Conceptual Learning:
The Investigation of Brain Region Effect on Representative Concept Categorisation

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Bachelor Thesis

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Abstract

This study investigates semantic categorical representations in the brain and takes a closer look at how different brain regions might influence the way in which semantic categories are cognitively represented. Cognition controls a large part of what we can perceive of the world. Through various input and stimuli, we learn about this complex world to make sense of our environment. Cognition is largely influenced by what is described as concepts. Conceptual categorisations reduce the complex world and its systems to an amount that is comprehensible for us. In this study, a card-sorting task and a questionnaire were used to investigate the relationship of concepts and their representation in the brain, based on the brain map established by Huth et al. (2016). More specifically, it was tested whether the representation of concepts in the brain as provided by Huth et al. (2016) could be compared to the grouping of concepts during the card sorting task. In addition, the different representation in distinct brain regions was examined, specifically, differentiated into semantic categorization in the anterior cortices versus posterior cortices and left versus right brain hemisphere. The findings showed that the representation of conceptual categories established by Huth et al. (2016) could be replicated to some extent. However, it was demonstrated that no difference in conceptual representation based on the distinctive brain regions could be established through the card sorting task.

Keywords: semantic categorical representation, conceptual categorisation, card sorting, brain map

Table of Contents

1. Introduction

''A concept is sense, it is sometimes psychological, sometimes logical, and sometimes perhaps a confused mixture of both.'' (Frege, 1951)

Lang (1985) defined cognition as the symbolic processing of certain information that is entering the brain. To be able to fully understand this information and its meaning, this information needs to be reduced to an understandable degree (de Mattos, 2014). This is achieved through symbolic representation, which is the necessary foundation for central processing as well as planned actions or responses (Harnad, 2017; Lang, 1985). Symbolic representation categorises information in the form of concepts (Peacocke, 1992). Constituting a sub-category of symbolic representation, this leads to the notion of learning concepts as a tool to reduce information to a comprehensible level.

Zeithamova et al. (2019), defined conceptual learning as the process in which experiences become represented by generalised concepts. This process of acquiring concepts is hence-forth labelled as cognitive categorisation. Cognitive categorisation is a crucial aspect of cognition (Zeithamova et al., 2019). To explain cognitive categorisations two distinct perspectives can be used, namely *the exemplar model* and *the prototype model*. The exemplar model explains that different categories are represented by *one* specific category that an individual has encountered over time. The representative categories are defined by *exemplars*, for example, memories that are afterwards labelled with their category name (Murphy, 2016; Rouder & Ratcliff, 2006; Zeithamova et al., 2019). To specify, concepts are represented by comparing a new stimulus with a previous experience the individual has encountered earlier on. This experience is saved in the memory as an *exemplar* and afterwards is categorised based on the similarity of exemplars in an existing category (Nosofsky, 2011). The prototype model, on the contrary, implies that categories are being represented by a *universal* overarching category representation that is abstractly used beyond *exemplars* (Zeithamova et al., 2019). This means, various categories are summarised as a whole based on similar properties found in the afore-mentioned category (Murphy, 2016). As the exemplar model assumes that this descriptive summary of a category is not needed, the exemplar and prototype models differentiate the categories in terms of exemplary memories and summary representations, respectively.

A large part of cognitive categorisations is related to semantics. Semantics provide a wide-ranged array of knowledge, from simple concepts such as shapes and patterns to complex insights like self-awareness (Martin, 2007). Semantics, in this case concepts, are part of larger categorical representation. Meaning that a concept is more prominent in a category than others, therefore building a semantic prototype. (Lemmens, 2015). Here, cognitive semantics describe the use of words or mental image to represent concepts and categories (Coseriu et al., 2000; Geeraerts, 2004; Taylor, 2013). Cognitive semantics, therefore provide a method of conceptualisation on an encyclopaedic basis (Lemmens, 2015). Semantic cognition plays an important role in enabling persons to make sense of non-verbal and verbal cues experienced in a social context (Maddox & Ashby, 2004). Research conducted by Ralph et al. (2017) supported the above-indicated notion of cognitive categorisation on a semantic basis. In turn, when presented with a different stimulus the semantic system is shaped by strengthening and building categorisations and semantic relationships. (Ralph et al., 2017). While cognitive categorisations explain the building of concepts, Ralph et al. (2017) additionally described the adaptation of categorisation to an immediate situation and external stimuli. Therefore, as described by Zeithamova et al. (2019), semantic cognitive categorisation is the overarching ability to derive and highlight meaning across various experiences.

This is connected to current cognitive research and neural networking models. Contemporary research into the meaning of concepts in the brain is focused on semantic cognition. Thereby, different brain mechanisms and regions were shown to play a role in cognitive categorisation (Zeithamova et al., 2019). The hippocampus and the hippocampal functions offer different toolsets for building new concepts in the brain. The anterior cortex encodes new information connected to previous life experiences, showing its close interrelationship to exemplar and prototype modelling of concepts (Zeithamova et al., 2019). On the other hand, Zeithamova et al. (2019) demonstrated that the posterior cortex contains stimulus-specific and categorical memory representations showing how differently the representation of cognitive categorisations might be divided in the brain. Additionally, while brain imaging, like fMRI, plays a large role in the investigation of semantic cognition, today's research focuses on the representation of semantic content through neuro-representative maps (Ralph et al., 2017; Whitney et al., 2010). In line with this, to investigate the relationships of categorisations and the representational network of the brain, Huth et al. (2016) aimed at establishing how concepts and their categories are represented over the brain.

Concretely, Huth et al. (2016) investigated the cerebral cortex and where representations of certain semantic categories can be viewed. Participants were asked to listen to various narratives of natural language in order to build a map of the selective activity of various semantic categories. Using the fMRI data of seven participants, it was shown that there is a specific pattern of various semantic categories building a semantic system (Huth et al., 2016). Based on this, Huth et al. (2016) built a virtual representation of the brain, where semantic knowledge of conceptual categories is represented. The semantic representation in the brain was divided into eleven semantic categories. These are namely, *visual, bodypart, number, outdoor, social, personal, place, mental, violent, tactile, and time* (see Table 1). These eleven categories were divided into two smaller categories. The first category consists of conceptual categories that are more prominent in the anterior cortices of the brain, like *social, personal, mental, violent, and time*. The second category containing conceptual categories being more prominent in the posterior cortices such as *tactile, visual, number, bodypart, outdoor, and place* (Huth et al., 2016).

Table 1

Semantic Categories Identified by Huth et al. (2016)

Categories

Semantic Categories	Brain Location
Visual	Posterior Cortex
Bodypart	Posterior Cortex
Number	Posterior Cortex
Outdoor	Posterior Cortex
Social	Anterior Cortex
Personal	Anterior Cortex
Place	Posterior Cortex
Mental	Anterior Cortex
Violent	Anterior Cortex
Tactile	Posterior Cortex
Time	Anterior Cortex

1.2 Current Study

The main aim of the present study is to investigate, based on brain activation, if active categorisation differentiates from passive listening, by using the categorisation of concepts. The cortical distribution of semantic categories established by Huth et al. (2016) offers unprecedented insights into processing of semantic information. This study, wants to explore if a similar semantic landscape emerges when participants actively categorise concepts as opposed to passively receiving input (for example passive listening), as done by Huth et al. (2016). Drawing from anatomical co-clustering of semantic categories (Huth et al., 2016), such as between the anterior/posterior cortices or the left/right hemispheres, the present study investigates whether such patterns likewise appear during active categorisation.

To investigate these differences of cognitive categorical representation, a card-sorting task was chosen for the organisation of the different words into categories. A card-sorting task was chosen, to investigate the participants knowledge structure, in case of this study their conceptual knowledge. This study entails two complementary assessment methods: firstly, the card-sorting study to investigate the representations of cognitive categorisation in the brain and, secondly, a questionnaire to investigate how the category names as provided by Huth et al. (2016) relate to the concepts inside that specific category. The link to the overarching category was similarly based on the brain map provided by Huth et al. (2016). Derived from the brain map by Huth et al. (2016), fifty words were picked from six of the eleven conceptual categories (see Table 2; Appendix B) and built the basis for the semantic card-sorting study and the questionnaire.

Table 2

Words Identified in the Chosen six Semantic Categories, and their Brain-Location According to the Brain Map from Huth et al. (2016)

Word Map

Word	Category	Brain Location
evenly	visual	Right Hemisphere/ Anterior
items	visual	Right Hemisphere/ Anterior
shaped	visual	Left Hemisphere/ Anterior
top	visual	Right Hemisphere/ Posterior
thinner	visual	Left Hemisphere/ Posterior
thick	visual	Left Hemisphere/

		Anterior
powdered	visual	Left Hemisphere/ Anterior
round	visual	Right Hemisphere/ Posterior
stripes	visual	Left Hemisphere/ Posterior
plus	number	Right Hemisphere/ Anterior
quarter	number	Right Hemisphere/ Posterior
fifty	number	Right Hemisphere/ Posterior
annual	number	Left Hemisphere/ Posterior
pounds	number	Left Hemisphere/ Anterior
minimum	number	Right Hemisphere/ Anterior
seven	number	Right Hemisphere/ Anterior
order	number	Left Hemisphere/ Anterior
male	bodypart	Right Hemisphere/ Posterior
female	bodypart	Left Hemisphere/ Anterior
breast	bodypart	Left Hemisphere/ Posterior
flesh	bodypart	Left Hemisphere/ Anterior
hips	bodypart	Right Hemisphere/ Anterior
bank	place	Left Hemisphere/ Anterior
bedroom	place	Right Hemisphere/ Anterior
house	place	Right Hemisphere/ Posterior
stadium	place	Left Hemisphere/ Posterior
shop	place	Right Hemisphere/ Anterior
motel	place	Right Hemisphere/ Anterior
apartment	place	Left Hemisphere/ Anterior
home	place	Left Hemisphere/ Posterior
restaurant	Place	Right Hemisphere/ Posterior
School	Place	Right Hemisphere/ Posterior
murdered	Violence	Right Hemisphere/ Anterior
Cruel	Violence	Left hemisphere/ Anterior
Crime	Violence	Left Hemisphere/

		Posterior
Cursing	Violence	Right Hemisphere/ Posterior
Innocent	Violence	Right Hemisphere/ Anterior
Guilty	Violence	Left Hemisphere/ Anterior
Confessed	Violence	Left Hemisphere/ Posterior
Killed	Violence	Right Hemisphere/ Posterior
Abuse	Violence	Right Hemisphere/ Anterior
Victim	Violence	Left Hemisphere/ Anterior
Years	Time	Right Hemisphere/ Anterior
Week	Time	Left Hemisphere/ Anterior
Times	Time	Left Hemisphere/ Anterior
Month	Time	Right Hemisphere/ Posterior
Days	Time	Right Hemisphere/ Anterior
Next	Time	Left Hemisphere/ Anterior
Date	Time	Left Hemisphere/ Posterior
Since	Time	Right Hemisphere/ Posterior

To investigate how cognitive categorisation is reflected in a card-sorting task, a set of research questions is formulated. The first research question considers the general categorisation of words in the card-sorting study. Thereby, it is examined whether the cognitive categorisation of words matches the categorisation that is outlined in the brain-map by Huth et. al (2016): *''Does the cognitive categorisation of words by participants relate to the semantic representation in the brain as depicted by Huth et al. (2016)''*

The second set of research questions considers a more specific hypothesis to investigate representational differences when it comes to words taken from a specific brain region from the Huth et al. (2016) brain map. Thereby, it is examined whether a different strength of representation of words into categories is achieved in different regions of the brain: *''Do words obtained from the left-brain hemisphere show different cognitive categorical representativeness to their original semantic category than words from the right-brain hemisphere?''* and *''Do words obtained from the anterior cortices' show different cognitive categorical representativeness to their original semantic category than words from the posterior cortices?''*

The last research question relates to the questionnaire as a complementary part of the study. Thereby, it is examined whether the questionnaire can support observed findings of the card-sorting task and, more importantly, if the findings of Huth et al. (2016) regarding cognitive categorisation of semantics can be reproduced: *“Do the Likert scores obtained in the questionnaire support the findings on semantic representation in the brain according to Huth et al. (2016)?”*

2. Methods

2.1 Participants

This study has obtained ethical approval from the ethics committee of the BMS (Behavioural-Management-Social) faculty. Participants were provided with a consent form which they had to accept and sign in advance to the study (see Appendix A). The participants of this study (*n=30*) were approached via an online sampling tool called "SONA". This tool provided by the University of Twente purposefully draws students from the BMS department to take part in studies. Any participant that was not approached through the SONA-system was approached personally and asked to participate in the study. Thirty participants with an average age of 20.93 (*SD= 2.6*) were sampled and took part in the study. The oldest participant was thirty years of age, while the youngest was eighteen years of age. The participants were of diverse nationalities, while the majority of them was from Germany (*China= 3.3%, Dutch= 20%, Germany= 63.3%, Mexican= 3.3%, Romania= 6.7%, South Korea= 3.3%*). Furthermore, eighteen of the thirty participants were female *(60%)* and twelve of the thirty participants were male *(40%)* (see Appendix C).

2.2 Measures

The study consists of two complementary measures: A card-sorting task and a questionnaire. The card-sorting task is made up of fifty concepts with the task of sorting them into clusters. The questionnaire contains seventy items to investigate the relationship of words with their respective conceptual semantic category. Twenty of these seventy items are filler concepts. These fillers were chosen at random and in an arbitrary manner in order to provide a control group to the original six categories.

2.3 Design

2.3.1 Card-Sorting Design

A card sorting study as described by Schmettow and Sommer (2016) is a research method to investigate various knowledge models a person can have which, in this study, targets conceptual knowledge. While card-sorting can be hierarchical, this study conducts the card sorting on only the first level. Non-hierarchical card-sorting was used due to the Covid-19 pandemic. The study had to be conducted online, where multi-level card-sorting would not have been implementable. This first level of card-sorting is used to assess the semantic categorisation of concepts by participants (Schmettow & Sommer, 2016). The card-sorting task itself follows a free approach in so far that participants were asked to sort different words into categories without any more specific instruction. Not providing a specific instruction, participants could make use of their inherited assumptions of similarity and relationships.

2.3.2 Questionnaire Design

The use of a complementary questionnaire was important to this study to understand the perceived relatedness of the words with their original semantic conceptual category. In that sense, participants were asked to assess the relationship of a word to a higher-level category on a five-point Likert scale, ranging from one to five (1= weak relation, 2= somewhat weak relation, 3= average relation, 4= somewhat strong relation, 5= strong relation) This is derived from the original scaling which usually entails a range of five points from "strongly agree'' to "strongly disagree''. (Allen, 2007; Burns, 2008; Joshi et al., 2015). Likert scales are a widely used psychometric tool in order to investigate various factors in social sciences (Joshi et al., 2015). In the present study, such scales were used to investigate the participants' understanding of how a word relates to its original semantic category.

2.4 Materials

2.4.1. General Materials

General materials used in this study were the online survey tool ''Qualtrics''. It was used to code, compute and disseminate the card-sorting task as well as the questionnaire. Furthermore, at the beginning of the study, the informed consent was provided to ensure ethical correctness. Additionally, a small array of questions was asked to gather demographic data for example to determine gender or nationality (see Appendix A). The study was conducted online on a medium chosen by the participants.

2.4.2 Card-Sorting Task Materials

The online brain map provided by Huth et al. (2016), a 3D model of the human cortex, was used to gather the semantic stimuli for the card sorting task. This brain map provides eleven different coloured conceptual categories represented all over the cortex. Each specific point on the brain map has a specific voxel, a three-dimensionally specified location (Huth et al., 2016). For the card-sorting task, fifty words were specified from six of the eleven semantic categories (see Table 2). To answer the second set of research questions, it was important that words were sampled equally from the right and left-brain hemisphere as well as the anterior and posterior cortices. In order to provide the card-sorting study, a clustering task was coded in ‘’Qualtrics’’, an online research tool provided by the BMS Lab. In specific, sixteen different clusters were provided in which people could freely and to their own satisfaction sort the fifty words into categories.

2.4.3 Questionnaire Materials

The questionnaire made use of the same fifty words that were deployed in the card-sorting study and was deployed through the online survey tool “Qualtrics”. Taken from Huth et al.’s (2016) semantic categories of *“time”, “place”, “violence”, “bodypart”, “number”,* and *“visual’”,* each of these fifty words were then paired with the original semantic category it was derived from. In this way, participants could be asked to assess the relationship between each word and its original category. Additionally, based on the brain map provided by Huth et al. (2016) twenty filler items were deployed (see Appendix B). The filler items were chosen at random from categories not related to the above-mentioned ones. The items were selected to be used as a control group. Within the questionnaire, questions were formulated to address the relation of each word to its semantic category *(“How strong does the word evenly relate to the concept of “Visual”?).*

2.5 Procedure

2.5.1 General Procedure

After clicking on the provided link to the study on "Qualtrics", the study and its goals were explained to the participants. Participants were then asked questions regarding their consent to take part in the study. If they answered every question with yes, they signed off on the consent form and were ready to begin the study. Afterwards, the participants were asked questions to assess demographic information, namely, age, gender, and nationality (see Appendix A).

2.5.2 Card-Sorting Procedure

After answering the demographic questions, the participants were shown fifty words that were deployed from the Huth et al. (2016) brain map (see Appendix B). People were asked to sort these fifty words into different categories. To build these categories, sixteen empty clusters were provided. The participants were informed they did not require all sixteen clusters and that it was not necessary to rank words hierarchically inside the clusters. Next, participants were asked to start the card-sorting by freely sorting the fifty words into perceived categories. Since this study was conducted in an online format, a multiple level hierarchical card sorting was not implementable so that participants were only asked to sort the fifty words into categories once.

2.5.3 Questionnaire Procedure

After completing the card-sorting task, the participants were asked to complete the seventy-item long questionnaire to the best of their ability. In specific, the participants were asked to rank the relation between a word and its original semantic conceptual category, on a Likert scale from one to five. Upon completion of the final question, participants were thanked for their participation and instructed to contact the researcher if any questions or concerns would arise later.

2.6 Data Analysis

2.6.1 Demographics Data Analysis

To analyse the demographics, the data provided by the participants was transcribed into a data matrix. The contents of this data matrix were afterwards analysed using frequency analysis to gain information about the means, standard deviation, minimum, and maximums. Furthermore, percentages were calculated through frequencies to gain a better understanding of the data.

2.6.2 Card-Sorting Data Analysis

The data of all thirty participants were used in the analysis of the card-sorting study. The following procedures were used to analyse the data of the card-sorting task. Firstly, the data obtained from the task sorting task was translated to Jaccard scores and written down in a table. A Jaccard score was used to identify semantic clusters on the basis of the card-sorting task to provide a measure for relatedness or similarity. A Jaccard score of *1* indicated a measure of relatedness, while on the other hand a Jaccard score of *0* indicated no similarity. This way the categorisation of the words can be analysed.

By doing this, a data matrix is computed with all scores for the fifty words on the x-axis as well as the y axis. Thus, every possible combination of words was calculated in the matrix. Providing scores in the rows as well as columns making the table symmetrical. This was implemented for each individual participant.

This provided thirty individual data matrixes featuring the Jaccard scores. For ease of analysis, the average of the Jaccard scores was calculated across all tables leaving us with one data matrix of averaged Jaccard scores.

Using this averaged data matrix of the Jaccard Scores a heatmap and a dendrogram were drawn by using cluster analysis. The cluster analysis provided the relatedness between words by calculation the Euclidean distance across them.

Analysing the cognitive categorisation of the different words even further and to support the findings of the heatmap a new data matrix was computed listing all, previously averaged, Jaccard scores of the concepts in the six categories namely "visual", "bodypart", "number", "time", "violence", and "place". After a simple descriptive analysis, a UNIANOVA was calculated between each subject.

For the analysis of the specific research question namely, the difference in brain location, a third data matrix was computed listing the average Jaccard scores from each concept of the six categories "visual", "bodypart", "number", "time", "violence", and "place", in a new category related to brain location. Namely, the left- and right brain hemisphere and further, posterior and anterior cortices. Based on that data matrix again frequencies were calculated, as well as a between-subject analysis (UNIANOVA) between each category.

2.6.3 Questionnaire Data Analysis

To analyse the questionnaire the response data was downloaded from "Qualtrics" in a CSV format. The data however was still in text format which needed to be adjusted. Therefore, a data matrix was created including all the responses. These responses were then recoded to give them a numerical value. Afterwards, the average of each category response and an overall average were calculated for the questionnaire (e.g., MeanVis; MeanFIll). Next, the average scores were analysed using frequency analysis. For further analysis, new variables for the cortex areas and hemispheres were calculated (e.g., AvgAnterior; AvgLeft). A frequency analysis was conducted with the average scores to analyse the amount of relatedness the words have to their original semantic category as described by Huth et al. (2016).

3. Results

3.1 Semantic Categorization of Words

The first research question asked whether *cognitive categorization of words by participants relates to the semantic representation in the brain as depicted by Huth et al. (2016).* The results of the heatmap analysis (HMA) and dendrogram can be seen in Figure 1 and Table 2. The dendrogram shows word relations by length and shortness of clusters as well as connectivity, while the HMA deisplays the degree of similarity by colour (*red= high similarity; yellow= low similarity*). The HMA and dendrogram display six distinct clusters the card-sorting task build, making it comparable to the original study by Huth et al. (2016). Accordingly, the results of the HMA provide a high similarity *(=red colour*) in the semantic conceptual categories of ‘’violence’’, ‘’time’’, and ‘’place’’. A lower similarity *(=yellow colour*) can be seen in the conceptual categories of ‘’visual’’, ‘’number’’, and ‘’bodypart’’. The dendrogram confirms these findings by expressing six overarching clusters (see Figure 1). The clusters one, two, and three show a high relational cluster, with large cluster categories. Cluster five additionally displays adequate relational value. However, the clusters four and six show lower overall similarity. Comparing this to the original categorical clusters provided by Huth et al. (2016), cluster one, two, and five are identical to their original semantic category (see Table 2 & Table 3). Cluster one represents the complete conceptual category of ´´Violence´´, the second cluster is identical to the semantic category of ´´place´´. Furthermore, cluster five represents the conceptual semantic category of ´´bodypart´´. Comparing cluster three to its original semantic category of ´´time´´ it shows that the cluster is represented quite well, however it is mixed with words from the category ´´number´´ like *annual, fifty, seven* and *quarter.* Additionally, the word *next* is categorised into cluster four. Discussing the cluster four and six, they don’t represent their original semantic category and seem to be mixed to high degree. This shows how these clusters are arbitrary to their original semantic categories making an interpretation of the results difficult. Consulting the heatmap, it shows that these arbitrary clusters instead built smaller clusters inside the respective clusters. These smaller clusters even display high similarity with combinations like the words *breast and hip*. Another example of one of these small high relational clusters are the words *thick and thinner,* or *male and female*. The analysis further shows that the semantic categories of ‘’time’’ and ‘’number’’ are intertwined in their similarity. While ‘’time’’ is building a strong distinct cluster, the conceptual category of ‘’number’’ is represented to a high degree in the cluster of “time”. As mentioned above, the words *quarter, fifty, seven* and *annual* are sorted in cluster three representing “time”. This suggests that the two clusters are intertwined with one another. The only words remaining related to ‘’number’’, namely the words *minimum and plus* are sorted into category four, building an arbitrary cluster with other words from the card-sorting task like *items, powdered, stripes* and *evenly.*

Table 3

Results of the Clustering Analysis

Cluster

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6
Cursing	Bedroom	Quarter	Items	Male	Pounds
Innocent	Home	Fifty	Powdered	Female	Shaped
Confessed	Apartment	Seven	Stripes	Flesh	Round
Guilty	House	Since	Order	Breast	Thick
Abuse	Bank	Date	Next	Hips	Thinner
Cruel	School	Times	Top		
Victim	Shop	Annual	Evenly		
Murdered	Stadium	Years	Plus		
Crime	Motel	Week	Minimum		
Killed	Restaurant	Month			
		Days			

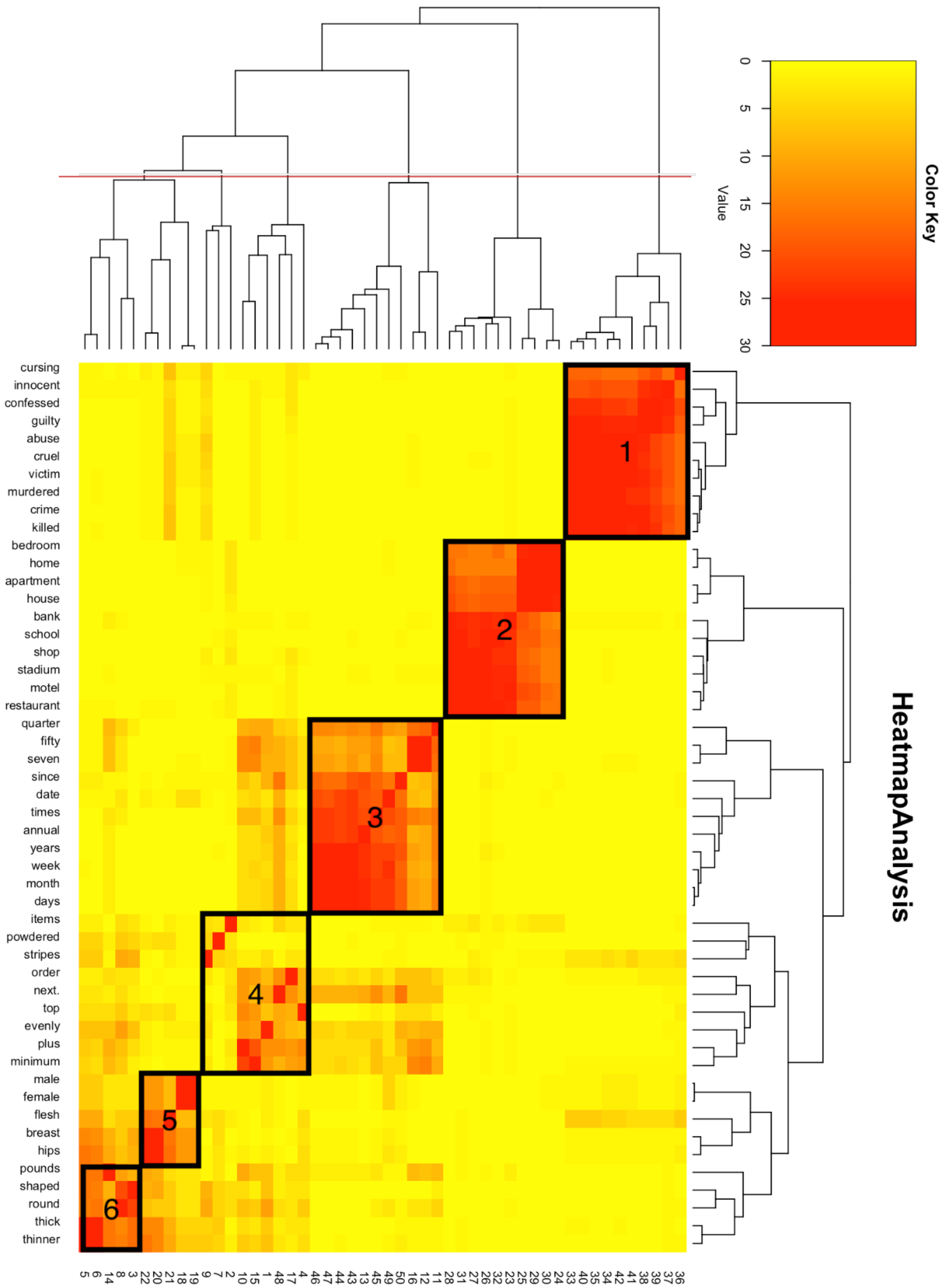

Figure 1. Heatmap & Dendrogram Representation of Clusters and Similarity.

To confirm these findings, a descriptive analysis, as well as a between-subject design (UNIANOVA) of the categories, was performed.

A descriptive analysis of the Jaccard scores (see Table 4) of the individual categories has shown that there is variation between the Jaccard scores displaying conceptual relatedness within the clusters provided by Huth et al. (2016). Noteworthy, the analysis has shown that ‘’violence’’ displayed the highest intra-category similarity, meaning “violence” has shown the highest Jaccard scores of concepts within their category, from all the categories (*M= 23.49, SD= 4.21)*. The conceptual category ‘’visual’’ meanwhile displayed the lowest intra-categorical similarity (*M= 7.2, SD= 5.92).* The descriptive analysis confirmed the above-mentioned findings of the high similarity clusters with the category of ‘’place’’ displaying a mean of 21.24 (*SD= 4.82)* and the semantic category of ‘’time’’ showing a mean value of 19.96 (*SD= 6.59).*

Table 4

Descriptive Analysis of the Average Jaccard Scores

Descriptives Category

	N	Minimum	Maximum	Mean	Standard Deviation
Visual	35	1	28	**7.2**	**5.92**
Number	28	2	27	10.18	5.66
Bodypart	10	8	29	15.4	7.47
Place	45	14	29	**21.24**	**4.82**
Violence	45	17	37	**23.49**	**4.21**
Time	28	9	29	**19.96**	**6.59**
Valid N (listwise)	10				

Additionally, to support the findings of the HMA and the Dendrogram a UNIANOVA between each category (e.g., "visual") and the remaining categories (e.g., "number", "bodypart", "place", "violence", and "time") was conducted to investigate any similarity or contrast of the average Jaccard scores, to account for any interrelatedness or mixing of the words between conceptual semantic categories. (see Table 5). The only noteworthy finding was a significant relationship between the semantic conceptual categories “time” and “number” [*F(1, 5) = 8.15, p= .046*]. This confirmed the results shown in the heatmap and dendrogram supporting an interrelatedness between the two categories, meaning words from the cluster of “number” are most likely represented within the category of “time”.

Table 5

Test of Between-Subjects Effect

Dependent Variable Number

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	162.13	5	32.43	2.95	0.16
Intercept	0.54	1	0.54	0.05	0.84
BPart	10.30	1	10.30	0.94	0.39
Place	19.35	1	19.35	1.76	0.26
Violence	7.76	1	7.76	0.71	0.45
Time	89.62	1	89.62	**8.15**	**0.05**
Visual	3.74	1	3.74	0.34	0.59
Error	43.97	4	10.99		
Total	1575	10			
Corrected Total	206.1	9			

a. *R Squared = 0.79 (Adjusted R Squared = 0.52)*

3.2 Representation of Semantic Categories in Brain Regions

The second set of research questions investigate whether the brain region affects the representation of cognitive categorical similarities in the different clusters. It was assessed whether *words obtained from the left-brain hemisphere show different cognitive categorical representativeness to their original semantic category than words from the right-brain hemisphere* and whether *words obtained from the anterior cortices’ show different categorical representativeness to their original semantic category than words* *from the posterior cortices.* A frequency analysis of Jaccard scores relating to the selected brain regions was conducted (see Table 6).

The analysis showed that the four brain regions present similar Jaccard score averages, suggesting there is no large difference within the four selected regions, namely the anterior cortices, the posterior cortices, the right-brain hemisphere, and the left-brain hemisphere. The analysis of the Jaccard scores derived from the left-brain hemisphere provided a mean score of 95.63 (*SD= 53.68*), the results of the right-brain hemisphere has shown a mean score of 101.63 (*SD= 54.87*). Comparing the Jaccard averages of the anterior and posterior cortex a mean score of 104.75 (*SD= 54.81*) was displayed for the posterior cortices. The anterior cortices displayed a mean of 92.50 (*SD= 53.19*).

Table 6

Frequency Analysis of the Brain Regions

Frequencies

		Left Brain Hemisphere	Right Brain Hemisphere	Anterior Cortices	Posterior Cortices
N	Valid	24	24	24	24
	Missing	0	0	0	0
Mean		**95.63**	**101.63**	**104.75**	**92.50**
Std. Deviation		**53.68**	**54.87**	**54.82**	**53.19**
Minimum		17	2	23	2
Maximum		200	216	216	176
Sum		2295	**2439**	**2514**	2220

Lastly, a UNIANOVA between the brain regions was conducted to investigate any significant similarity or contrast between the Jaccard scores, in order to account for any relation of values between the cortices and hemispheres. However, as predicted, since the words provided in each region are chosen partly from the same semantic conceptual categories, provided by the Huth et al. (2016) brain map, none of the brain regions has shown a significant semantic relation with each other (see Table 7).

Table 7

Significance (p-values) of all the Between-Subject Design Analyses

P-Value

	Left Brain Hemisphere		Right Brain Hemisphere		Anterior Cortex		Posterior Cortex	
	Sig.	F	Sig.	F	Sig.	F	Sig.	F
Left Brain Hemisphere								
Right Brain Hemisphere	**0.88**	**0.02**						
Anterior Cortex	**0.40**	**0.72**	**0.41**	**0.72**				
Posterior Cortex	**0.86**	**3.27**	**0.54**	**0.39**	**0.71**	**0.14**		

3.4 Results Questionnaire

To confirm the results of the card-sorting task and investigate the representative correctness of the study conducted by Huth et al. (2016), a third research question assessed whether *the Likert scores obtained in the questionnaire support the findings on semantic representation in the brain according to Huth et al. (2016).*

Firstly, a frequency analysis of the average Likert scores for each semantic category was conducted (see Table 8). The minimum average Likert score derived from the questionnaire was produced by the conceptual semantic category “visual” (*M= 3.33, SD= 0.52*). The category with the highest average Likert score was “place” with an average of 4.53 (*SD= 0.64*). Overall, the questionnaire has shown that the relation between the various words to their original semantic category was considered rather high. It supports the findings from the card-sorting study by showing that “visual” as a category has low relational value, while the categories “place”, “time” (*M= 4.57, SD= 0.34*) and “violence” (*M= 4.35, SD= 0.51*) have higher similarity value when it comes to categorical representativeness.

Overall, the results moreover, supported the findings of Huth et al. (2016), since each of the individual provided, clusters were represented to a large extent by the Likert scores of the questionnaire.

Table 8

Frequency Analysis of the Average Likert Scores Derived from the Questionnaire

Frequency

		Visual Average	Number Average	Bodypart Average	Place Average	Violence Average	Time Average	Filler Average
N	Valid	32	31	32	32	32	32	32
	Missing	0	1	0	0	0	0	0
Mean		**3.33**	4.00	3.71	**4.53**	**4.35**	**4.57**	3.4
Std. Deviation		**0.52**	0.46	0.72	**0.64**	**0.51**	**0.34**	0.45
Minimum		2.22	3.00	2.60	2.20	2.80	3.50	2.65
Maximum		4.33	4.88	5.00	5.00	5.00	5.00	4.25
Sum		106.61	124.13	118.80	144.81	139.20	146.36	108.77

To investigate the support of the findings for the second set of research questions, another frequency analysis was conducted. Thereby, the relational value produced in the questionnaire was discussed for each brain region, namely, the left versus right brain hemisphere and the anterior cortices versus posterior cortices.

The analysis has shown that the relational value of words produced by differentbrain regions is quite similar scores across the spectrum (see Table 9). Considering the right versus the left-brain hemisphere, the right hemisphere produces an average Likert score of 4.20 (*SD= 0.37*) which is just slightly higher than the left hemisphere (*M= 4.03, SD= 0.43*). Discussing the relational values between the anterior and posterior cortices the findings are quite similar. The posterior cortex (*M= 4.16, SD= 0.41*) produces just a slightly higher score than the anterior cortex average which has shown an average value of 4.08 (*SD= 0.37*).

Overall, it was shown that the relational value of the words derived from the specific brain location compared to their original semantic conceptual category does not seem to vary largely. Only slightly higher scores were found concerning the posterior cortices (*Sum= 132.99*) and the right-brain hemisphere (*Sum= 134.39*).

Table 9

Frequency analysis of the relation between words derived from different brain regions in the Huth et al. (2016) brain map and their original semantic category.

Frequency

		Anterior Average	Posterior Average	Left-Brain Average	Right-Brain Average
N	Valid	32	32	32	32
	Missing	0	0	0	0
Mean		**4.08**	**4.16**	**4.03**	**4.20**
Std. Deviation		**0.37**	**0.41**	**0.43**	**0.37**
Minimum		3.19	3.00	3.09	3.20
Maximum		4.82	4.76	4.71	4.77
Sum		130.47	**132.99**	128.91	**134.39**

4. Discussion

The current study aimed at investigating whether the cognitive representation of semantic categories as described by Huth et al. (2016) can be replicated and to explore whether active categorisation of words provides a similar semantic landscape in comparison to passive listening. Furthermore, the study examined the cognitive categorical similarity of words derived from different brain regions, in accordance with the brain map provided by Huth et al. (2016). Established in the study by Huth et al. (2016), eleven different categories in accordance with semantic selectivity were provided. Six of these semantic categories were chosen to investigate the difference in cognitive categorical similarity and the influence of the brain location on this categorisation of semantics. This formed the basis for the card-sorting task and questionnaire implemented in this study.

4.1 Discussion Card-Sorting

The card-sorting task was used to investigate whether i) cognitive categorization and their semantic representation as provided by Huth et al. (2016) can be replicated and ii) differences in similarity cluster on the basis of brain location can be found.

Considering the first investigation, the semantic structure demonstrated by Huth et al. (2016) was replicated to a certain extent. Specifically, four of the six clusters established by Huth et al. (2016) could be reproduced in the current study. These clusters consisted of "*violence", "time", "place"* and "bodypart". However, two clusters namely "visual" and "number" could not be replicated. These two arbitrary clusters suggest that there are differences between cognitive categorical representation between the six clusters derived from Huth et al. (2016). Based on these findings, Huth et al.'s (2016) semantic conceptual categories could only be replicated partly. Showing that through the active categorisation of concepts a partly similar semantic landscape is build compared to a passive input of semantic stimuli.

An interesting point regarding the cluster of "number" was its relationship to the cluster of "time". More specifically, words that are considered part of the semantic category of "number" like *seven, fifty, quarter,* and *annual* were repeatedly sorted into the category of time. This suggests that the clusters of "number" and "time" are intertwined. Therefore, in the card-sorting task, the similarity of both clusters in terms of numerical components seems to be of relevance.

This might be further explained by taking into account the different exemplars. The reason for words such as *years* and *fifty* to appear in the same cluster, rather than separate clusters, might be that concepts like *fifty,* appear in the most representative cluster after sorting different words previously. While *fifty* and *seven* might appear as an atypical example of the concept “time”, since they belong to the cognitive semantic category of “number”, it might still be the most representative category after taking into account previous exemplars (Coxon, 1999).

The high similarity inside the categories of "violence", "place", “bodypart” and "time" suggests that the conceptual learning categories defined by Huth et al. (2016) can partly be replicated, based on the sorting of words chosen from overarching semantic concepts. The replication of clusters indicates that semantically structured learning takes place while forming various groups based on own personal understanding, or on similar experiences with *exemplars* earlier on (Coxon, 1999; Rouder & Ratcliff, 2006). However, two categories that could not be replicated. They were instead intertwined with one another and built arbitrary clusters. This suggests that the chosen fifty words could have been influenced by prior experiences of the participants with the chosen words concerning different conceptual categories. In accordance with Clapper (2012), these prior experiences might have led to the mixing of clusters or the building of arbitrary clusters.

Moreover, Medin (1989) argued that there are major problems in describing a conceptual semantic categorisation in terms of their similarity. Specifically, showing actual conceptual similarity within categories was described as too unconstrained, potentially explaining why some categories might have shown stronger similarity inside their respective clusters (Medin, 1989).

Discussing the second part of the investigation, a significant role of brain location in cognitive categorization could not be shown. The analysis has shown that only small differences can be identified between the brain regions, specifically, the anterior cortices, the posterior cortices, the left-brain hemisphere, and the right-brain hemisphere. However, looking at the results in detail, it could be argued that the right-brain hemisphere, as well as the anterior cortices, provide a higher intra-categorical relatedness of concepts. And therefore, take influence on the categorical representativeness of concepts in cognition.

In terms of the relational value of clusters for different brain regions, it was shown that the brain regions did not have a large effect on the relational similarity of conceptual clusters. Therefore, brain location by itself showed no difference in similarity. This means semantics derived from a specific brain region were not shown to contribute to the value of cognitive categorisation of concepts. This is surprising as Zeithamova et al. (2019) suggest differences in brain region when it comes to cognitive categorisation.

This might be the case since the categories might not be separated in cognitive representativeness of similarity by brain regions but rather on a semantic basis. Huth et al. (2016) suggest that a difference exists between *concrete* and *abstract* conceptual semantic categories. On the one hand, the concrete categories are made up of the concepts tactile, visual, numeric, bodypart, outdoor, and place (Huth et al., 2016). On the other hand, the abstract categories are made up of social, personal, mental, violence, and time. This suggests that differences in cognitive representativeness of concepts might not be related to brain regions but are based on semantic knowledge of abstract or concrete clusters (Huth et al., 2016).

Moreover, the slight differences in semantic similarity that were noted for the anterior cortices might be explained by the interconnectivity of the anterior cortex as suggested by Alvarez and Emory (2006). In line with the pattern of cognitive categorisation that participants in this study displayed, Hagmann et al. (2008) have demonstrated decreased activation in the posterior cortices when considering conceptual semantic categorisation.

As current research suggests, semantic representation (similarity) might not be the only explanatory factor in semantic knowledge. Recent research was able to demonstrate that semantic cognition is controlled by two larger systems (Chiou et al., 2018; Lambon Ralph, 2014). The first system is involved in the overall semantic representation, the hub-and-spoke system, as mentioned by Rogers et al. (2004). The second system is more focused on executive tasks and mediates the various selection processes of relevant information related to the current task at hand, generating appropriate behaviour (Chiou et al., 2018; Lambon Ralph, 2014). This shows that the semantic conceptual activity and similarity might not only be facilitated by semantic knowledge but by two separated systems overall. Linked to this study this means that instead of specific brain regions being involved in cognitive categorisation of semantic cognition, a large multi-modal system (the hubs and spokes) that is distributed all over the cortex makes sense of non-verbal and verbal information processing (Rogers et al., 2004). According to Chiou et al. (2018) and Lambon Ralph (2014), this system could act as a central structure integrating information into concepts.

4.2 Discussion Questionnaire

The purpose of the questionnaire was to examine whether participants validate concept-category relationships (pairs) that were provided in the semantic brain map of Huth et al. (2016) and whether differences between brain regions exist. Overall, it can be stated that results drawn from the questionnaire supported the previous findings to some extent. The conceptual semantic categories as described by Huth et al. (2016) were replicated almost entirely. The Likert scores suggest, that the perceived similarity withing the categories is high to average. However, the Likert scores suggest that "visual" as a category as well as "bodypart" are only represented in their relation to the original semantic category to an average extent. Suggesting the representation of the conceptual categories "bodypart" and "visual", as provided by Huth et al., were not replicated substantially. Overall, the questionnaire has proven that the relation value of words between their respective semantic category was quite high.

The findings regarding specific brain regions further substantiate the results observed in the card-sorting task. A lack of differences was found between categorisation in the anterior vs. posterior cortex and between the left and right brain hemisphere. However, as already shown in the card-sorting task, the right-brain hemisphere produced slightly higher scores on the Likert scale, showing that participants objectively observed higher relational value in words derived from these brain regions.

Thus, the questionnaire results support the inferences drawn from the card-sorting study regarding the overall structuring of semantic categories and their value in semantic similarity. In conclusion, the questionnaire replicated the results of the card-sorting study and the study by Huth et al. (2016).

4.3 Limitations

Lastly, there are several limitations to this study that need to be considered when discussing the results and implications.

The strongest limitation is a flaw in the questionnaire construction by the researcher. The filler items were not represented the way they were intended to and could, therefore, not act as a control group. Instead of relating the filler items to the main six categories in this study, they were related to their original semantic category. If implemented correctly, the scores of the filler items were expected to be significantly lower than the scores of the original six categories. However, by failing to assign the correct conceptual categories to the filler items the purpose of the filler items was missed.

Additionally, one needs to consider how different words were chosen inside their conceptual category in the brain map provided by Huth et al. (2016). First, the words were chosen based on an assigned colour (e.g., green=visual, see Appendix A). However, this colour was not always a specific green but was mixed with a different colour and had no clear distinction, which is why there might be an overlap of the different word chosen from a mix of two categories. Second, the researcher might have been biased when choosing a specific word for one of the semantic categories. The choice of words was based on the objective of how well these words might fit into the context. While for the researcher a distinct relation might exist between a certain concept and word, a different person might see a completely different link between categories. In addition, the researcher only implemented words from six of the eleven conceptual categories, which leads to a loss of data regarding all semantic categorical knowledge.

Lastly, a limitation regarding the questionnaire might be the prolonged mental effort of participants when taking part in the questionnaire. The average time for the whole study was about sixteen minutes. Shenhav et al. (2017) highlighted in their study on the mechanistic account of mental effort that a significant decline in attention and performance takes place when making use of mental effort. Thus, after taking part in the card-sorting task which already implicates a large amount of mental effort, the participation in the questionnaire might have been affected. Furthermore, the strong usage of mental effort over time has shown that there is a decline in cognitive ability (Fairclough & Houston, 2004). This could have influenced the performance in the questionnaire.

5. Conclusion

Overall, this study has tried to provide a different viewpoint on the topic of conceptual learning, as well as on semantic knowledge and its structure. While previous research has focused on the difference between *abstract* and *concrete* concept, like studies Huth et al. (2016), Binder et al. (2009), or Goldberg et al. (2007), or focused on the implications of two systems on conceptual connectivity and knowledge, this study tried to provide evidence towards the differences of representative categorisation in different parts of the brain. These were, specifically, the posterior cortices, the anterior cortices, the left-, and right-brain hemisphere.

The current research was able to partially replicate the results found in the study by Huth et al. (2016). First, the current study could partially verify the semantic categories established in the map of Huth et al. (2016). The categorisation taken from the card-sorting task replicated the representation of four out of six conceptual categories in the brain in their entirety: “time”, “place”, “violence”, and “bodypart”. This showed that the categorisation of concepts in the brain needs to be further investigated. However, it was shown that the categorisation of concepts represented in the brain can be replicated through active categorisation, for example a card-sorting task, in comparison to passive listening as done by Huth et al. (2016).

Second, focusing on the link between brain location, categorisation, and conceptual similarity, a significant relationship could not be produced. This leads to the conclusion that the categorisation of concepts in the brain might be related to different factors not considered in this study.

In conclusion, it cannot be assumed that the anatomical differences between the posterior cortices and anterior cortices, nor the differences between the left- and right-brain hemisphere take any significant effect on similarity or semantical processing of concepts. Rather, there might be a difference in semantic knowledge that precedes anatomical issues, leading to differences in similarity related to cognitive categorisation.

Instead of investigating either brain location or abstract versus concrete concepts, it is suggested that a combination of both could lead to relevant implications in the representation of concepts in cognition. Therefore, for future research, it is recommended to investigate the semantic categorisation in conceptual learning to a higher degree, related to brain location, mental effort, brain processes, and the influence of concrete versus abstract clusters.

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Appendices

Appendix A

Informed Consent

Q1 I have read and understood the study information dated [02/04/2021], or it has been read to
me. I know I can contact the researcher to ask questions about the study if I have any.

[] yes [] no

Q2 I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason

[] yes [] no

Q3 I understand that taking part in the study involves a card-sorting task as well as a questionnaire.

[] yes [] no

Q4 I understand that information I provide will be used for a bachelor thesis. I also understand that the data will be retained anonymously.

[] yes [] no

Q5 I consent in participating in this study – Date

[____________]

Demographics

Gender

[] Male [] Female [] Non-Binary

Age

[__]

Nationality

[_______]

Appendix B

Items List

Number	Word	Category	VoxelNumbr	Location	Reliability	ColourVoxel	Spec. Category
1	evenly	visual	17,28,28	Right Hemisphere/ Anterior	Good, very reliable	green	visual
2	items	visual	19,18,44	Right Hemisphere/ Anterior	Good, very reliable	green	Visual (visual-tactile)
3	shaped	visual	10,29,62	Left Hemisphere/ Anterior	Excellent, extremely reliable	green	visual
4	top	visual	15,87,35	Right Hemisphere/ Posterior	Excellent, extremely reliable	green	visual
5	thinner	visual	7,59,64	Left Hemisphere/ Posterior	Good, very reliable	green	Visual (visual-tactile)
6	thick	visual	10,28,62	Left Hemisphere/ Anterior	Excellent, extremly reliable	green	visual
7	powdered	visual	10,28,64	Left Hemisphere/ Anterior	Good, very reliable	green	Visual (visual-tactile)
8	round	visual	17,83,34	Right Hemisphere/ Posterior	Good, very reliable	green	visual

9	stripes	visual	15,82,62	Left Hemisphere/ Posterior	Excellent, extremly reliable	green	visual
10	plus	number	18,19,41	Right Hemisphere/ Anterior	Not bad, pretty reliable	Yellow-green	number
11	quarter	number	19,85,40	Right Hemisphere/ Posterior	Excellent, extremly reliable	Yellow-green	number
12	fifty	number	18,85,39	Right Hemisphere/ Posterior	Excellent, extremly reliable	Yellow-green	number
13	annual	number	16,80,62	Left Hemisphere/ Posterior	Good, very reliable	Yellow-green	number
14	pounds	number	17,25,71	Left Hemisphere/ Anterior	Not bad, pretty reliable	Yellow-green	Number (number-tactile)
15	minimum	number	18,27,29	Right Hemisphere/ Anterior	Good, very reliable	Yellow-green	number
16	seven	number	19,45,33	Right Hemisphere/ Anterior	Good, very reliable	Yellow-green	number
17	order	number	19,20,55	Left Hemisphere/ Anterior	Not bad, pretty reliable	Yellow-green	number
18	male	bodypart	14,77,33	Right Hemisphere/ Posterior	Good, very reliable	Yellow	Bodypart (bodypart-person)
19	female	bodypart	18,16,61	Left Hemisphere/ Anterior	Not bad, pretty reliable	Yellow	Bodypart (bodypart-person)

20	breast	bodypart	11,78,71	Left Hemisphere/ Posterior	Good, very reliable	Yellow	Bodypart (bodypart-tactile)
21	flesh	bodypart	17,37,73	Left Hemisphere/ Anterior	Not bad, pretty reliable	Yellow	Bodypart (bodypart-tactile)
22	hips	bodypart	20,20,44	Right Hemisphere/ Anterior	Not bad, pretty reliable	Yellow	Bodypart
23	bank	place	22,38,50	Left Hemisphere/ Anterior	Excellent, extremly reliable	brown	Place
24	bedroom	place	22,30,40	Right Hemisphere/ Anterior	Good, very reliable	brown	Place
25	house	place	14,81,32	Right Hemisphere/ Posterior	Excellent, extremly reliable	brown	place
26	stadium	place	16,79,61	Left Hemisphere/ Posterior	Good, very reliable	brown	place
27	shop	place	18,15,41	Right Hemisphere/ Anterior	Good, very reliable	brown	place
28	motel	place	23,32,39	Right Hemisphere/ Anterior	Good, very reliable	Brown	place
29	apartment	place	22,38,58	Left Hemisphere/ Anterior	Excellent, extremly reliable	Brown	place

30	home	place	14,88,65	Left Hemisphere/ Posterior	Good, very reliable	Brown	place
31	restaurant	Place	16,78,35	Right Hemisphere/ Posterior	Excellent, extremly reliable	Brown	Place
32	School	Place	16,80,33	Right Hemisphere/ Posterior	Excellent, extremly reliable	Brown	Place
33	murdered	Violence	16,17,38	Right Hemisphere/ Anterior	Good, very reliable	Magenta	Violence
34	Cruel	Violence	20,28,58	Left hemisphere/ Anterior	Good, very reliable	Magenta	Violence
35	Crime	Violence	15,79,73	Left Hemisphere/ Posterior	Good, very reliable	Magenta	Violence (violence-person)
36	Cursing	Violence	14,74,25	Right Hemisphere/ Posterior	Good, very reliable	Magenta	Violence
37	Innocent	Violence	16,21,39	Right Hemisphere/ Anterior	Excellent, extremly reliable	Magenta	Violence
38	Guilty	Violence	20,29,60	Left Hemisphere/ Anterior	Not bad, pretty reliable	Magetnta	Violence
39	Confessed	Violence	15,76,68	Left Hemisphere/ Posterior	Good, very reliable	Magenta	Violence
40	Killed	Violence	16,72,68	Right Hemisphere/ Posterior	Good, very reliable	Magenta	Violence (violence-person)

41	Abuse	Violence	22,24,47	Right Hemisphere/ Anterior	Not bad, pretty reliable	Magenta	violence
42	Victim	Violence	18,21,62	Left Hemisphere/ Anterior	Good, very reliable	Magenta	Violence
43	Years	Time	17,22,33	Right Hemisphere/ Anterior	Good, very reliable	Brown-red	time
44	Week	Time	22,34,61	Left Hemisphere/ Anterior	Not bad, pretty reliable	Brown-red	time
45	Times	Time	19,18,64	Left Hemisphere/ Anterior	Not bad, pretty reliable	Brown-red	Time
46	Month	Time	22,79,36	Right Hemisphere/ Posterior	Good, very reliable	Brown-red	Time
47	Days	Time	24,32,38	Right Hemisphere/ Anterior	Not bad, pretty reliable	Brown--red	Time
48	Next	Time	19,24,59	Left Hemisphere/ Anterior	Not bad, pretty reliable	Brown-red	Time
49	Date	Time	15,86,66	Left Hemisphere/ Posterior	Good, very reliable	Brown-red	Time
50	Since	Time	22,79,39	Right Hemisphere/ Posterior	Good, very reliable	Brown-red	Time

Filler Items

1	sheriff	person	16,13,40	Right Hemisphere	Good, very reliable	Orange	person
2	Father	Social	16,16,57	Left Hemisphere	Not bad, pretty reliable	Red	Social
3	Wife	Scoial	15,86,67	Left Hemisphere	Excellent, extremly reliable	Red	Social
4	Sleep	Mental	20,76,28	Right Hemisphere	Not bad, pretty reliable	Purple	mental
5	Calm	Mental	22,22,41	Right Hemisphere	Good, very reliable	Purple	mental
6	Liquid	Tactile	18,33,63	Left Hemisphere	Not bad, pretty reliable	Green-blue	tactile
7	Relatives	Social	13,79,72	Left Hemisphere	Excellent, extremly reliable	Red	Social
8	Widow	Person	17,79,31	Right Hemisphere	Good, very reliable	Orange	Social
9	Boyfriend	Social	15,75,29	Right Hemisphere	Good, very reliable	Red	social
10	Atmosphere	Outdoor	19,22,34	Right Hemisphere	Not bad, pretty reliable	Blue	outdoor

11	Nephew	Social	16,21,39	Right Hemisphere	Excellent, extremly reliable	Red	Social
12	Melted	Tactile	15,22,67	Left Hemisphere	Excellent, extremly reliable	Green-blue	tactile
13	Remembering	Mental	19,26,61	Left Hemisphere	Not bad, pretty reliable	Purple	mental
14	Leather	Tactile	17,86,58	Left Hemisphere	Excellent, extremly reliable	Green-blue	tactile
15	Pregnant	Social	15,77,69	Left Hemisphere	Good, very reliable	Red	social
16	dream	Mental	18,68,29	Right Hemisphere	Good, very reliable	Purple	mental
17	Speed	Tactile	16,67,31	Right Hemisphere	Good, very reliable	Green-blue	tactile
18	Exploring	Outdoor	20,23,34	Right Hemisphere	Not bad, pretty reliable	Blue	outdoor
19	Discover	Mental	19,23,61	Left Hemisphere	Not bad, pretty reliable	Purple	mental
20	Smooth	Tactile	20,83,54	Left Hemisphere	Not bad pretty reliable	Green-blue	tactile

Appendix C
Analysis of Demographics

Table 3
Relevant demographic statistics regarding age and duration
Frequency Age & Duration

	Age	Duration
Mean	**20.93**	**992.23**
Standard Deviation	**2.36**	**484.86**
Minimum	**18**	**354**
Maximum	**30**	**2374**
Variance	5.58	235087.77
Sum	628	29767

Table 4
Relevant data on nationality
Nationality Percentage

	Frequency	Percent	Valid Percent	Cumulative Percent
China	1	3.3	3.3	3.3
Dutch	6	20	20	23.3
Germany	19	63.3	**63.3**	86.7
Mexican	1	3.3	3.3	90
Romania	2	6.7	6.7	96.7
South Korea	1	3.3	3.3	100

Table 5
Descriptive Statistic on the variable Gender
Gender Percentage

	Frequency	Percent	Valid Percent	Cumulative Percent
Female	**18**	60	**60**	60
Male	**12**	40	**40**	100
Total	**30**	100	100	

Appendix D

Question Example

How strong does the word fifty relate to the concept of "number"?

weak relation	somewhat weak relation	average relation	somewhat strong relation (	strong relation
[__]	[__]	[__]	[__]	[__]
(1)	(2)	(3)	(4)	(5)

Appendix E

Syntax

Heatmap

```
> library(gplots)

> library(RColorBrewer)

> data <- read.csv("Desktop/RJaccardScores.csv")

> mat_data <- data.matrix(data[,1:ncol(data)])

> my_palette <- colorRampPalette(c("yellow","red"))(n = 299)

> heatmap.2(mat_data, col = my_palette, density.info="none", trace="none", revC = TRUE, main="ConeptsHeatmap")
```