Executive Summary

An aim of WP8 is to develop ‘objective’ components of creativity that could be used to evaluate the creativity of artificial systems and humans. Ideally, the components should form a semantic map with concepts related to the concept of creativity and related to each other. The notion ‘objective’ entails that the semantic map should be derived by objective (i.e., repeatable) methods, instead of consisting of an intuitive (self-made) conceptual structure.

To derive the map, a set of words associated with the concept creativity was selected by human raters and human subjects in an experiment. In turn, human subjects in an experiment produced words associated with the words in the first set. Both sets of words were used to select a set of 42 words that were used in a card sorting categorization experiment. The results of this experiment were analyzed with a Hierarchical Cluster Analysis. This produced a semantic map consisting of 2 to 16 clusters and their relations, consisting of terms associated with the concept creativity. A selection of 5 main clusters (based on a difference in item-distances within and between clusters) is proposed. The ongoing and future work based on the prototype semantic map presented here is briefly discussed.
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1 Introduction

This document concerns the deliverable D8.1 of CONCRETE WP8: Prototype emergent semantic map for creativity evaluation. Here, we will present this prototype and briefly outline how it was derived.

WP8 aims to evaluate the creativity produced by the prototypes derived in CONCRETE using human raters. However, evaluating creative artifacts and systems is notoriously difficult, due to the subjectivity of the definition of the terms involved. Recently, Jordanous [1, 2] analyzed the evaluation of creativity in the scientific literature related to computational creativity. She found that evaluation ratings (if performed at all) were based on criteria set up by the researchers themselves (or by other researchers in the literature). She argued that a more ‘objective’ basis for rating computational creativity (i.e., not just derived from the subjective acceptance by researchers) would be needed (see also [3]). Jordanous [1] used a statistical analysis by comparing word frequencies in scientific articles related to the study of computational creativity with word frequencies in scientific articles related to other topics, and derived a set of 694 terms that occurred more frequently in the ‘creativity’ set of articles. On the basis of these words, she derived 14 dimensions on which creativity could be evaluated [1, 2]

In WP8 we aim to derive a more limited set of dimensions “that could be used to evaluate the creativity of artificial systems and humans” (Task 8.1). The latter is needed for WP4, in which human creativity is investigated in a neuroscientific way. Also, to allow a comparison between human and artificial creativity, a single set of rating dimensions would be needed. Hence, WP8 aims to develop ‘objective’ components of creativity that could be used to evaluate the creativity of artificial systems and humans. Ideally, the components should form a semantic map with concepts related to the concept of creativity and related to each other. The notion ‘objective’ entails that the semantic map should be derived by objective (i.e., repeatable) methods (in line with [1]), instead of consisting of an intuitive (self-made) conceptual structure.

The initial method used consisted of a self-organizing process derived from statistical physics by Samsonovich and Ascoli [4], based on synonyms and antonyms related to creativity. These words were represented at random in a finite, multidimensional space. The word representations in the space were modified by a dynamical process based on ‘attracting’ synonyms and ‘repelling’ antonyms. Samsonovich and Ascoli [4] showed how a large set of concepts derived from corpora such as WordNet could be represented in a reduced-dimensional semantic space. With this method and synonyms and antonyms related to creativity based on WordNet we derived a basically two-dimensional space. By repeating this procedure (e.g., using different random initiations) the robustness and stability of the space was tested. The results revealed that the space lacked stability and robustness. This may be due to the fact that the set of synonyms and antonyms related to creativity is not sufficiently ‘dense’. In particular, useful antonyms related to creativity (i.e., antonyms other than ‘un-‘, as in ‘unoriginal’), are lacking for a single concept such as creativity (in contrast to the original result of Samsonovich and Ascoli, who used a large set of concepts).

Therefore, a number of studies were conducted in which human subjects were asked to provide terms related to creativity as associations, synonyms and antonyms. The synonyms and antonyms were again analyzed using the method of Samsonovich and Ascoli [4]. The results were similar to the one presented above. The associations of creativity were first used in a ‘reverse’ association study (to see whether concepts like “creativity” are in turn associated with these terms). A selected set of words based on both association studies was used in a card sorting study with human raters. The words used were augmented with a selected set of words from Jordanous [1], who derived a set of 694 words related to creativity on the basis of the statistical analysis outlined above. The card sorting study with the overall set of words provided a prototype for a semantic map related to creativity.
The remainder of this document is structured as follows. Section 2 outlines how a set of words was derived as the basis for the semantic map. In Section 3, the card sort study used to derive the semantic map is presented and discussed. The prototype of the semantic map is presented and discussed in Section 4. Section 5 presents the conclusions and briefly discusses future work.

2 Words related to creativity

This study consisted of two parts. The first part aimed to derive a set of terms associated with the word “creativity”. This set of words was derived in two steps:

1. A selection was made of the set of words derived by Jordanous [1]. She analyzed two corpora of texts: one consisting of scientific articles related to the study of creativity and one consisting of scientific articles not related to the study of creativity. A statistical analysis revealed a set of 694 terms that occurred statistically more frequently in the scientific articles related to the study of creativity. This set was reviewed by three human raters. They each selected words from this set that in their view were associated with creativity. The words on which all three raters agreed were included in the set of words associated with creativity. This procedure resulted in an initial list of 32 words based on the list provided by Jordanous [1].

2. In a free association study, 36 subjects between the age of 18 and 52 (29 Dutch and 7 German) were asked to give at most three terms associated with the word “creativity”. From this list again the three human raters selected the list of words on which they all agreed as words associated with creativity. This resulted in a set of 58 words. This list of 58 words contained eight words from the list of Jordanous [1] which were not selected by the three independent researchers in step 1. So, the overall set of words derived from Jordanous’ [1] list consists of 40 words. Ten other words were named in both lists. Hence, the combined list of words associated with creativity consists of 80 words. In this list, 40 words are from the list of [1] and 58 are based on the human free association study, in which 18 words overlap with the list of Jordanous [1].

The second part of the study used the list of 80 words derived in the first part to conduct a ‘backward’ (or reverse) association study. That is, for each of these 80 words human subjects were asked to provide one term associated with that word. The list of words was presented in a randomized order to prevent priming effects. The subjects consisted of 50 students between age 19 and 27. None of them participated in the first part of the study. There were 29 Dutch and 21 German participants from whom 24 were men and 26 women. There were 25 technical students, 22 social studies students and 3 art students.

One aim of this study was to see whether words like “to create”, “creative” or “creativity” are in turn associated with the words associated with the word “creativity” (derived in part one). A second aim of this study was to see whether words in the list derived in part one are associated with each other. After providing the associated terms for each of the 80 words derived in part one, each subject was also asked to provide synonyms and antonyms for each of these words (to be used in the statistical analysis based on Samsonovich and Ascoli, see Introduction).

A subset of the list of 80 words derived in part one gave a ‘creativity’ word (“creativity”, “creative” or “to create”) as a (backward) association in part two. In this subset, 55.17% of the words came from the human list derived in part one, 27.58% from the list presented by Jordanous [1] and 17.24% from both lists. However, the whole list of ‘backward’ associated words obtained in the second part of the study was used as one of the lists to select the words for the card sorting study.
3 Card sorting study related to creativity

The lists of words obtained in parts one and two described in Section 2 were used to select the words for the card sorting study. This selection was based on three conditions:

- A word had to appear in both lists of words obtained in Section 2. Hence, a word is considered strongly associated with creativity if that word is both directly and indirectly associated with creativity. Direct association entails that the word is associated with creativity (more specifically, the word belongs to the word list of part one in Section 2). Indirect association entails that the word is associated with a word that is in turn associated with creativity (more specifically, the word is associated with a word that belongs to the word list of part one in Section 2).

- A word had to appear more than once as an answer in the second part of the study in Section 2 (to avoid the use of idiosyncratic words in the card sorting study).

- The word could not be the word “creative” or any derivative of that base word. Hence, the aim of this card sorting study was to investigate the internal semantic structure of the words strongly associated with creativity.

In all, 42 words were selected for the card sorting study. In the study 40 Dutch participants took part. They did not participate in any of the previous studies. Card sorting can be used to evaluate how people organize a set of items (e.g., [5]). As an illustration, consider the following set of words: \{keyboard, printer, mouse, cat, dog\}. In a card sorting study, these words are printed on cards and subjects are asked to group these cards into categories. If, in their view, a word cannot be placed in a category, it forms a category on its own. All words have to be selected in this way. The set of words above could, for example, be grouped as \{keyboard, printer, mouse\} and \{cat, dog\} or as \{keyboard, printer\} and \{mouse, cat, dog\}. The number of times a particular categorization is chosen determines the (relative) strength of that categorization.

The results of the card sorting study were analyzed with a Hierarchical Cluster Analysis (HCA), using the statistical programming environment R [6]. The HCA technique (e.g. [7]) selects the two highest associated words (i.e., that most often occur together in a card sorted group) and replaces them with a single item. The associations of this item with the other words are the average of those of the two words forming the item. Continuing in this way, a hierarchical cluster can be obtained of the results of the card sorting study. The result of the HCA on the card sorting data is presented in Figure 1.
**Figure 1.** Hierarchical cluster analysis (dendrogram) of a card sorting study of terms associated with creativity.

The results from the HCA can also be represented in a heat map, in which the color indicates the strength of the association between two terms. Figure 2 illustrates the heat map based on the hierarchical cluster presented in Figure 1. It is clear that the squares that form groups of words are related to the clusters in Figure 1. For example, in the top left corner there is a 5x5 square that is much darker than the yellow around it. This 5x5 square belongs to a group of five words: *unconventional, different, extraordinary, original* and *unique*. If we wanted to label this group with one name, it could be ‘originality’. Originality is often referred to in the literature as a characteristic of creativity (e.g., [8]).

Although the dendrogram in Figure 1 and the heat map in Figure 2 are based on the same data, they reveal different aspects of the semantic map based on the card sorting study of terms associated with creativity. The dendrogram shows a metric within and between the clusters of terms related to creativity. The metric is given by the (vertical) distance that needs to be travelled in going from one word to another. So, for example, the distance between *unconventional* and *innovation* is shorter as that between *unconventional* and *skill*. This metric is not directly revealed in the heat map. But the heat map shows that a word that belongs to a group can also be associated to words outside that group. For example, *unconventional* belongs to the 5 by 5 group referred to above, but it also has some association strength with *renewing*. These outside associations are not directly revealed by the dendrogram, due to the forced choice procedure on which the dendrogram is based. But indirectly these outside associations do determine the metric in the dendrogram, as seen by the distance between *unconventional* and *renewing.*
Figure 2. Heat map based on the hierarchical cluster analysis presented in Figure 1.

### 4 Prototype emergent semantic map for creativity evaluation

The dendrogram in Figure 1 shows that the semantic map of terms associated with creativity can be organized into a number of different groups. This varies between two groups at the top to 16 or 26 groups at the bottom (based on whether a group can consist of one word or should consist of at least two words). Each of these groupings could be used to derive dimensions for rating creativity. Perhaps an in between number of groups should be used for this purpose.

Figure 3 illustrates the dendrogram of Figure 1 in which 6 basic clusters of terms associated with creativity are selected (as indicated by the red line), by using the same distance from the basis as a selection measure. A basis for the selection is the observation that item-distances between clusters are substantially larger than item-distances within clusters.
Figure 3. Hierarchical cluster analysis (dendrogram) with six basic clusters (indicated by the red line) of terms associated with creativity.

Figure 4 presents the clusters and tentative cluster names. Perhaps the last two clusters could be combined into one, given that the item-distances between these clusters and the other clusters are the largest distances of the hierarchy. This would provide the following five main clusters of items associated with the concept creativity:

- **Original** (originality)
- **Emotion** (emotional value)
- **Novelty / innovation** (innovative)
- **Intelligence**
- **Skill** (ability)
Figure 4. Five to six main clusters of items associated with creativity.

These main clusters could be used to develop rating scales for evaluating the creativity of artificial systems and humans. All of the 42 items listed in the hierarchical dendrogram could be used as dimensions on which creativity is rated, each one as an example of the main cluster to which it belongs.

5 Conclusions and future work

The prototype of the semantic map consists of a limited set of clusters, based on the difference between the item-distances within the clusters and the item-distances between the clusters. This seems to offer the possibility to rate the creativity produced by the prototypes derived in CONCRETE using a limited set of dimensions. Furthermore, the clusters seem to be (partly) related with more intuitive notions that have been used in the past to rate creativity, such as originality, novelty and (emotional) value [2, 3].

In ongoing and future work we will investigate this semantic map further. In one study we will compare the map illustrated in Figure 4 with a map based on a card sorting study in which words from the map in Figure 4 are combined with words like “creative” and “useful” and other (neutral) words. The word “useful” is often referred to as a characteristic of creativity (e.g., [9, 3]), but it seems to be missing in the map illustrated in Figure 4. By including this word in this new card sorting study we will investigate
the semantic relations between the words “useful” and “creative” and words related to creativity based on the map of Figure 4.

We will also derive rating scales from the semantic map as presented here and as further developed in ongoing work. We will use these scales to rate the creativity produced by the prototypes derived in CONCRETE using human raters, and we will use them to develop and evaluate experimental paradigms for investigating the neural basis of creativity in WP4 (starting at month 19).

In ongoing and future work we will also compare a semantic map as illustrated in Figure 1 (and developed in ongoing work) with the conceptual space developed in CONCRETE and the geometrical conceptual space as proposed by Gärdenfors [10]. At face value, the semantic map in Figure 1 provides a metric (defined by the inter-item association distance). This, in turn, would seem to offer a relation between a semantic structure as illustrated in Figure 1 and the conceptual space developed in CONCRETE and the geometrical conceptual space as proposed by Gärdenfors. In Task 8.3 we will investigate how a mapping between these conceptual spaces and the semantic space related to creativity can be formulated and whether the mapping could be used to investigate how conceptual changes in the conceptual space can be described in terms of the emergent metric of creativity instantiated in the semantic space, and how an artificial system could use this mapping to evaluate its own creativity.
Acknowledgements

The studies of words associated with creativity (part one and two in Section 2), and their synonyms and antonyms, were part of the bachelor theses of Saskia Hartmann and Janina Roppelt and the master thesis of Roger Wolf. The card sorting study (Section 3) was part of the master thesis of Roger Wolf.

References


