is confined to surprise (the emotion elicited by unexpectedness) and curiosity (the drive elicited by novelty and unexpectedness). Nonetheless, other emotions, drives and other motivations will be included in this module in the future.

The objects of the environment may elicit surprise and curiosity in the agent.

The agent is almost continuously presented with an *input proposition* [22], which in the case of the environment described above corresponds to some information (visual or not) of a building (for instance, "a house with squared

[3] Unexpectedness, unpredictability and surprise are not exactly the same concepts, but, since they are highly related, they are used interchangeably.

windows”). In response to this external stimulus, the surprise and curiosity unit outputs the intensity of these motivations, respectively.

In what concerns to surprise, we think, like Ortony and Partridge [22], that it may result from three situations: (i) *active expectation failure*: resulting from a conflict or inconsistence between the *input proposition* and the *active prediction* or *expectation* (i.e., propositions explicitly represented in memory); (ii) *passive expectation failure* (or *assumption failure*): resulting from a conflict or inconsistence between the *input proposition* and what the agent knows or believes (*passive expectation or assumptions*), i.e., propositions that are not explicitly represented but that may be inferred easily; (iii) *unanticipated incongruities* or deviations from norms: resulting from a conflict or inconsistence between the input proposition and what, after the fact, may be judged to be normal or usual.

In their cognitive-psychoevolutionary model, the research group of the University of Bielefeld (e.g.: [19]) has defended similar ideas to those presented by Ortony and Partridge, namely that surprise consists of the appraisal of unexpectedness. They suggest that surprise-eliciting events give rise to a series of the following mental processes: (i) appraisal of a cognised event as exceeding some threshold value of unexpectedness (schema-discrepancy) - according to Reisenzein [25], there is a comparator, the appraisal function, that computes the degree of discrepancy between new and old beliefs or schemas; (ii) interruption of ongoing information processing and reallocation of processing resources to the investigation of the unexpected event; (iii) analysis/evaluation of that event; (iv) possibly, immediate reactions to that event and/or updating or revision of the “old” schemas or beliefs.

Let us now describe how the intensity of surprise may be computed. There is experimental evidence supporting that the intensity of felt surprise increases monotonically, and is closely correlated with the degree of unexpectedness (see [26] for a review of these experiments). This means that unexpectedness is the proximate cognitive appraisal cause of the surprise experience. Considering this evidence, we have already proposed [13] that the surprise felt by an agent *Agt* elicited by an object Obj_k is given by the degree of unexpectedness of Obj_k, considering the set of objects present in the memory of the agent *Agt:*

$$SURPRISE(Agt, Obj_k) = UNEXPECTEDNESS(Obj_k, Agt(Mem))$$

According to probability Theory (e.g.: [31]), the degree of expecting that an event X occurs is given by its probability P(X), and then the improbability of X, denoted by 1-P(X), defines the degree of not expecting X. Thus, the surprise function is as follows:

$$SURPRISE(Agt, Obj_k) = 1 - P(Obj_k)$$

Although other probabilistic methods might be used to compute P(X), in case of objects comprising several components we may compute the probability of the whole object Obj_k computing the mean of the conditional probabilities of their *n* constituent parts, which are individually computed using the Bayes’s formula [31] (notice that each one of those conditional probabilities individually gives the degree of expectedness of a specific piece of the object, given as evidence the rest of the object):

$$P(Obj_k) = \frac{\sum_{l=1}^{n} P(Obj_k^l \mid Obj_k^1, Obj_k^2, ..., Obj_k^{l-1}, Obj_k^{l+1}, ..., Obj_k^n)}{n}$$

We define curiosity (following McDougall [17], Berlyne [1] and Shand [32]) as the desire to know or learn an object that arouses interest by being novel or extraordinary, which means that novel and possibly unexpected objects stimulate actions intended to acquire knowledge about those objects. These actions usually comprise, firstly, the focus of the senses on the unknown object. Therefore, curiosity is elicited by novelty [7]. For instance, humans usually focus their eyes in the new objects of an environment. Actually, when faced with a set of objects, they are more attracted by new objects. Objects that are familiar to the agent do not attract them as new ones do, at least for a few moments. Thus, if we accept the above definition, the curiosity induced in an agent *Agt* by an object Obj_k depends on the novelty or difference of Obj_k relatively to the set of objects present in the memory of *Agt* and on the unexpectedness of Obj_k:

$$CURIOSITY(Agt, Obj_k) = f(f1(Obj_k, Agt(Mem)), f2(Obj_k, Agt(Mem)))$$

where,

$$f1(Obj_k, Agt(Mem)) = NOVELTY(Obj_k, Agt(Mem)) = DIFFERENCE(Obj_k, Agt(Mem))$$

and

$$f2(Obj_k, Agt(Mem)) = UNEXPECTEDNESS(Obj_k, Agt(Mem))$$

Roughly speaking, the measure of difference is described as follows: relying on error correcting code theory [4], the function computes the distance between two objects represented by graphs, counting the minimal number of changes (insertions and deletions of nodes and edges) required to transform one graph into another (e.g., [18]). To compute the difference of a given object relatively to a set of objects, we apply the above procedure to each pair of objects formed by the given object and an object from the set of objects. The minimum of those differences is the difference of the given object relatively to the given set of objects.

2.6 Reasoning/Decision-making

The reasoning/decision-making module of the agent receives the information from the external/internal world and outputs the action that has been selected for execution. This module comprises several subprocesses described as follows.

2.6.1 Computation of the Current World State

The current state of the world (e.g., the agent's current position, the position of the objects, the shape of the objects, etc.) is computed by taking as input the information of the external world provided by the sensors (which may be incomplete) or the information from the internal world (mind).

2.6.2 Computation of Future World States

Possible future world states and respective probabilities are computed for the actions that the agent can perform by taking as input the current state of the world, Probability Theory [28, 31] and the memory-stored information. These actions may be of two kinds: movements to certain locations in the environment (*MoveTo*(*Obj1*), *MoveTo*(*Obj2*), *MoveTo*(*LocationXY*), etc.) or addition of pieces to the product that is currently under construction (*AddPiece(X)*, *AddPiece(Y)*, etc.). For the former kind of actions, the resulting new world states include not only the new position of the agent, but also the information (e.g., relative position, shape, etc.) of the near objects, provided in that new world state. Instead, for the latter kind of actions, the new world states comprise the imaged or seen products (possibly partially constructed) resulting from the additions of pieces that have just been performed.

Usually, an action A may lead to one of a set of possible world states W_1, W_2, ..., W_n (it is not possible to know with complete certainty to which one, but it is possible to assign probabilities to them). This is described by what is called within Utility Theory as a Lottery [28, 31], which is represented by a list of elements, each one comprising a possible resulting state of the world and its associated probability:

$$Lottery(A) = [p_1, W_1; p_2, W_2; ...; p_n, W_n]$$

where p_i is the probability of the i^{th} possible resulting world state W_i of the action A, and $\sum_i p_i = 1$.

2.6.3 Selection of the Best Action

A single action (presumably the best one – the one with the highest Expected Utility Value) is selected from the available ones. These Utility Values result from the application of the Utility Theory as follows. For each action, the following Expected Utility Function, denoted by EU, is applied to its Lottery:

$$EU(p_1, W_1; p_2, W_2; ...; p_n, W_n) = \sum_i p_i \times U(W_i)$$

where $U(W_i)$ denotes the Utility Function of state W_i.

This Utility Function relies heavily on the anticipated intensity of unexpectedness (elicits surprise and curiosity) and novelty (elicits curiosity) elicited by the future state of the world. Thus, the preferences of the agent are reflections of its anticipated surprise and curiosity:

$$U(W_i) = f(U_{surprise}(W_i), U_{curiosity}(W_i))$$

Note that this function is used both by creators and by explorers to make decisions: creators decide to add to a product the piece that confers more originality to the resulting product (possible still incomplete), and explorers decide to visit the more creative products (those that elicit more surprise and curiosity, i.e., those that are more unexpected and newer).

We propose the following two possibilities for this Utility Function *f*, namely the Cartesian product and the arithmetic mean of unexpectedness and novelty (note that appropriateness should also be included, but it is out of scope of this paper):

$$U_{creativity}(W_i) = U_{unexpectedness}(W_i) \times U_{novelty}(W_i)$$

$$U_{creativity}(W_i) = \frac{U_{unexpectedness}(W_i) + U_{novelty}(W_i)}{2}$$

3 EXPERIMENTAL TESTS

Although our model is consistent with the theoretical reports, we performed experiments to test the following issues: (i) whether the novelty values generated by the artificial agents match those of humans under similar circumstances (Experiment 1); (ii) whether the creative values rated by humans are the Cartesian product or the arithmetic mean of the unexpectedness/surprise and novelty values rated by them (Experiments 2), (iii) whether the creative values generated by the artificial agents match those of humans under similar circumstances (Experiment 3). Notice that we have previously performed experiments to test whether the intensity values rated by an artificial agent (with the model of surprise described above) match the ones rated by humans under similar circumstances [13]. Those experiments were carried out in two domains: the domain of buildings (described in this paper) and in an abstract domain with hedonically neutral events. Best results were achieved with an hedonically neutral domain, in which an average difference of about 6% was obtained between the values given by the humans and by the artificial agent.

The experiments presented in this paper were performed in the domain of buildings. The participants (an artificial agent and 60 humans with mean age of 20.5 years) were presented with 40 quiz-like items. Each "quiz item" consisted of the presentation of a building. The participants were asked to rate the novelty and the unexpectedness/surprise of the whole building as well as the creative value.

Figure 3 presents the results of Experiment 1. In this experiment, the agent answered the "quiz items" several times, each time with a different episodic memory. Due to the lack of space, we reported only the results of three sessions, denoted by Agent-I, Agent-IV and Agent-V (with I, IV and V denoting an increasingly large memory). The best results were obtained with Agent-IV and Agent-V (average difference = .06, i.e., 6%). This difference happened most likely because in the domain of buildings the knowledge of humans and of the agent is different. However, the results suggest that the larger the episodic memory, and the closer its probability distribution corresponds to the real world, the closer are the novelty values given by the agent and by the humans. This experiment also confirms to some extent the obvious dependence of novelty on the contents and developmental stage of memory. Actually, as the agent learns more objects some of the objects that were novel to it in the past are not anymore in a subsequent moment in time.

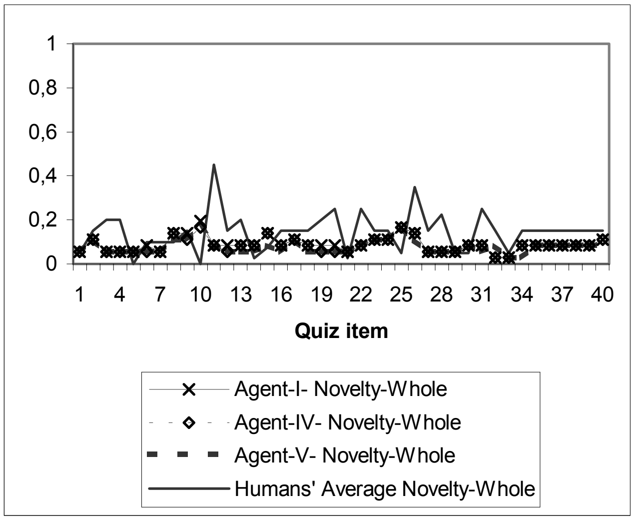


Figure 3. Results of Experiment 1.

Figure 4 and 5 present the results of Experiment 2. Figure 4 presents a comparison of the novelty, surprise and creative values rated by humans. There is evidence that the creative value of a product does not depend only on novelty (this is clearly seen in the last nine quiz items, whose novelty values are equal, but whose creative values are different, as it happens also with their surprise values). Thus there is a correlation, not only between novelty and creativity (correlation = .83; Spearman's ρ = .99), but also between surprise and creativity (correlation = .93; Spearman's ρ = .97). Figure 5 presents the comparison between the creative values rated by humans with those resulting from the Cartesian product (*fA*) and arithmetic mean (*fB*) of surprise and novelty. It can be seen that the curve of *fB* is closer to the curve of the creative value, although there is a considerable difference. This difference might be due partially to not taking into account in this function the contribution of appropriateness to the creative value.

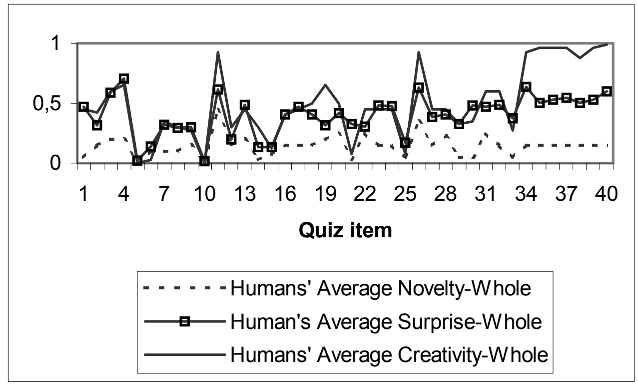


Figure 4. Results of Experiment 2.

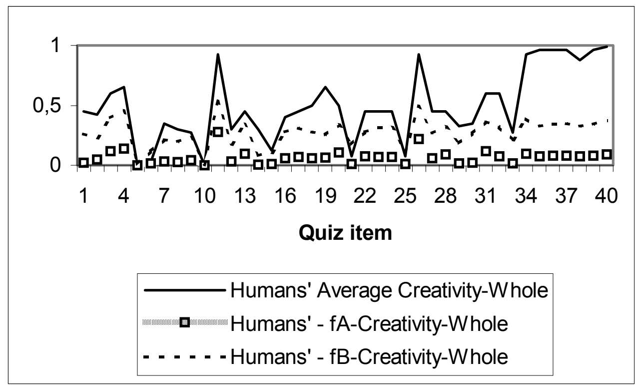


Figure 5. Results of Experiment 2.

Figure 6 presents the results of Experiment 3. It presents the curves of the creative values rated by humans and those rated by two agents, one using the Utility Function *fA* and another using *fB*. The later Utility Function (based on the arithmetic mean) is the one that seems to be more appropriate, although there is a meaningful difference. Despite the difficulty to achieve an accurate function, note that the artificial agents computations relied on the surprise and novelty values rated by it, which were different from those of humans as shown in Figure 3 (Experiment 1) and in [13].

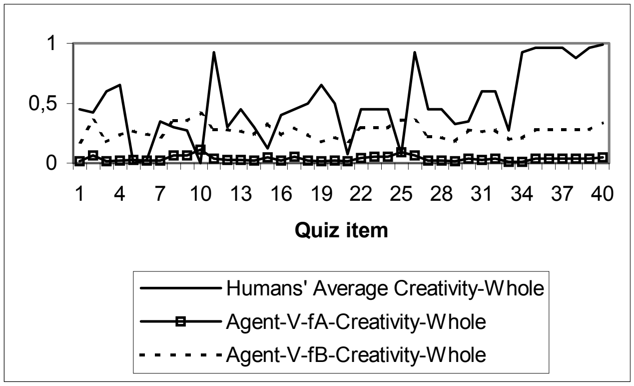


Figure 6. Results of Experiment 3.

4 DISCUSSION, CONCLUSIONS AND FURTHER WORK

The results of the experiments presented above allow us to take some positive conclusions about the model of creativity that we have adopted. However, these conclusions cannot be definite for the following reasons. Firstly, humans' ratings are subjective, depending on factors such as the social status, educational status, age, etc. Secondly, humans are confronted with drawings of buildings instead of pictures of the real buildings they usually deal with. Therefore, given a drawing of a building, they probably have to imagine how that building will be in the real world. Thus, the artificial agents and the humans are not precisely under the same circumstances. Thirdly, the domain of buildings is just an example of a possible domain. The experiments should be performed also in other domains such as musical composition or writing. Finally, appropriateness, an important feature of creative products, has not been taken into account.

We expect to work in the near future on these matters, attempting to get even more accurate results. For instance, we are currently working on a more realistic virtual environment, where in addition to buildings there are other kinds of objects as well as other animate agents. We are also working on a slight different reasoning/decision-making module which gives importance to the selection of actions that maximize the overall creativity of the final product instead of actions that maximize locally that creativity as happens with the current reasoning/decision-making module.

A final comment goes to the distinction between novelty and unexpectedness. As shown in Experiment 2, the unexpectedness value of a product is usually higher than its novelty value. This happens because a product can be unexpected without being novel.

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