



# CARD SORTING: A TOOL FOR IDENTIFYING CONCEPT BLENDS

University Twente



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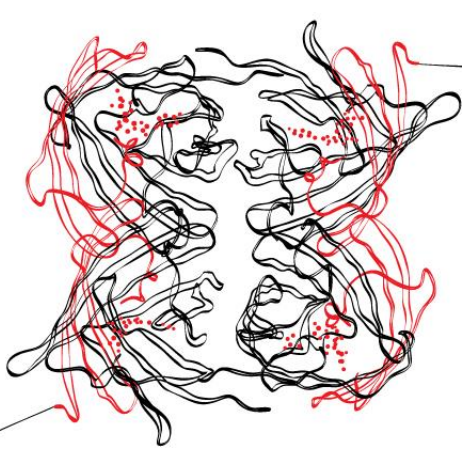
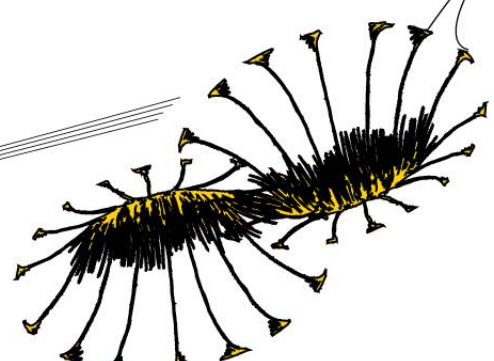
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## Abstract

The cognitive process of concept blending is a powerful mechanism in making a creative computer system. This master thesis addresses the hypothesis that a card sorting study could be a useful tool when trying to identify concept blends. In order to investigate this hypothesis a card sorting study was conducted using the well-known blends of the windows desktop and the computer virus. The participants (N=108) in this experiment carried out the card sorting task and afterwards two methods of analysis were used; a heat map analysis and an analysis using triangle inequality violations in the conceptual spaces. The analysis of the heat map showed various hot spots for blending terms. When analyzing the results of the conceptual spaces the only triangle violations found were between clusters indicating the presence of bridge concepts. The clusters containing the known concept blends formed the majority of their bridges between the concepts from their base clusters. Both the results from the heat map analysis and the conceptual space analysis indicate that a card sorting study is an excellent tool in identifying concept blends.

*Keywords: Concept Blending, Creativity, Card Sorting, Geometrical Concept Space, Heat Map, Triangle Inequality Violations, Virus, Windows.*

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## Samenvatting

Het cognitieve proces dat concept blending heet is een heel krachtig proces dat kan helpen bij het creëren van een creatief computer systeem. Deze these poneert de stelling dat een card sorting study een gereedschap is om deze concept blends te identificeren. Om dit te onderzoeken is er een card sorting studie uitgevoerd met de welkbekende concept blends van Windows en het computer virus. Bij deze studie zijn de resultaten van 108 respondenten geanalyseerd door middel van een heat map en zogenoemde driehoeksongelijkheid overtredingen in de geometrische conceptuele ruimte. De heat map analyse liet zien dat er zogeheten hot-spots te vinden waren bij concepten uit de blend clusters. Bij de analyse van conceptuele ruimte werden alleen driehoeksongelijkheid overtredingen gevonden tussen de verschillende clusters wat duidt op concepten die bruggen bouwen tussen clusters. De clusters die de welbekende blends bevatten vormden het grootste deel van alle bruggen tussen concepten uit de basis clusters. Zowel de resultaten van de heat map analyse als de resultaten van de conceptuele ruimte analyse bevestigen de hypothese dat card sorting een uitstekend gereedschap is om concept blends te identificeren.

*Sleutelwoorden: Concept Blending, Creativiteit, Card Sorting, Geometrische Conceptuele Ruimte, Heat Map, Driehoeksongelijkheid Overtredingen, Virus, Windows.*

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# 1. Introduction

## 1.1 Creativity

Computers keep getting faster and faster, they are getting better and better in performing all kinds of tasks for us. We are even currently trying to make them think for themselves. Science knew a proper step in the right direction was taken when IBM's supercomputer WATSON managed to win the game show Jeopardy (IBM, 2015). Jeopardy is a game show in which the contestants are presented with general knowledge clues in the form of answers, and must phrase their responses in the form of questions (Wikipedia, 2015). The reason why this could be called a breakthrough is because in this case WATSON had to deal with a lot of incomplete data. Normally computers need complete and certain data to work with in order to function properly. Human beings have learned to function on incomplete data. Although this system was able to beat two all-time Jeopardy champions, I would not call it intelligent per se. The WATSON projects main goals were targeted at being able to understand natural spoken language and processing speed. Therefore WATSON won the game show by loading a huge amount of information onto its RAM memory and then performing a statistical analysis of the goodness of fit for the data (Ferrucci et al., 2010). Human beings tackle these problems by applying more native processes. Intelligence is closely related to something called creativity and therefore one of the big hurdles still to take to make a computer system intelligent is making it creative; in its own way (Peters, 1998). Some are even calling the search for a creative A.I. the "Quest for the Holy Creative Process" (F. Pereira & Cardoso, 2002). Creativity would sure go a long way if the system wants to pass the Turing Test. For a machine to pass the Turing test, a person interacting with the machine should be thinking it is interacting with another person and not a machine. This would cause the machine at least to appear to be intelligent (Saygin, Cicekli, & Akman, 2003).

Then what is creativity exactly? While creativity is a big part of our daily lives and most people instinctively know what it means, there are still a lot of questions unanswered regarding the psychological foundation, the neurological basis and the cognitive mechanisms underlying creative acts (Abdel-Fattah, Besold, & Kühnberger, 2012). Berthold (2012, p12) found a working definition for creativity based on the work of Margaret Boden (Boden, 1994).

*Creativity is the ability to come up with ideas or artifacts that are new, surprising and valuable.*

New means that the ideas or artefacts shouldn't have been discovered before. This can be thought of as either historically or personally. There is a first time an idea like for instance evolution theory was put out there by Darwin. This was new at that time. But personal creativity means someone comes up with an idea independently of someone else who had actually already invented it before. If this re-invention was made without any of the knowledge about the first invention, this would still constitute as "true" creativity (Berthold, 2012).

An idea should also be valuable as in it should be non-trivial in its nature. It should actually have a useful component to it to be creative. If an idea is redundant it will not be considered creative (Berthold, 2012). Coincidentally and not surprisingly the role of the concept 'useful' in relation to creativity is currently the subject of a study conducted by both supervisors (van der Velde, Wolf, Schmettow, & Nazareth., 2015). Here the researchers concluded after their experiments that while useful does not have a strong direct connection to creativity it does play an important role in forming bridges between creativity and seemingly unrelated topics.

One of the last factors of creativity is that besides new and non trivial, an idea should be surprising. It could be dubbed surprising because the idea is unlikely (as in it has a low probability of occurring) or it is unfamiliar (Berthold, 2012). Because this concept is very abstract the next section will explain three processes that taken together will approximate the road to creativity. These three processes were identified by Boden (1994).

First off a small distinction has to be made. While the working definition spans multiple fields including music and literature (Berthold, 2012), this thesis is interested in conceptual creativity. The kind of creativity that is associated with knowledge structures. These knowledge structures are a combination of the representations of data stored in the memory as well as their processing methods (Purves et al., 2008). If such structures could be applied to a system like WATSON and it would more closely represent human thought patterns and we could come a step closer to making it truly intelligent.

The first of the three roads to creativity is called combinational creativity. This process takes two or more familiar concepts or constructs and combines these into a previously unfamiliar combination. In humans, this would be called an analogy. Niels Bohr's model of the atom and the way it resembles our heliocentric solar system is a typical example of an analogy, they are both entities revolving around a center mass. In order for this creative process to take place the agent doing the inventing should possess a rich knowledge structure

as well as flexible methods of manipulating this structure. This new combination of elements should have a point or meaning though otherwise the valuable aspect of creativity will get violated (Berthold, 2012).

Another road to creativity can be found in the process of exploratory creativity. This form of creativity is looking for new concepts to match, outside of the predefined rules for that current field (Boden, 1994). This is still quite abstract but an example might clear things up. Consider for instance a game of poker. At its base it is just a game of chance. At least that was the case until someone discovered the ability to do a bluff. This idea brought with it a whole set of new possibilities for looking at the game.

The last road to creativity is described by Boden (1994) as transformational creativity. She states that exploratory creativity is limited by the possibilities defined within a conceptual space or thinking style; each conceptual space restricts the kind of thoughts that can be thought. To overcome this limitation it is necessary to transform the conceptual space the agent is operating in so the impossible becomes possible. This is the hardest to understand but consequently also the deepest form of creative processes.

To be able to translate how creativity or at least part of it would work in a computer first an understanding is required of how knowledge is represented in the human mind.

## **1.2 Semantic Map**

The knowledge of a human brain is stored in various different parts of said brain (Purves et al., 2008). For instance visual information about an object, like which color it has, will be stored in the visual cortex, while the sound it makes will be stored in the auditory cortex. This data is represented by an assembly of neurons in the brain that fire or activate when that concept, let's say the concept of red, is activated. Case in point, when looking at a red circle, both the neurons associated with "red" as well as the concept of "round" will both be activated. Looking at a red ball will activate "red", "round" and probably a concept like "bounce" and "play". This means that higher level constructs will be built up containing various lower level constructs.

When constructs get activated together they will form a connection. When they often get activated together that connection will become stronger and an association will be made (Purves et al., 2008). This is based on the cell assembly theory coined by Hebb (Hebb, 1949). To map the strength of these connections one can translate them into distance measures. In such a way concepts that are closely related will manifest as being closer together than

seemingly unrelated concepts. For instance the concept of “Apple” will have a shorter distance to “Red” than it will have to the concept of “Blue” (Collins & Loftus, 1975; Gardenfors, 2000). A visualization of the data is called a semantic map and sadly this can only be drawn for small examples. If you were to dive into more complex situations one would quickly run out of room to write on or dimensions to visualize in. Figure 1 shows a simple example centered around the concept of red.

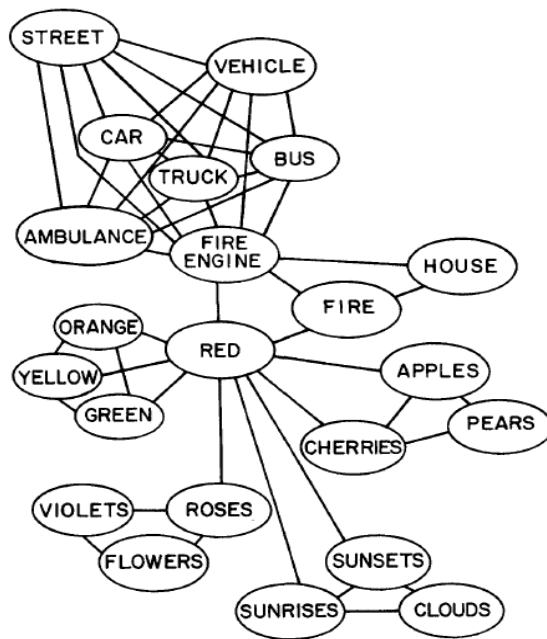


Figure 1 Semantic map, (Collins & Loftus, 1975)

Now how does the semantic map fit into the creativity picture? The conceptual spaces mentioned by Boden (1994) can be seen as clusters of knowledge as they are shown above in the complete semantic map. Because the sheer amount of information is so huge, the human brain cannot be ‘aware’ of all of it at the same time and has to activate the parts that it needs (Fauconnier & Turner, 2002; Fauconnier, 1985). And this is where creativity fits in. Activating a part of knowledge that is unrelated at first glance might prove insightful!

So we can see that a semantic map consists of multiple different clusters. A cluster will probably represent a concept, or a set of closely related concepts. Sometimes, these clusters can be related amongst themselves (Gentner, 1983). This opens up a framework for discussing higher order cognition, the mechanisms that transcend the notion of knowledge being just a simple dataset. These mechanisms include procedures like the analogy and blends. An analogy is where certain aspects of a concept get mapped on another concept. This does not have to be a literal copying. An example of an analogy was already mentioned

before: Electrons revolve around the nucleus the same way planets revolve around the sun. Here, properties of the electron get mapped on the way planets interact with the sun. Both are heliocentric systems.

Another example of higher order cognition is concept blending. Since this is a major topic in this thesis the next paragraph will give a more detailed description of this mechanism.

### 1.3 Concept Blending

When looking into creativity in computers, which is called computational creativity, the theory of concept blending is one that is very interesting. In this theory the semantic map mentioned previously is basically named a “mental spaces network”. A mental space is a partial and temporary knowledge structure created for the purpose of local understanding (Fauconnier, 1985). A concept blending framework consists of no less than four of those mental spaces. Two of these spaces are the input spaces. These spaces provide the input for the framework. These input spaces contain information about their respective concepts that they are representing. It contains all the information about the concept like color, shape, taste and sound, but also relational information like x contains y. These two input spaces will have certain aspects in common. These commonalities will be mapped in the generic space.

The most interesting space is the blend space. Here in this space the commonalities will be laid out, but enriched with certain aspects from either input space 1 or 2. So it will contain a lot of things that both concepts will have in common, but also a few things you will only find in either of the base concepts. Figure 2 gives a visual representation of this framework (Fauconnier & Turner, 2002).

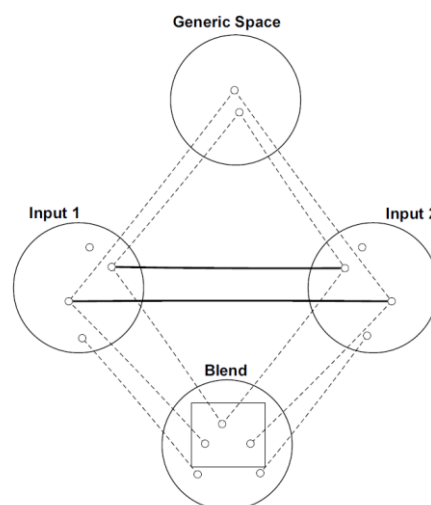


Figure 2 Four-space conceptual blending network, (Fauconnier & Turner, 2002)

Because this all sounds really abstract let's look at an example. Figure 3 below displays the blend computer virus. This blend is a result of blending two mental spaces namely "Computer" and "Virus". So to put it in terms of the previously explained, Computer and Virus will take up input spaces 1 and 2. These mental spaces have a few things in common, like how the computer could be seen as the host to a virus, and how the DNA of a virus is comparable to a computer program. The outcome of the blending process is shown below. The computer virus acts like both a computer program, as well as a virus on its own. It's got attributes of a computer program like: it has been written in code, which is a collection of instructions and is binary in nature. These are all attributes the virus does not have. The virus input of the blend gives it attributes like the ability to replicate, it being unwanted and reducing the host's capacity to operate. These are all attributes not found in the computer input. In layman's terms you could say we take 2 things that aren't really related at first glance, Computer and Health, and find some similarities. When blended together these two give an explanation of the way a computer virus works. Not surprisingly that is the name this blend ended up with.

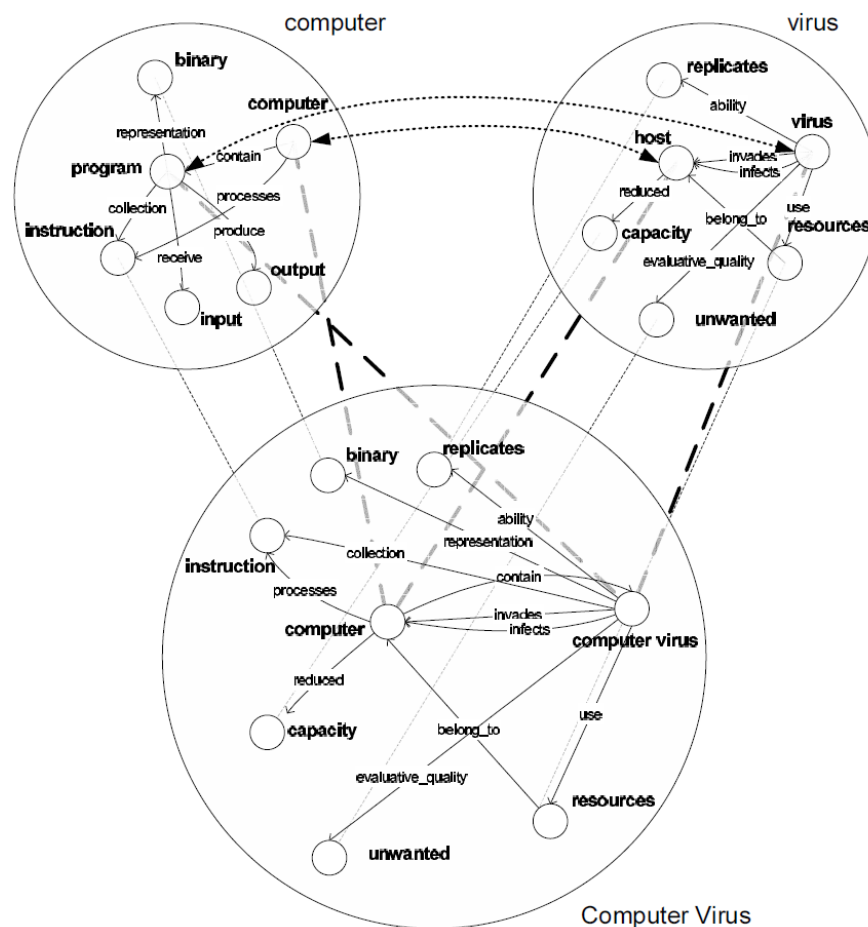


Figure 3 Computer Virus Blend, (Pereira, 2007)

## 1.4 Hypothesis

Concept blending is interesting for computational creativity because it gives the computer a framework for coming up with creative solutions like analogies, which at least in part, is a step towards making a creative A.I. (Berthold, 2012). Blends are forming bridge terms in knowledge structures. A bridge term is a concept that connects two seemingly unrelated subjects. In terms of our previous example; the domains of Computer and Health are not closely related. But when the Computer Virus got introduced this all changed. A computer virus has both its roots in the computer domain as well as the virus domain. If this is true then the presence of these bridges should also be present in the way humans think. This would be represented by the way knowledge structures would be formed in human beings. These knowledge structures are sometimes studied by applying card sorting tests. Therefore this thesis poses the hypothesis:

*Card Sorting is a valid tool for identifying concept blends.*

We think card sorting can be a powerful tool in the research being conducted towards concept blending. The next section offers an explanation of what card sorting entails, while the following chapter will give a rundown of how the experiments are conducted. The results chapter will present this thesis' findings, followed by a conclusion and discussion chapter.

## 1.5 Card Sorting

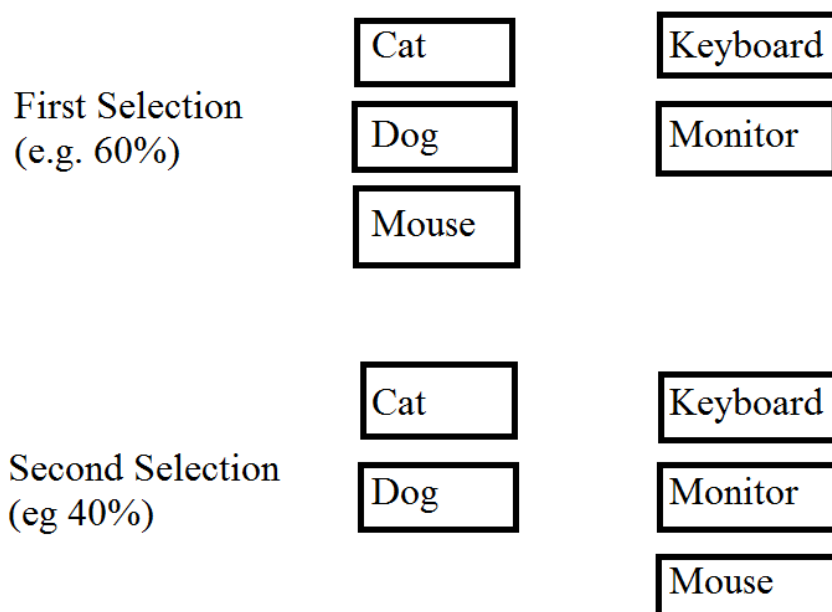
Card sorting is a method to identify underlying knowledge structures in the people participating in the experiment (Cooke, 1994). This makes it a powerful tool in discovering optimal organization of information for potential users in the world of information technology, where this method is currently widely used to design features like navigation structures (Wood & Wood, 2008). Navigation structures could best be explained by example; an example of a navigation structure would be the way someone can browse around a website. Which buttons are available at what time, and which items get grouped in certain sub-menus. But because the method is actually tied to the underlying knowledge structures, which can be called mental models (Purves et al., 2008), this paper poses that this is an interesting method in concept blending.

First let's see what card sorting is. Participants in this experiment will be given a set of cards with a concept written on them. These cards will have to be sorted into categories that make the most sense to the user, based on the semantic relations (Spencer, 2009). Whether the card sorting is done in person with physical cards and supervision; or whether it is done

online without supervision makes no difference (Bussolon, Missier Del, & Russi, 2006). The example used in the briefing for this experiment had the following set of words:

{Elephant, Cat, Dog, Mouse, Computer, Monitor, Keyboard}

When people are asked to sort out these cards, a logical possibility would be to divide them into a group of animals and a group of computer related items. This goes well for all but Mouse, since it would be possible to assign this term to both categories. Figure 4 below depicts an example of a possible outcome. When we would conduct a card sorting test, some people would put ‘Mouse’ together with the animals, for instance 60%. But another group of 40% of the people might think that mouse belongs with ‘Keyboard’ and ‘Monitor’ because they are thinking of the computer mouse. Please note that there are no wrong answers here, it just shows what most people associate “Mouse” the strongest with. We are seeing where the concept ‘Mouse’ fits best in their mental models.



*Figure 4 Example of a simple card sorting test*

In regular card sorting practices these terms that are often split between groups are called ambiguities and this is something regular practice tries avoided (Spencer, 2009). In this case we are actually interested in these ambiguities since they seem to form a bridge between two seemingly unrelated families of concepts. So when we will apply a card sorting task to a set of known concept blends we expect the results to show us these ambiguities.

## **1.6 Blends**

This paper will make use of two well-known concept blends. The first one will be the blend between the families of computer concepts and viruses, the blend of the computer virus explained by Pereira (2007). The second blend that will be used is the windows desktop. Built on the design by Xerox, this powerful blend was used to make the transition from the analog to the digital age a little easier. The Xerox Star as it was called was created in the time the computer was making a breakthrough. Because the manufacturers wanted to get a lot of computers into the workplace, they needed the systems to be simple to adapt to and work with. They recognized that computers would probably look alien in an analog world therefore they had the idea to structure the digital workplace as you would structure your workdesk at the time. When you come to work, you sit down at your desk. This got translated to a desktop in the digital world, the base screen on which all activity takes place. Data would be written on files, which were stored in folders. You used the notepad to make notes and paint would allow you to paint. By staying close to what people knew they hoped the transition would be smooth and allowed the manufacturers to sell a lot of machines (Johnson et al., 1989).

## **2. Method**

### **2.1 Participants**

In this experiment 108 participants (45 male and 53 female, 64 Dutch and 44 German, ages ranged from 18 to 59 with an average age of 26.4 years) participated on a voluntary basis. Their educations differed from VMBO-T, to PHD students to the German Abitur (High School). Participants were partly recruited through the Universiteit Twente's SONA participant program for which the students gained study credits. The other part was recruited via the researcher's social network.

### **2.2 Apparatus**

A card sorting study can be conducted either physically or online. Because research pointed out both methods give the same results (Bussolon et al., 2006), this paper used an online version since greatly increased the number of participants this study could reach. The participants carried out their tasks from their own computer systems, both Windows and Mac. Due to constraints on the card sorting program this could not be performed on iOS which runs on iPhones and iPads.

## 2.3 Procedure

Either through the SONA recruitment tool or through the researcher's social network the participants got presented with the link for participation in this experiment. First the participants got sent to a Qualtrics (Qualtrics LLC, 2015) research page where they would be presented with information about the experiment as well as an informed consent notice. After the participants consented they would be asked for some of their demographic data like age, sex and education. Then followed the instructions for the card sorting study after which they would be taken over to the Concept Codify (Concept Codify LLC, 2015) website for the actual card sorting task. During this task participants got presented with 48 concepts which they had to sort into groups of their own choosing with a maximum of 10 groups so the participants were forced to group the concepts. The 48 concepts from this study are derived from both the computer virus (Pereira, 2007) and desktop blend (Johnson et al., 1989). These concepts were presented in either Dutch or German, depending on the native language of the participants. Since the researcher's German language skills are less than outstanding, these concepts were translated by a native speaker to maintain construct validity. The full list of concepts and their translations can be found in Table 1.

Table 1 Concepts in the card sorting study

| ID | English   | Nederlands       | Deutsch         | ID | English     | Nederlands    | Deutsch      |
|----|-----------|------------------|-----------------|----|-------------|---------------|--------------|
| 1  | Trashcan  | Prullenbak       | Mülleimer       | 25 | Destroy     | Verwoesten    | Zerstören    |
| 2  | Room      | Kamer            | Zimmer          | 26 | Protect     | Beschermen    | Schützen     |
| 3  | Office    | Kantoor          | Büro            | 27 | Invade      | Binnendringen | Eindringen   |
| 4  | Worktable | Werktafel        | Arbeitsstisch   | 28 | Processor   | Processor     | Prozessor    |
| 5  | Desk      | Bureau           | Schreibtisch    | 29 | Computer    | Computer      | Computer     |
| 6  | Drawer    | Lade             | Schublade       | 30 | Mouse       | Muis          | Maus         |
| 7  | Work      | Werken           | Arbeiten        | 31 | Monitor     | Monitor       | Monitor      |
| 8  | Write     | Schrijven        | Schreiben       | 32 | Keyboard    | Toetsenbord   | Tastatur     |
| 9  | Sheet     | Blad             | Blatt           | 33 | Document    | Document      | Dokument     |
| 10 | Pen       | Pen              | Kugelschreiber  | 34 | Folder      | Map           | Ordner       |
| 11 | Paper     | Papier           | Papier          | 35 | Instruction | Instructie    | Anleitung    |
| 12 | Notepad   | Kladblok         | Notizblock      | 36 | Copy        | Kopiëren      | Kopieren     |
| 13 | Cells     | Cellen           | Zellen          | 37 | Cut         | Knippen       | Ausschneiden |
| 14 | Infection | Infectie         | Infektion       | 38 | File        | Bestand       | Datei        |
| 15 | Heal      | Genezen          | Heilen          | 39 | Program     | Programma     | Programm     |
| 16 | Body      | Lichaam          | Körper          | 40 | Connection  | Verbinding    | Verbindung   |
| 17 | Medicine  | Medicijn         | Medizin         | 41 | Memory      | Geheugen      | Speicher     |
| 18 | Multiply  | Vermenigvuldigen | Verfielfältigen | 42 | Code        | Code          | Code         |
| 19 | Replicate | Repliceren       | Replizieren     | 43 | Hack        | Hacken        | Hacken       |
| 20 | Recieve   | Ontvangen        | Erhalten        | 44 | Save        | Opslaan       | Speichern    |
| 21 | Contain   | Bevatten         | Enthalten       | 45 | Type        | Typen         | Tippen       |
| 22 | Virus     | Virus            | Virus           | 46 | Input       | Invoer        | Eingabe      |
| 23 | Spread    | Verspreiden      | Verbreiten      | 47 | Proces      | Proces        | Verfahren    |
| 24 | Weaken    | Verzwakken       | Schwächen       | 48 | Output      | Uitvoer       | Ausfuhr      |

The concepts were designed to come from either one of five categories; Office, Computer, Health, Windows, Virus. Windows being a blend between Computer and Office, Virus is a blend between Computer and Health. If our hypothesis is correct the concepts from Cluster 4 and 5 will form bridges between Clusters 1, 2 and 3. How these bridges show up in the data will be explained in the next chapter.

*Table 2 Distribution of the concepts among the clusters*

| Cluster 1<br><b>Office</b> | Cluster 2<br><b>Computer</b> | Cluster 3<br><b>Health</b> | Cluster 4<br><b>Windows</b> | Cluster 5<br><b>Virus</b> |
|----------------------------|------------------------------|----------------------------|-----------------------------|---------------------------|
| Desk                       | Memory                       | Multiply                   | Folder                      | Virus                     |
| Worktable                  | Monitor                      | Heal                       | Trashcan                    | Spread                    |
| Paper                      | Mouse                        | Medicine                   | File                        | Replicate                 |
| Write                      | Keyboard                     | Protect                    | Document                    | Weaken                    |
| Drawer                     | Save                         | Cells                      | Notepad                     | Destroy                   |
| Room                       | Computer                     | Body                       | Type                        | Hack                      |
| Pen                        | Processor                    | Infection                  | Cut                         | Invade                    |
| Office                     | Program                      |                            | Copy                        | Instruction               |
| Sheet                      | Input                        |                            |                             | Proces                    |
| Work                       | Output                       |                            |                             | Contain                   |
|                            | Code                         |                            |                             | Recieve                   |
|                            |                              |                            |                             | Connection                |

## 2.4 Analysis

For our hypothesis to be true, we would expect to find so called bridges linking concepts from the different clusters. More specifically we would expect the Office and Computer cluster to be linked by concepts from the windows cluster. In order to evaluate whether this is true we need a formal analysis. First we will perform a Hierarchical Cluster Analysis (HCA) on the data. This allows us to check whether the participants sorted the concepts in roughly the same groups as the researchers envisioned. Next we will produce a heat map off the data. This heat map shows how often two concepts have been named together in one group. The scores will be color coded, where related concepts show up in brighter red. This heat map is rearranged using the outcome of the HCA so we can see the clusters being formed. After that is done we will dive further into the data using Gardenfors' (2000) observation of a geometrical concept space and try to identify blends using logic and metrics.

In order to produce a heat map first we will have to create a summed proximity matrix. In this matrix we will count how many times two concepts were put together into one group by the participants. Because this study had 108 participants, the maximum score in the matrix

would be 108. The highest actual score in the matrix was between the word pair 32 (monitor) and 33 (keyboard). These have a score of 103, meaning 103 participants put these concepts together into one group. By assigning a color to the scores on a color scale we can visualize the data. In this instance we used yellow for low scores, red for high scores which would mean that scores in the middle would be more or less orange based on their height. In its current state this heat map would be hard to read, therefore some regrouping is needed. This could be done by hand but that would be tedious work (Hudson, 2005). A powerful alternative is to rearrange the concepts using a HCA. This method uses the Jaccard Proximity Measure to produce nested clusters (Salamoni, 2012). When the concepts will be rearranged by the outcomes of this measure we should get a clear picture of concepts that belong together according to the participants. Then it will be possible to look for so called “hot spots”. These spots are concepts that lie outside of the clusters formed, but still have a high score (red color). That means that these concepts will be linked to another cluster as well and are forming bridges between the clusters, which is what we are looking for.

While the aforementioned method is a nice tool in identifying those bridges it still is somewhat subjective. A better and objective fit would be to use logic and metrics. Gardenfors (2000) already taught us that a concept space can be viewed as a geometrical space. If the space is geometrical the distance between two concepts can be given by a distance function. In order for the function  $d(a,b)$  to be a distance function it will have to fulfill four requirements for all (different) elements of  $a$  and  $b$  (Barnsley, 1988):

- R1:  $0 < d(a,b) < \infty$
- R2:  $d(a,a) = 0$
- R3:  $d(a,b) = d(b,a)$  (symmetry)
- R4:  $d(a,b) \leq d(a,c) + d(c,b)$  (triangle inequality)

First, the distance between  $a$  and  $b$  should be between zero and infinity. Secondly the distance between a concept and itself should be zero. Then the distance from  $a$  to  $b$  should be the same as the distance from  $b$  to  $a$ , this is called symmetry. And lastly the distance from  $a$  to  $b$  should be the shortest route possible, any route through any other point should result in a longer distance.

As a distance measure, following Van der Velde and Nazareth (2015) we will use the scores from the heat map in a logarithmic function so to get a better sensitivity, since the data distribution is skewed toward the lower regions:

$$d(a,b) = -\ln(x) \quad \text{for } x = \text{CST}(a,b)/S$$

It uses the heat map score for two concepts ( $CST(a,b)$ ) and  $S$  is the number of participants in this study, hence the maximum score. The score of a concept with itself is not defined, but we can assume that a word is maximally related to itself. The results of our analysis will point out whether this distance function is a good fit.

### 3. Results

#### 3.1 Hierarchical Cluster Analysis

First let's take a look at the Hierarchical Cluster Analysis. Figure 5 shows the HCA results from this card sorting study.

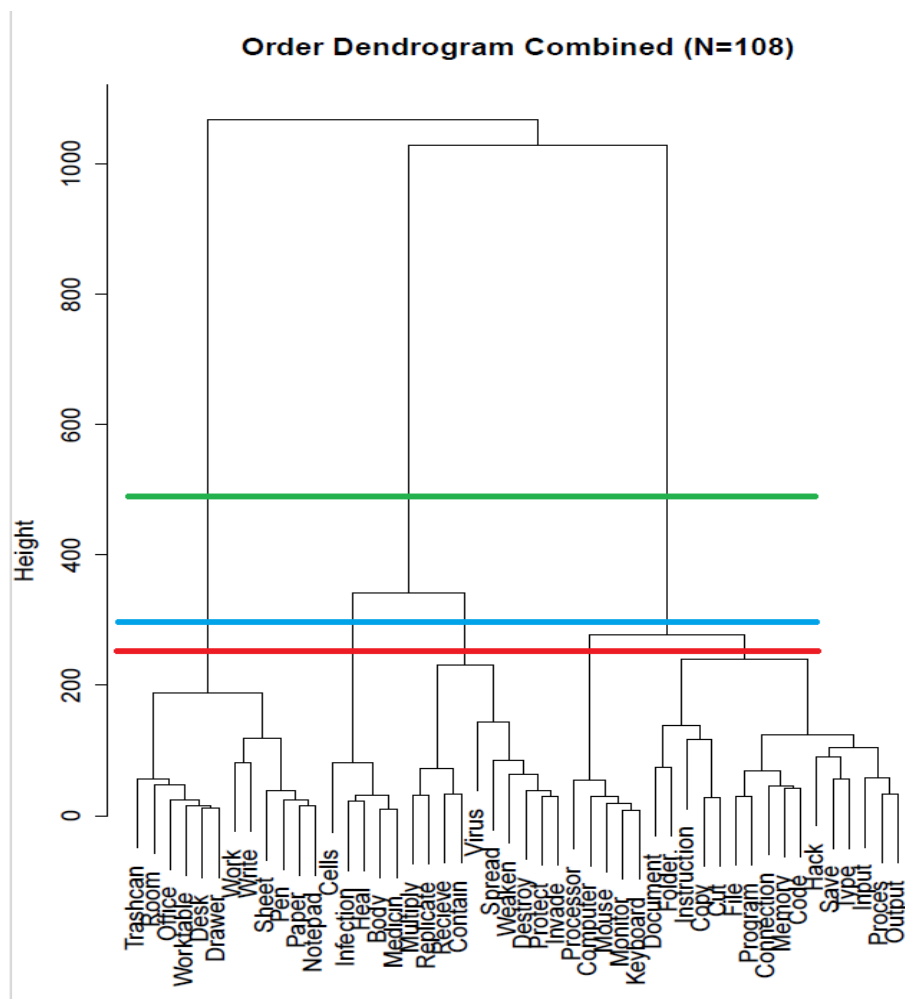


Figure 2 Hierarchical Cluster Analysis of the Card Sorting Data

What we see here is a visualization of the distances between two concepts. The longer a road you have to travel following the lines, the further removed they are. If we were to cut off the scores at the green line we would end up with three clusters of concepts. The left one contains mostly concepts from our Office cluster, together with some items from the

Windows blend cluster. The middle group would contain concepts from the Health and Virus blend cluster. The right group contains concepts from the Computer cluster, as well as the Windows and Virus Blend.

If we were to cut at the blue line, the split between the Health and Virus blend clusters would be realized and we would end up with four off the defined groups. Cutting at the red line gives us a mostly Office cluster, a Health cluster, a Virus cluster, a Computer cluster and cluster containing concepts from the Computer, Virus and Windows clusters. Overall this is very close to what we would expect to get. Our concepts have been sorted into roughly the same groups. Working with just a HCA has a big downside. It will only show a concepts connection to the closest other connection. Therefore if a concept would be closely related with concepts from other clusters this would not at all show up in the HCA analysis. But that is why we also use a heat map.

### **3.2 Heat Map**

Using both a heat map together with a HCA strongly improves our ability to improve the data. A raw heat map on its own would be very hard to read. It would have the concepts scattered all over the place making it almost impossible to identify recurring patterns. When the concepts are rearranged using the HCA we can paint a much clearer picture. Now the upside of the heat map becomes clear. Remember, white/yellow means concepts are far removed from each other, which means they are very far apart; the participants think these concepts are not related. Red/orange means the concepts are closer together; these concepts are related according to our participants.

Let's take a look at the heat map which is shown in Figure 6. Here a few things stand out. When looking at the squares we can see three clear groups. We can see the office cluster is strongly grouped together. Then when we look at the other clusters, we can see that there is a big one that looks to be a combination of the computer and windows cluster. The other big cluster is a mixture of the health and virus clusters.

What we are interested in are the so called hot spots. These hot spots are spots of red/orange that fall outside the big main squares. This indicates that besides being related to the other concepts inside their square or group we derived from the HCA, these concepts are also related to concepts of other groups. So when we look at our heat map three more things stand out, pointed out by the blue shapes. First the concept 'Folder' is placed in the computer/windows cluster where it would be expected. But as shown in the blue shape 1 'Folder' also has a strong connection to concepts like 'Drawer', 'Desk' and 'Worktable'

which belong to the office cluster, indicating a bridging concept. In blue shape 2 we see the word 'Hack', belonging to the virus cluster, but it also has a strong connection with the computer cluster. This is also true for blue shape 3, but to a lesser extent, but they all might indicate the presence of bridging concepts.

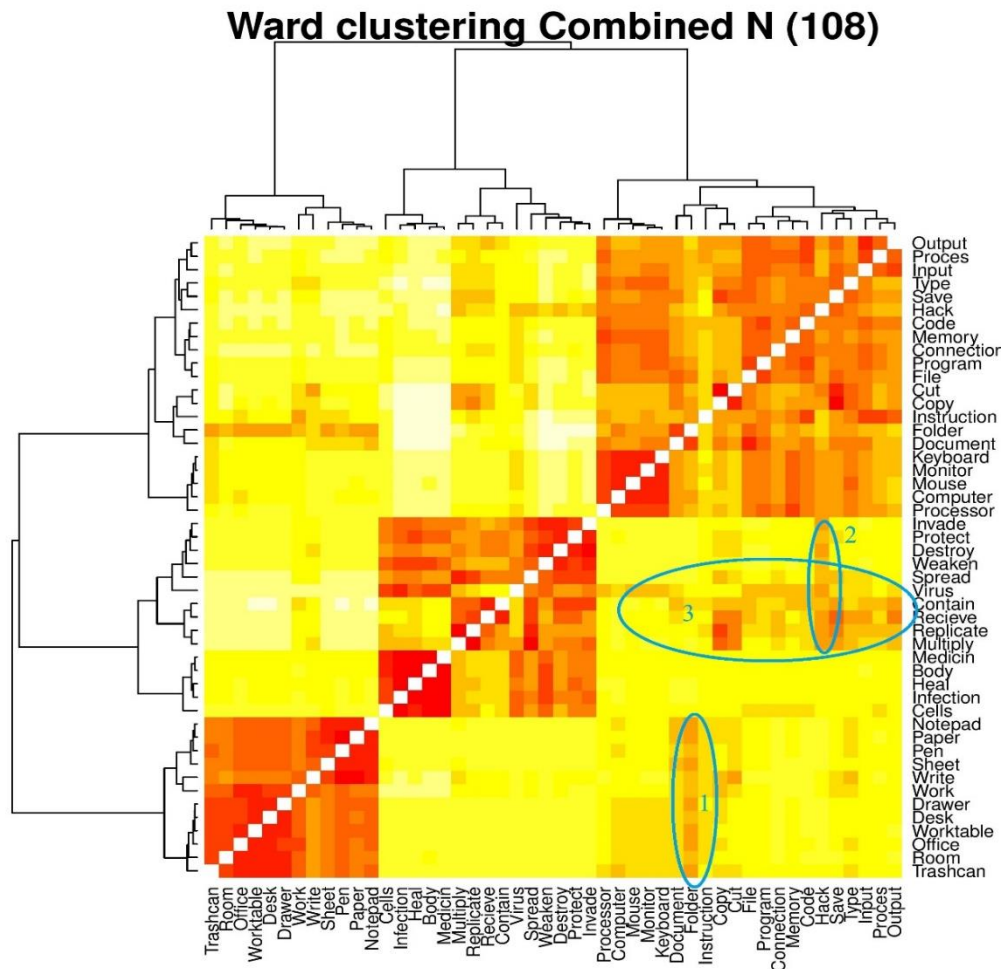


Figure 6 Heat map depicting results of Card Sorting Study

### 3.3 Geometric Spaces

#### 3.3.1 Distribution

Remember, in order for the function  $d(a,b)$  to be a distance function it will have to fulfill four requirements for all (different) elements of  $a$  and  $b$  (Barnsley, 1988):

- R1:  $0 < d(a,b) < \infty$
- R2:  $d(a,a) = 0$
- R3:  $d(a,b) = d(b,a)$  (symmetry)
- R4:  $d(a,b) \leq d(a,c) + d(c,b)$  (triangle inequality)

To determine whether the distance function  $d(a,b) = -\ln(x)$ , for  $x = \text{CST}(a,b)/S$  is a valid distance function we looked at the distribution of data derived from our card sorting study.

Figure 7 depicts the distribution of the scores in the heat map on the card sorting study (CST) and the score values based on the distance function. This figure illustrates that the distribution is indeed comparable to the  $\ln$  function which suggests that it is a good distance measure.

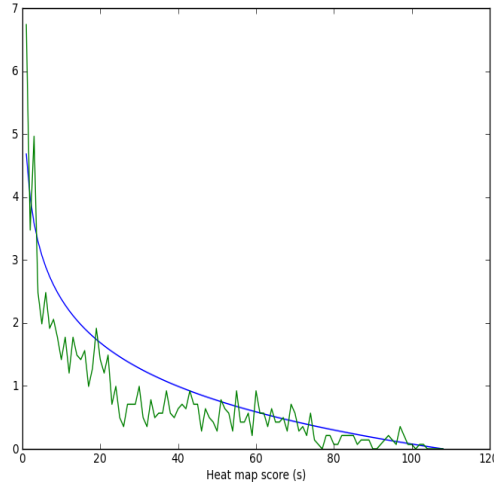


Figure 7: Green (ragged) line: Distribution of heat map scores in CST.  
Blue (smooth) line:  $-\ln(x)$  with  $x = \text{CST}(a,b)/S$

In this function R3 is satisfied, since the heat map is symmetrical. R2 is satisfied because  $d(a,a) = -\ln(\text{CST}(a,b)/S) = -\ln(108/108) = -\ln(1) = 0$ .  $\ln(0)$  is not defined, but since the difference between the low score values is not very interesting, the scores of  $\text{CST}(a,b) = 0$  have been combined with the scores of  $\text{CST}(a,b) = 1$ . This way the scores vary between 0, given by  $-\ln(1)$  for  $d(a,a)$  and  $-\ln(1/S)$  satisfying R2. Now that R1, R2, and R3 are satisfied we can look at R4.

When we investigate R4, we are calculating all the relations of  $d(a,b)$  vs  $d(a,c) + d(c,b)$  with our distance function mentioned before. Doing this we found 6110 violations out of 51888 possible violations which is around 12%. While this would suggest that our function is not an appropriate distance function, these violations are still very informative. When focused on significant violations, meaning  $d(a,b) - (d(a,c) + d(b,c)) \geq 1$ , we found that none of the remaining 1173 violations occurred within their own cluster. This means that our distance function would be valid when looking at distances within clusters, but apparently some concepts are forming bridges between the clusters. Which again is what we are looking for. The next section dives into the concepts that actually provide these bridges and links multiple clusters together.

### 3.3.2. Triangle Violations

Table 3 below shows the distribution of the triangle violations occurring in this experiment. Concepts a,b and c are the same variables as the a,b and c from the distance function. The numbers, 1,2,3,4 and 5 represent the clusters the concepts came from. So please look in the table below, to the value of 95 that has been highlighted. In this case, a concept from cluster 5 (Virus) acted as parameter (a) in the distance function. A concept from cluster 1 (Office) acted as parameter (b) in the distance function. Also a concept from cluster 1 (Office) acted as parameter (c) in the distance function. This means that while some of these concepts from cluster 1 and 5 did not have a strong connection amongst themselves, they were more strongly connected through another concept in cluster 1.

Table 3 Crosstabulation of the Geometric Space

| Concept A * Concept B * Concept C Crosstabulation |           |   |           |     |    |     |       |
|---------------------------------------------------|-----------|---|-----------|-----|----|-----|-------|
| Count                                             |           |   |           |     |    |     |       |
| Cluster c                                         |           |   | Concept b |     |    |     | Total |
|                                                   |           |   | 1         | 3   | 4  | 5   |       |
| 1                                                 | Concept a | 2 | 4         | 0   | 0  | 0   | 4     |
|                                                   |           | 3 | 43        | 0   | 7  | 0   | 50    |
|                                                   |           | 4 | 0         | 0   | 0  | 5   | 5     |
|                                                   |           | 5 | 95        | 0   | 20 | 0   | 115   |
|                                                   | Total     |   | 142       | 0   | 27 | 5   | 174   |
| 2                                                 | Concept a | 2 | 17        | 36  | 4  | 22  | 79    |
|                                                   |           | 3 | 0         | 0   | 2  | 0   | 2     |
|                                                   |           | 4 | 0         | 12  | 0  | 22  | 34    |
|                                                   |           | 5 | 40        | 0   | 5  | 0   | 45    |
|                                                   | Total     |   | 57        | 48  | 11 | 44  | 160   |
| 3                                                 | Concept a | 2 | 0         | 70  | 0  | 25  | 95    |
|                                                   |           | 3 | 33        | 0   | 3  | 0   | 36    |
|                                                   |           | 4 | 0         | 52  | 0  | 16  | 68    |
|                                                   |           | 5 | 3         | 7   | 0  | 0   | 10    |
|                                                   | Total     |   | 36        | 129 | 3  | 41  | 209   |
| 4                                                 | Concept a | 2 | 17        | 6   | 5  | 19  | 47    |
|                                                   |           | 3 | 11        | 0   | 5  | 0   | 16    |
|                                                   |           | 4 | 2         | 1   | 0  | 20  | 23    |
|                                                   |           | 5 | 63        | 0   | 18 | 0   | 81    |
|                                                   | Total     |   | 93        | 7   | 28 | 39  | 167   |
| 5                                                 | Concept a | 2 | 2         | 151 | 0  | 80  | 233   |
|                                                   |           | 3 | 35        | 0   | 3  | 0   | 38    |
|                                                   |           | 4 | 0         | 112 | 0  | 53  | 165   |
|                                                   |           | 5 | 4         | 16  | 6  | 1   | 27    |
|                                                   | Total     |   | 41        | 279 | 9  | 134 | 463   |
| Total                                             | Concept a | 2 | 40        | 263 | 9  | 146 | 458   |
|                                                   |           | 3 | 122       | 0   | 20 | 0   | 142   |
|                                                   |           | 4 | 2         | 177 | 0  | 116 | 295   |
|                                                   |           | 5 | 205       | 23  | 49 | 1   | 278   |
|                                                   | Total     |   | 369       | 463 | 78 | 263 | 1173  |

An example of one of the 95 triangle violations occurring on the previous page is the one that is occurring between the concepts 'Contain' from cluster 5 (parameter a), 'Room' from cluster 1 (parameter b) and 'Work' also from cluster 1 (parameter c). Figure 8 visualizes this triangle violation.

'Room' and 'Contain' got named together 3 times. So following our distance function  $-\ln(x)$  for  $x = \text{CST}(a,b)/S$ , we end up with  $-\ln(3/108) = 3.6$ .

'Contain' and 'Work' got named together 19 times. So following our distance function  $-\ln(x)$  for  $x = \text{CST}(a,b)/S$ , we end up with  $-\ln(19/108) = 1.7$ .

'Room' and 'Work' got named together 64 times. So following our distance function  $-\ln(x)$  for  $x = \text{CST}(a,b)/S$ , we end up with  $-\ln(64/108) = 0.5$ .

The direct distance calculated from our distance function between 'Contain' and 'Room' is 3.6, while the distance through 'Work' is only 2.2. This means that 'Work' acts as a bridge connecting the concepts 'Contain' and 'Room'.

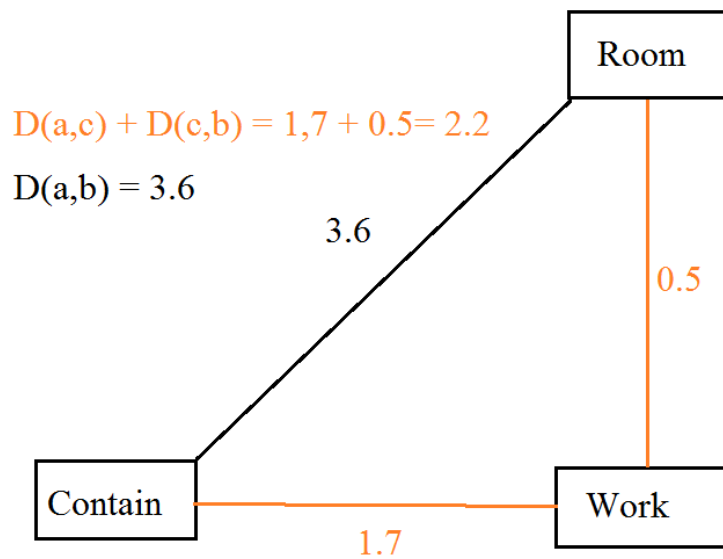


Figure 8 Triangle violation of 'Contain' and 'Room' through 'Work'

Analyzing the results from table 3 we can see that for clusters 1,2 and 3 most of the bridges are being formed within their own respective clusters. What is interesting here is that the clusters containing the designed blends Windows and Virus, clusters 4 and 5, are mostly forming bridges between other clusters. The next section will take a closer look at those bridges.

### 3.3.3 Windows Blend

Figure 6 below depicts the relation between the concepts 'Room' and 'Code'. In total there are 14 different paths available for which  $d(\text{room}, \text{code}) - (d(\text{room}, \text{'bridge'}) + (d(\text{code}, \text{'bridge'}))) \geq 1$  is valid. This means that while 'Code' and 'Room' are not linked directly there are four concepts in cluster 1, six concepts in cluster 2 and four concepts in cluster 4 which link the two. Cluster 4 is the windows cluster, which would prove that there are bridging concepts within the blend cluster which would prove the hypothesis.

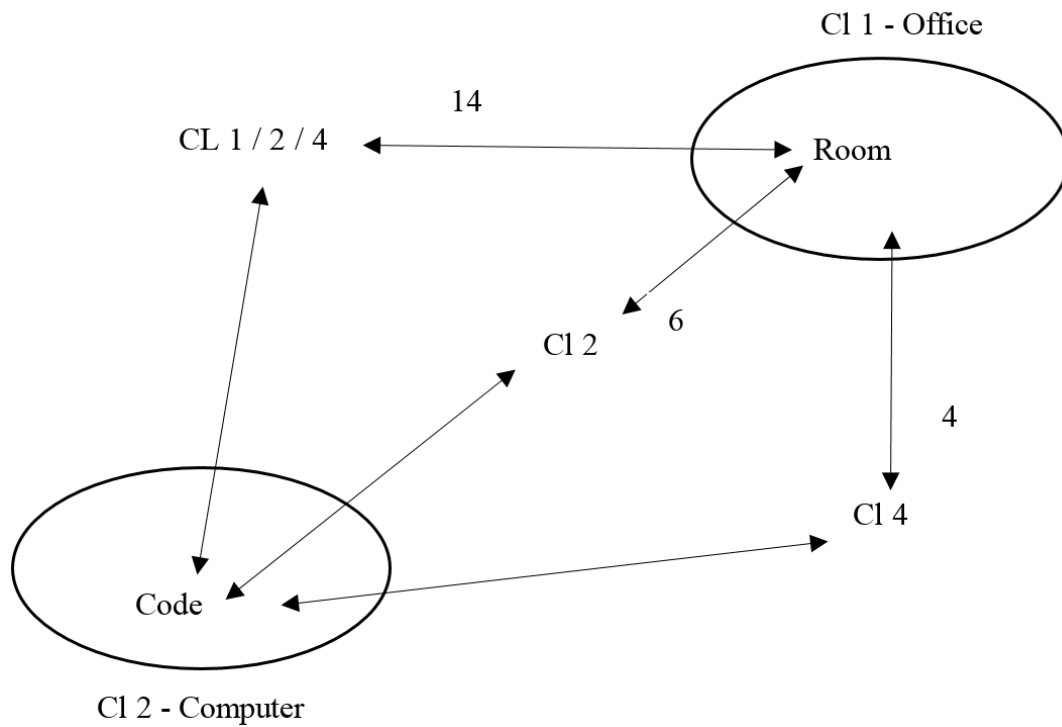


Figure 9 'Code' and 'Office' connected through the clusters

Figure 10 below visits another example of a blend occurring in this card sorting study. First it shows us the relation between ‘Worktable’ from cluster 1 and ‘Program’ from cluster 2. The direct distance between these two concepts is 2.7. But when looking at the distance from ‘Program’ to ‘Folder’ to ‘Worktable’ this distance becomes:  $0.7 + 0.9 = 1.6$ . This is significantly shorter than the 2.7 direct distance. This effect also occurs between ‘Program’ and ‘Pen’. These two concepts are linked through two concepts from cluster 4, namely both ‘Folder’ and ‘Document’. The direct distance would be 2.9, whereas the distance through ‘Folder’ and ‘Document’ are 1.7 and 1.8 respectively. This shows us some of the bridges being formed between the Computer and Office clusters by concepts from the Windows blend cluster.

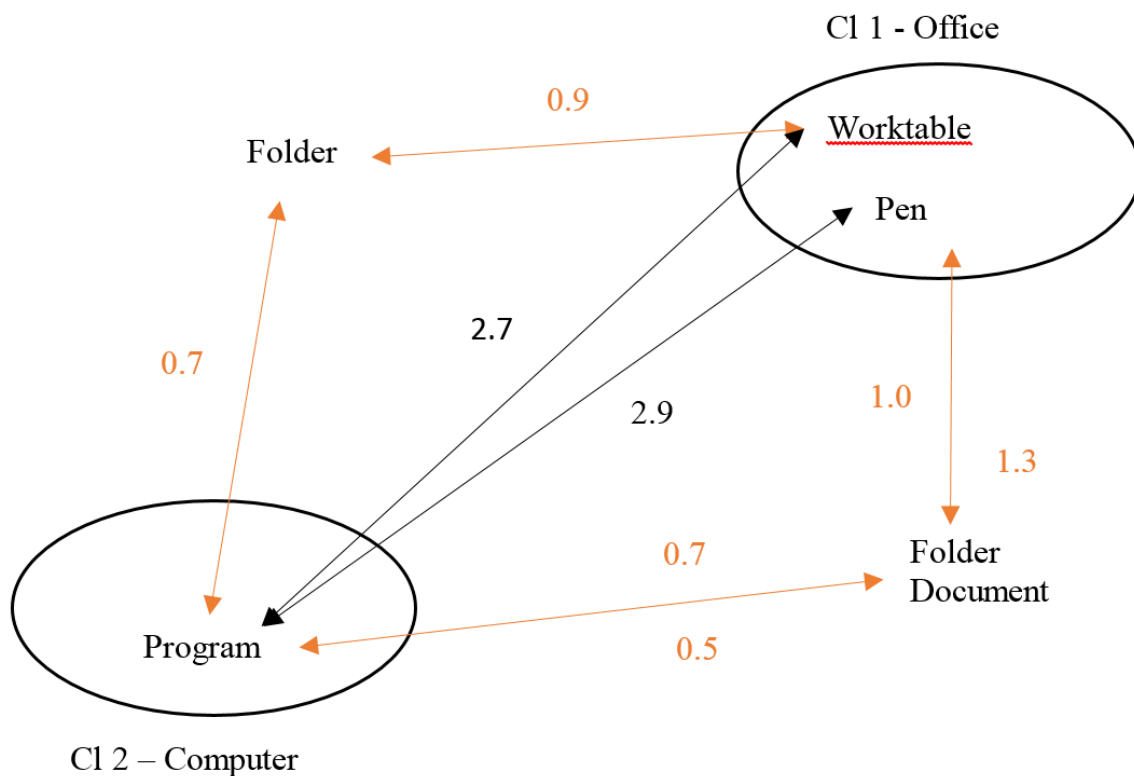


Figure 10 Cluster 1 and 2 blending through the 'Folder' and 'Document'

Now that we have determined bridges between clusters exist for the Windows blend, we will have a look at the Virus blend in the next section.

### 3.3.4. Virus Blend

Figure 11 below depicts some of the bridges being formed between the Computer and Health clusters, clusters 2 and 3. In particular, it look at the concept 'Save' from cluster 2 and 'Body' and 'Medicine' from cluster 3. Here we can see that 'Save' and 'Body' are connected through 15 concepts in total, 9 of which are coming from cluster 5, the Virus blending cluster. The same goes for 'Save' and 'Medicine' who again have 9 concepts from the Virus cluster connecting them. The Virus cluster only contained 12 concepts so 75% of these concepts acted as a bridge in these two cases.

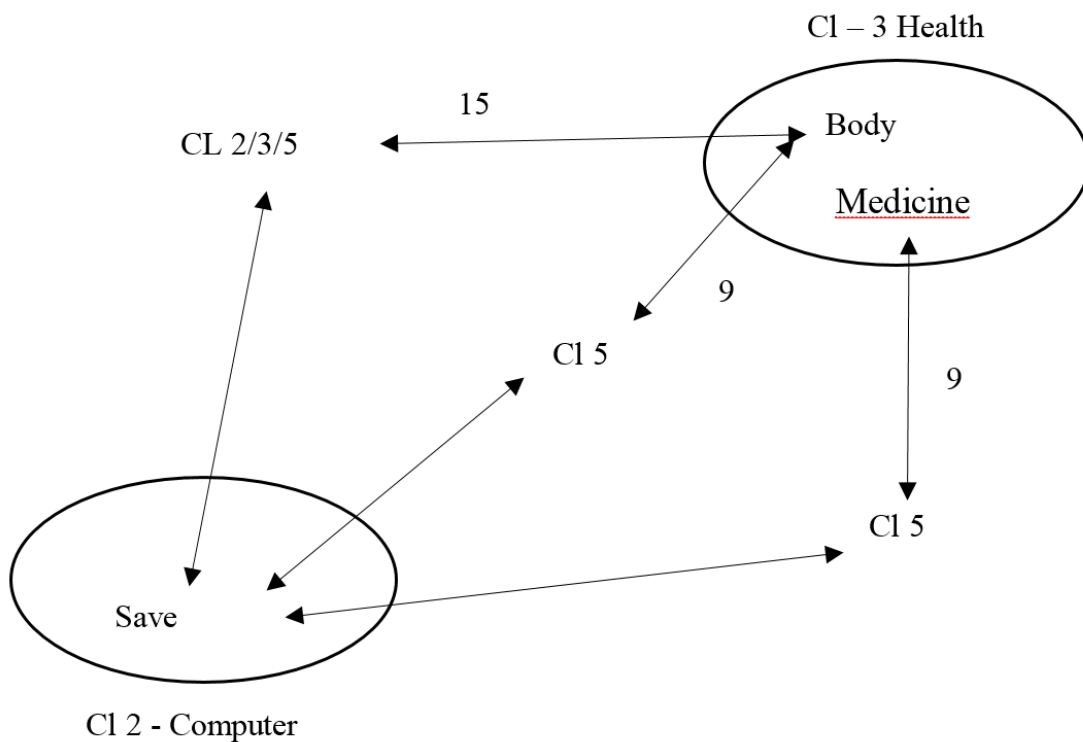


Figure 11 Bridges forming between Clusters 2 and 3

On the next page we will look at one of the strongest bridging term identified in this card sorting study. Maybe not surprisingly this is the concept of 'Virus'. Figure 12 on the next page shows the concept of 'Medicine' being connected to 'Computer' and 'Processor' from cluster 2 and 'Copy' and 'Folder' from cluster 4. A distance of 4.7 is the highest possible distance ( $-\ln(1/108) = 4.7$ ) and 4.0 is the second longest distance, so they could not be further removed from each other. But when we go through the concept 'Virus' these distance shrink considerably as shown in figure 12. In total, the concept 'Virus' formed 100 bridges to other concepts, the vast majority of those were to concepts from other clusters.

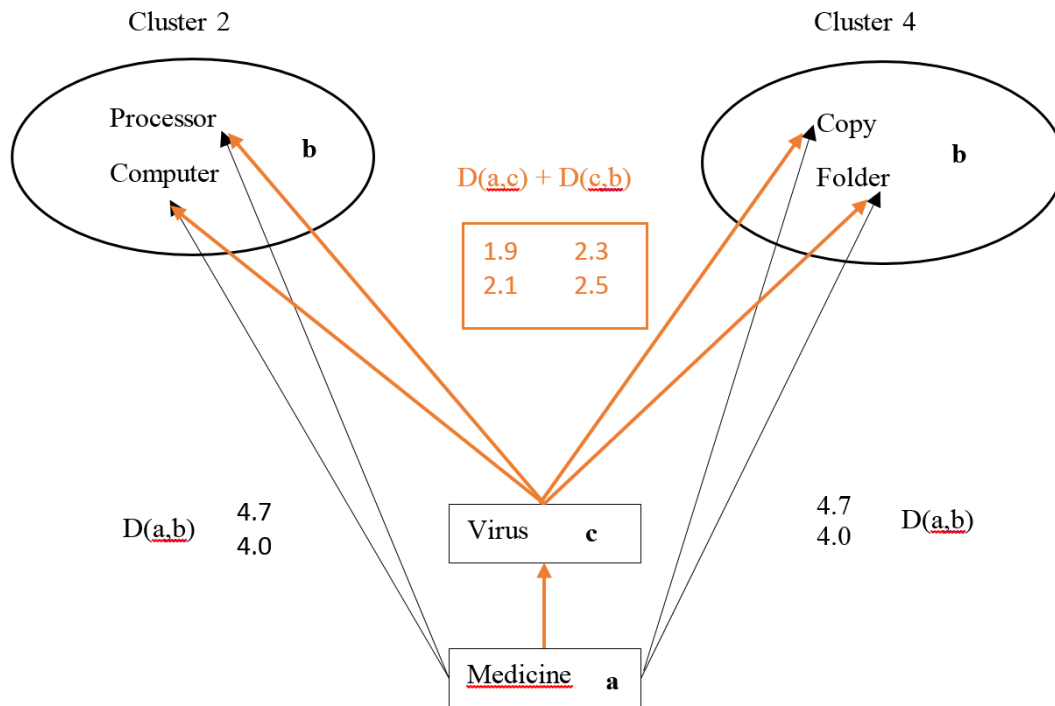


Figure 12 Virus forming bridges to Clusters 2 and 4

Figure 13 Might be our strongest evidence. It shows the concepts of the Computer cluster, 'Mouse', 'Computer', 'Processor', 'Keyboard' and 'Monitor', which are alle connected to the concepts from the Health cluster; 'Heal', 'Medicine', 'Infection' and 'Body'. This shows what a powerfull bridge the concept 'Virus' is in this card sorting study.

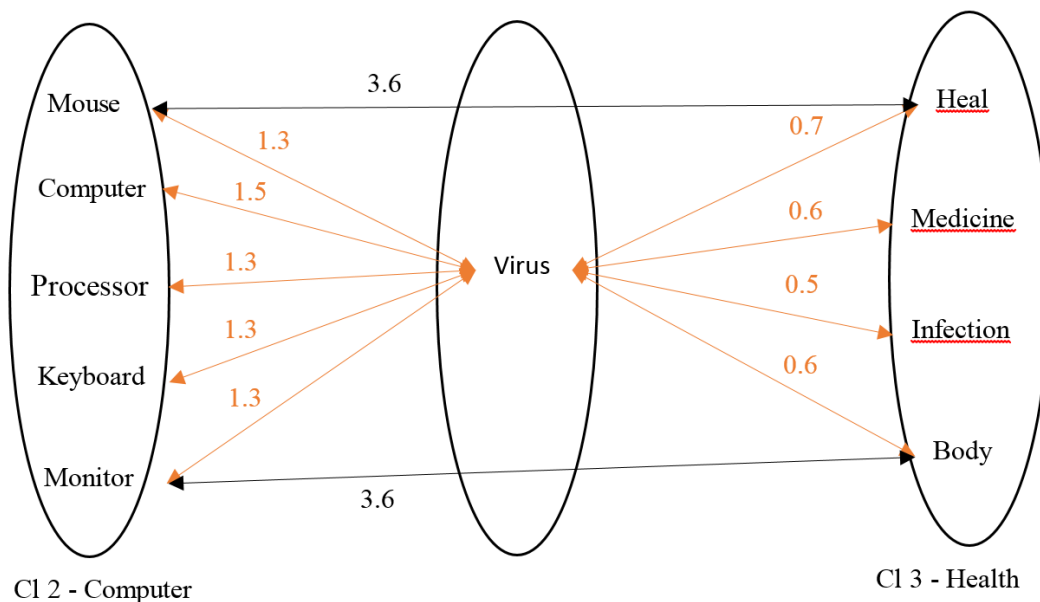


Figure 13 Virus forming bridges between Cluster 2 and 3

## 4. Conclusion and Discussion

Creativity is a very hot item in computer sciences nowadays. Some even took to calling creativity the Holy Grail in computer science. IBM's WATSON was a very smart machine, but true intelligence would require a system to create something on its own. Creativity in computer systems is called computational creativity and this paper tried to lay some groundwork so that someday someone can create a truly intelligent artificial.

First we started off exploring what creativity is exactly; and here we made the distinction that we are looking at the cognitive process of creativity, and not trying to define the abstract term used in art and music. The cognitive process of creativity is being able to come up with ideas or artefacts that are new, surprising and valuable. If it has already been done, if it is to be expected or if it has no value in any sense, then it cannot be called creative. To arrive at a creative destination, a number of three roads can be taken; Combinational creativity, exploratory creativity and transformational creativity

In order to be able to map the cognitive process of creativity onto a computer first we would need to know how this would work in human beings. This is tied tightly to how the storage of knowledge is accomplished in the human mind. Knowledge is stored in the brain by semantic map. The neurons in the brain that are associated form a connection. If that connection is often used, this connection gets stronger; according to the cell assembly theory by Hebb. This results in a huge web of interconnected nodes, where the strength of the connection can be described in a geometrical distance. Nodes that belong together are called clusters.

When these clusters can be related amongst each other this opens up the possibility for higher order cognition, like analogies and blends. Blends are what this thesis uses as a basis for attaining creativity. This follows the combinational road to creativity. Blends consist of two seemingly unrelated topics. These topics will have some things in common, as most topics do. The blend consists of the commonalities of the two topics combined, together with some aspects from topic A and some aspects from topic B. This is called concept blending.

Concept blending is very interesting to the field of computer science because it gives the computer a framework for coming up with creative ideas. Blends are forming bridges between two seemingly unrelated topics. The forming of bridges should show up in human beings' knowledge structures. These structures are often studied by applying card sorting tests to test subjects.

Therefore this thesis' research question was: Card Sorting is a valid tool for identifying Concept Blends.

This was investigated by conducting a card sorting test on two well-known blends; the Computer Virus blend and the Windows blend, designed by Xerox Star. 108 Participants took part in the study where they had to perform an online card sort. The answers of these participants were analyzed using a number of methods. Firstly a Hierarchical Cluster Analysis was performed. This showed that the participants' mental models roughly matched the five clusters used as the basis for the study. Secondly the heat map revealed certain hot spots. These hot spots were centered on a lot of concepts from the blending clusters. This was the first, albeit a bit vague proof to our hypothesis. Lastly this thesis conducted an investigation of the triangle violations occurring in the geometrical concept spaces. This investigation showed that multiple concepts acted as bridging terms. These bridging terms came mostly out of clusters 4 and 5. These were the Windows and Virus clusters. The concept making acting as a bridging term the most was the concept of 'Virus' which was not surprising, assuming our hypothesis to be true. All in all the evidence is clear that Card Sorting is indeed a powerful tool in identifying concept blends.

Now where does this leave us? Applying card sorting tests to everything is not an answer. What it is though is a powerful tool in verifying concept blends. Because human beings have a limited amount of real estate in their minds, they cannot be aware of all the knowledge they have. A computer can actually do this more easily and therefore it will be very capable of working with a lot of information. A possibility would be that a computer system would use a 'farming' script to run down which words often get used together on the web. The number of times they get named together could be used as a distance measure in our geometrical concept spaces model. If we then look for triangle violations in the resulting data, it is possible we end up with new concept blends; some which we have not even thought of. If we wanted to verify these concept blends it could be done using Card Sorting again. Because the card sorting task is not fun per se it would be wise to present it in a form of a 'Serious Game'.

I regret using two blends that both had Computer in its input spaces. This makes all the clusters connected in some way. If we would have used loose distinct clusters the effect of the card sorting study is expected to have been a lot more pronounced.

I would like to thank it's supervisors for putting up with my erratic nature. Communication has not been my strong suit during this venture and at times maybe even nonexistent. I would like to think that is because I try to figure out everything on my own and value my independence but surely, would I have asked sooner would have been stuck a lot less. This would in turn probably have caused me to finish this product a lot sooner. My supervisors showed great amounts of patience for which I would like to thank them.

All's well that ends well.

*This thesis, together with all its resources can be found online at:*

<https://www.dropbox.com/sh/qxzfrq8nr0mcvp5/AAAj9t-v1Gi-uyYgRpJoW3aqa?dl=0>

or

<http://tinyurl.com/thesis-stienen>

## 5. Bibliography

- Abdel-Fattah, A. M. H., Besold, T., & Kühnberger, K. U. (2012). Creativity, cognitive mechanisms, and logic. *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 7716 LNAI, 1–10.
- Barnsley, M. F. (1988). *Fractals everywhere*. Academic press.
- Berthold, M. R. (2012). *Bisociative Knowledge Discovery*. (M. Berthold, Ed.). Heidelberg [u.a.] : Springer.
- Boden, M. A. (1994). Précis of the creative mind: Myths and mechanisms. *Behavioral and brain sciences*, 17(03), 519–531. Cambridge Univ Press.
- Bussolon, S., Missier Del, F., & Russi, B. (2006). Online card sorting: as good as the paper version. *ECCE 13 - 20-22 September, 2006*, 14(2004), 1.
- Collins, A. M., & Loftus, E. F. (1975). A spreading-activation theory of semantic processing. *Psychological Review*, 82(6), 407–428.
- Concept Codify LLC. (2015). Concept Codify. Retrieved May 1, 2015, from <https://conceptcodify.com/>
- Cooke, N. J. (1994). Varieties of knowledge elicitation techniques. *International Journal of Human - Computer Studies*, 41, 801–849.
- Fauconnier, G. (1985). *Mental Spaces: Aspects of Meaning Construction in Natural Language*.
- Fauconnier, G., & Turner, M. (2002). *The Way We Think: Conceptual Blending & the Mind's Hidden Complexities*. New York: Basic Books. Retrieved from <http://www.scribd.com/doc/37961286/Fauconnier-Turner-2002-The-Way-We-Think-Conceptual-Blending-the-Mind-s-Hidden-Complexities#download>
- Ferrucci, D., Brown, E., Chu-Carroll, J., Fan, J., Gondek, D., Kalyanpur, A. a., Lally, A., et al. (2010). Building Watson: An Overview of the DeepQA Project. *AI Magazine*, 31(3), 59–79. Retrieved from <http://www.aaai.org/ojs/index.php/aimagazine/article/view/2303>
- Gardenfors, P. (2000). *Conceptual Spaces*. Massachusetts: MIT Press.
- Gentner, D. (1983). Structure-Mapping: A Theoretical Framework for Analogy. *Cognitive science*, 7(2), 155–170. Retrieved from [http://dx.doi.org/10.1016/S0364-0213\(83\)80009-3](http://dx.doi.org/10.1016/S0364-0213(83)80009-3)  
[http://doi.wiley.com/10.1016/S0364-0213\(83\)80009-3](http://doi.wiley.com/10.1016/S0364-0213(83)80009-3)  
[http://onlinelibrary.wiley.com/doi/10.1207/s15516709cog0702\\_3/abstract](http://onlinelibrary.wiley.com/doi/10.1207/s15516709cog0702_3/abstract)
- Hebb, D. O. (1949). The Organization of Behaviour. *Organization*, 62.
- Hudson, W. (2005). Playing Your Cards Right : Getting the Most from Card Sorting for Navigation Design. *Interactions*, 10(2), 56–58.
- IBM. (2015). IBM Watson: What is Watson. Retrieved May 25, 2015, from <http://www.ibm.com/smarterplanet/us/en/ibmwatson/what-is-watson.html>

- Johnson, J., Roberts, T. L., Verplank, W., Smith, D. C., Irby, C. H., Beard, M., & Mackey, K. (1989). Xerox Star: A retrospective. *Computer*, 22(9), 11–26, 28.
- Pereira, F. C. (2007). *Creativity and artificial intelligence: a conceptual blending approach* (Vol. 4). Walter de Gruyter.
- Pereira, F., & Cardoso, A. (2002). Conceptual blending and the quest for the holy creative process. *Workshop on Creative Systems*, 5–8. Retrieved from <http://www.lsi.us.es/iberamia2002/confman/SUBMISSIONS/86-rapereicoc.pdf>
- Peters, M. (1998). Towards artificial forms of intelligence, creativity, and surprise. *Proceedings of the Twentieth Annual Conference of the Cognitive Science Society* (pp. 836–841).
- Purves, D., Brannon, E. M., Cabeza, R., Huettel, S. A., LaBar, K. S., Platt, M. L., & Woldorff, M. G. (2008). *Principles of cognitive neuroscience* (Vol. 83). Sinauer Associates Sunderland, MA.
- Qualtrics LLC. (2015). Qualtrics. Retrieved May 1, 2015, from <http://www.qualtrics.com>
- Salamoni, A. (2012). Open Card Sort Analysis 101. Retrieved from <http://www.uxbooth.com/articles/open-card-sort-analysis-101/>
- Saygin, A., Cicekli, I., & Akman, V. (2003). Turing Test: 50 Years Later. In J. Moor (Ed.), *The Turing Test SE - 2, Studies in Cognitive Systems* (Vol. 30, pp. 23–78). Springer Netherlands. Retrieved from [http://dx.doi.org/10.1007/978-94-010-0105-2\\_2](http://dx.doi.org/10.1007/978-94-010-0105-2_2)
- Spencer, D. (2009). *Card Sorting: Designing Usable Categories*. New York: Rosenfield Media.
- Van der Velde, F., & Nazareth., D. S. (2015). Mappings between semantic space and geometrical conceptual space. Deliverable 8.3: ConCreTe.
- Van der Velde, F., Wolf, R., Schmettow, M., & Nazareth., D. S. (2015). A Semantic Map for Evaluating Creativity. *The Sixth International Conference on Computational Creativity*. Park City, Utah, USA.
- Wikipedia. (2015). Jeopardy! - Wikipedia. Retrieved July 21, 2015, from <https://en.wikipedia.org/wiki/Jeopardy!>
- Wood, J. R., & Wood, L. E. (2008). Card Sorting : Current Practices and Beyond. *Journal of Usability Studies*, 4(1), 1–6.