MASTER THESIS

Textual versus pictorial organization of concepts

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Abstract

Concepts are used for communication and categorization of information. In symbolic approaches comprehension depends on the processing of symbols (e.g., words), in which modality, as given by perception, does not play a role. In embodied approaches comprehension depends on the activation of experiences of the world, meaning that modality does play a role. Brain research, like the hub-and-spoke theory and behavioral studies do not rule out one of the approaches. An example is an fMRI study of Huth, de Heer, Griffiths, Theunissen, and Gallant (2016). They derived a map of brain activity related to the presentation and categorization of a set of concepts, in which both modal and amodal aspects of concepts could be involved.

The current study investigates whether the categorization of concepts would be influenced by a textual (more amodal) versus a pictorial (more modal) representation of the concepts. Concepts represented in a set of brain areas (brain voxels) of the Huth brain map were chosen, and a questionnaire was conducted in which participants rated to what extent a picture and a word do represent the same concept. Thereafter, a selection of concepts was made with the highest association between word and picture presentation, and an open card sorting study was conducted online with these concepts. First, 23 pictorial and textual concepts and then 23 concepts in the reversed order (word - picture) had to be sorted. Thereafter, heatmaps based on textural and pictorial representation were analyzed and compared. The scores of concept combinations in the heatmaps were also compared for combinations of concepts derived from the same brain voxel in the Huth map and concept combinations derived from different brain voxels in the map.

The results indicate a monotonous positive relationship between ranks of concepts in the textual and pictorial heatmaps. Furthermore, they indicate a non-significant to weakly marginal difference in organization between pictorial and textual concepts. The results do indicate a significant low to high difference in card sorting scores for between versus within voxel/brain area categorization. The results could indicate that symbolic approaches could play a major role, but other processes could also be involved. This is in line with the hub-and-spoke theory, the symbol interdependency theory, and the linguistic and situation simulation system (LASS) framework. To conclude, this study helps to identify to what extent modality could differ in active concept organization and to what extent location of brain activation could play a role.

Keywords: concepts, card sorting, symbolic approach, embodied approach, hub-and-spoke theory, brain map

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1. Introduction

We use concepts to think about practically everything. Concepts are basic ideas of knowledge (Barsalou, Simmons, Barbey, & Wilson, 2003). They are fundamental for cognition, memory, and communication, and they are used for communication and organization of information (Ciccarelli & White, 2018; Medin & Rips, 2005). In categorization, concepts determine whether or not something is a category member based on features, function, or behavior. Memory organization is based on meaningful relations between concepts. Humans use categorization to understand new entities (e.g. this entity has a snail and wings, so it is a bird) (Medin & Rips, 2005). The new entities are used to update the categories and concepts (e.g., an ostrich has a snail and wings but it cannot fly, although it has wings, so not all birds can fly). Semantic knowledge allows us to recognize and make inferences between concepts (Lambon Ralph, Jefferies, Patterson, & Rogers, 2017). Knowledge about categories and concepts are stored in long-term memory (Medin & Rips, 2005). When an entity is encountered, the information from long-term memory wil be recalled and compared with the new entity, which is done in working-memory (Baddeley, 2010; Halford, Wilson, & Phillips, 2010). The category or concept can be updated and these updated version will be stored in long-term memory. Hence, concepts and categories are the basis of our semantic knowledge and memory. There are many things that can go wrong during this process. Using and categorizing concepts is often studied by doing tests with people with semantic deficits, such as semantic amnesia (Lambon Ralph et al., 2017; Mahon & Caramazza, 2009). The remaining of this chapter serves as a summary of the main points of the background, on which will be elaborated in more detail in the next chapter, because of the length of the background. Furthermore, an outline of this study will be given.

Barsalou (1999) stated that there are three basic approaches to knowledge and concepts: (1) classical representational approaches based on amodal symbols, in which concepts are represented as symbols that are independent of modality, (2) statistical and dynamical approaches, and (3) embodied approaches. This thesis elaborates more on two approaches: the symbolic and embodied approaches. Embodied approaches state that comprehension of concepts requires activation of experiences with the world (Louwerse & Jeuniaux, 2008). In embodied approaches the sensorimotor system is involved during conceptual processing (Mahon & Hickok, 2016). Conceptual processing depends on the way concepts are acquired in perception or action. This is called modal, because it depends on the modalities (e.g., sound, vision, motor) we use to perceive and interact with the environment. In the symbolic view

conceptual representations are symbolic and non-perceptual (Louwerse, 2007; Louwerse & Jeuniaux, 2008). In this approach, concepts are derived from perception and behavior, but are then labeled by amodal symbols, which are used to express relationships with other symbols (Louwerse, 2007). Semantic representation has also been studied in brain research. From classical brain research, as learned at the university, language is stored in the temporal lobe of the left hemisphere and especially in the Broca and Wernicke areas (Radvansky & Ashcraft, 2014). However, in different studies there is found that there are also other areas involved. An example is the hub-and-spoke theory. In this theory, there is an amodal hub and there are modal spokes (Lambon Ralph et al., 2017). Both the embodied and symbolic systems would be involved. Furthermore, Huth et al. (2016) found, using fMRI, that areas all over the cerebral cortex are activated in the processing of concepts. This resulted in a brain-map in which concepts are categorized based on brain activation obtained when subjects were passively listening to stories.The representation of concepts using either pictures or words (symbols) has been studied using behavioral studies. A number of studies indicate that pictures and words are encoded and processed differently, like the study of Schnotz and Bannert (2003), and the one of Baddeley (2010).

While many studies suggest that modal forms of concept representation play a role in concept categorization, as favored by the embodied approach, the symbolic approach can still play a role as well. Some studies even suggest that they work together. Hence, it is not sure to what extent modality plays a role in concept categorization. It is however important to know whether modality differs since this can have an influence on concept learning. It can have an impact on how wel learning material suits the capacities of the pupil, but it can also have an impact on usability and user experience of technological objects (Schnotz & Wagner, 2018).

To get to know to what extent modality matters in concept categorizationthe effect of pictorial versus textual representation on concept categorization will be studied by using concepts obtained from the brain map of Huth et al. (2016) in a card sorting study (CST). Two card sorting studies will be conducted per participant: one with pictures and one with texts. To do this, first a set of visual concepts from the brain map of Huth et al. (2016) needs to be tested on suitability for both pictorial and textual representation. This will be done by a questionnaire in which participants have to rate to what extent a pictorial and textual representation of a concept are the same. This gives a set of pictures and words that will be used for the card sorting studies.

The outline of this thesis is as follows. Section two is about symbolic versus embodied approaches to concept representation. First both approaches will be discussed. Then they will

be linked with brain research of the Huth map and the hub-and-spoke theory. Next, pictorial versus textual representation and their possible differences will be discussed based on two models: the multicomponent model and the integrated model of text and picture comprehension. This section ends with a conclusion. Section three is an outline of the current study. Section four is about a questionnaire on how well word – picture combinations, based on words of the Huth map, do represent the same concept. This section is divided in a subsection about why this is used, a method subsection, and a results and discussion subsection. The next section is about the card sorting (CST). First it will be discussed what card sorting is and why it is used in this study. Then, the method and procedure of the two CST studies will be discussed. Section 7 is about the results of the two CST studies. Section eight contains a general discussion, and the last section contains the conclusion.

2. Symbolic versus embodied concept representation

2.1. Symbolic concept representation

According to the symbolic approach, concept relations are based on rule-governed manipulation of symbols (Malhi, 2015; Pylyshyn, 1973; Weiskopf, 2010). Fodor (1998) stated that concepts are not images but descriptions. He stated that a concept is a list of features, stored in memory, that specifies taxonomically relevant properties what that concept applies to. Appropriate representation for information-processing application makes a distinction between important and invariant aspects of the environment in which a concept is represented and gives the processing access to a subset of related symbols (Pylyshyn, 1973). The symbolic view assumes that knowledge in the semantic system is separate from episodic memory and modality-specific systems for perception, action, and emotion (Barsalou et al., 2003). In this approach, the representation of concepts is amodal and thereby non-perceptual. Sensorimotor representations are transformed into an amodal representation (Barsalou, 1999; Barsalou et al., 2003). When amodal symbols become transmitted from perceptual states, they enter representational structures (e.g. feature lists, schemata, and semantic networks) (Barsalou, 1999). These structures form a fully functional symbolic system with a combination of syntax and semantics. This supports all higher cognitive functions (e.g., memory, knowledge, language and thought).

Relational knowledge is important for the symbolic approach. It shows why concepts and their relations are represented with symbols, and how concepts/symbols are categorized together. Halford et al. (2010) discussed the crucial role of relational knowledge for (higher) cognitive processes. In symbolic architectures, symbols represent a relationship and its intention, like ordering by size. For example, the relation ‘larger’ is expressed with a relation symbol (e.g., ‘Larger’) and symbols for the elements of the relation (e.g., ‘elephant’ and ‘mouse’). The elements have to be in a specific order to express the relation. For example, Larger(elephant, mouse) means that an elephant is larger than a mouse, whereas Larger(mouse, elephant) means that a mouse is larger than an elephant. According to the symbolic approach, this dependency on the order of the elements can be expressed only with the use of symbols.

More generally, symbols are used because logical reasoning and statistical knowledge, which are part of relations, would be hard without symbols (Louwerse, 2007). Relational knowledge has three characteristics: structure-consistent mapping, compositionality, and systematicity (Halford et al., 2010). According to the symbolic approach, these characteristics could not be expressed without the use of symbols. Structure-consistent mapping is the

relationship between concepts, consistently mapped, in a way that corresponds to the truth, as can be seen in Figure 1. It is important for higher cognition because it enables analytic cognition and promotes the selection of common relations, which are at a higher level of abstraction. They are relevant to reasoning by logical schemas. Compositionality means that the constituent entities from which representations of complex entities are built preserve their identity in the representation and are accessible. For example, you can ask: "What animal is larger than a mouse? (an elephant). Systematicity means that cognitive capacities are intrinsically connected to enable novel instances. The representational format is as follows: predicate (agent, object), so loves (Marc, Jane). We are able to fill in the slots unlimitelessly. Thus, when you understand the relation Marc loves Jane you are also capable to understand loves (Sarah, Jack). The characteristics of relational knowledge are important for higher cognition because they play a role in forming mental models to reflect logical consequences of a premise. Mental models are the basis for many forms of reasoning and they are part of working memory. The premises of Figure 1: the elephant is taller than the dog and the dog is taller than the mouse are presented, whereafter a mental model is formed in working memory by an ordering scheme like Figure 1. Mental models reflect content and context and are constructed in working memory. They also reflect the interaction of semantic content and structure. Mental models incorporate all core concepts of relational knowledge and it includes the interaction of analytic and nonanalytic knowledge. Relational knowledge is important in cognitive linguistics, categorization, and planning. Structural alignment facilitates learning of semantics and syntax and iteration is essential for language. Furthermore, categories can be based on relations and strategies for planning can be based on relational representations. Hence, symbolic architectures would claim that you need symbols for achieving and representing relational knowledge between concepts, to provide for the level of abstraction on which relational knowledge is based (Louwerse, 2007).

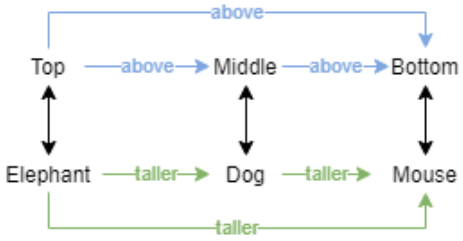

Figure 1. Example of a structured map.

In symbolic approaches both pictures and words have to be interpreted before they become conceptual contents, because there are many pictures and words in which

representations are equivalent (Pylyshyn, 1973). According to Fodor (1998) there exist concepts whose content cannot be pictured, such as ‘Wednesday’, ‘number’, or the word ‘concept’ itself. There are also concepts from which instances can be pictured but where features that a picture can show are not the instances that define the concepts. For instance, you can picture a brother but you cannot picture what brothers have in common. Fodor and Pylyshyn (2015) suggest that concepts are like words. This is in line with the Language of thought hypothesis (LOT) or Mentalese (Katz, n.d.). Fodor defines the LOT as ‘the idea that mental representational states or symbol structures that have semantic content also have a syntactic structure that is appropriate to the content that they have’ (Fodor, 1989; Fodor & Pylyshyn, 1988). When a concept has constituents like thoughts and sentences do, there are rules for combining them (Fodor & Pylyshyn, 2015). You can follow those rules even if you do not know what that constituent means. Pictures have no constituents, but only parts. According to Fodor and Pylyshyn (2015) you cannot put pieces of a picture back together unless you know what it is a picture of.

Categorizing concepts consists of evaluating overlap between feature lists (Fodor, 1998). In the symbolic approach, determining category membership is relatively static and amodal (Barsalou, 1999). The symbolic approach would claim that you would first activate the symbolic representation of a concept that is independent of input modality (picture or word) and then use that in a categorical relation. This would mean that there is no difference between organization of concepts presented as picture or word.

2.2. Embodied concept representation

In embodied approaches, a conceptual system is a collection of category representations, in which each category represents a different component of the experience. This includes categories for agents, objects, locations, times, events, actions, introspective states, relations, roles, and properties (Barsalou, 2008b). Introspection is the perception of internal systems (e.g. sensory-motor, affective, and cognitive systems) (Barsalou, Santos, Simmons, & Wilson, 2008). Barsalou et al. (2003) stated that the conceptual system can be based on modal representations, that is, representations that are closely related to the way the concepts are perceived or acted upon, without the need to translate these representations first into symbols. This form of world knowledge could support all cognitive activities, including perception, memory, language, and thought.

According to Barsalou (2008b) conceptual systems have the following important functions: supporting perceptual processing via figure-ground segregation, anticipation and filling in, predicting likely entities and events, producing categorizations, producing inferences based on those categorizations, supporting processing during memory and language and thought, interpretation of linguistics, and, lastly, representing object, event and mental states that constitute the content of reasoning and decision making and problem solving. The primary purpose is to support situated action and because of that it becomes organized around the action-environment interface (Barsalou, 2003). The conceptual system is dynamical, because a concept is placed in a particular situation, setting, and instance. This results in that a concept can give a variety of simulations, which means that the conceptual system is dynamical (Barsalou, 2003). In the embodied view the simulation is in the relevant modality-specific system when a concept is represented in a specific modality during conceptual processing (Barsalou et al., 2003). This is called 'modal'. This means that modality-specific states are captured by its adjacent memory systems (Barsalou et al., 2003; Louwerse, 2007). Perceptual symbols are modal because they are produced and represented in the same system (e.g. visual or auditory) (Barsalou, 1999).

Embodied theories refer to situation simulation. The brain captures modal states during perception, action and introspection and simulates these states to represent knowledge. The knowledge is simulated in the context of relevant settings actions, events and introspection (Barsalou, 2008a). When you perceive for example a horse, the brain captures modal situations in the auditory (how it sounds), visual (how it looks) and somatosensory system (how it feels). Then the linguistic system recognizes the word, and this activates associated simulations. Correlated information in the perceptual, motor and introspective brain areas becomes active to represent the concept in a common situation (Barsalou, 2009). This results in a distributed system of brain areas that gather modal representations of a concept category (Barsalou, 2008a). Situated conceptualizations play additionally a central role when attempting to predict information that is associated with categories in the absence of exemplars. Humans also describe properties for likely events, settings, and introspection instead of just describing the object (Barsalou, 2009).

According to Barsalou et al. (2008) words are typically used in research on cognition because they are easier being used as stimuli than pictures. This leads to biased views of the conceptual system and cognition. Language and words do play a central role in cognition and conceptualization, but the modal experience is at least as central because experiential input is

more likely to activate simulations that carry deep conceptual information about a situation than words can describe (Barsalou et al., 2008).

A fundamental property of the conceptual system is its categorical nature (Barsalou, 2003). In this view, a conceptual system is a collection of category knowledge, in which each category corresponds to a component of experience (Barsalou, 2003). In the embodiment view (Barsalou, 1999), learning produces categorical knowledge based on modal experiences, which is biased towards learning some categories more easily than others (Barsalou, 2003). If the simulator for a category can produce a satisfactory simulation of a perceived entity, it belongs to that category. If not, it does not belong to that category (Barsalou, 1999). Once a simulator for a category is memorized, it helps to identify members of the category on occasions and it can provide categorical inferences about them (Barsalou, 1999). Additionally, if attention focuses on a specific type of acting with a specific concept, simulators also develop and represent it (Barsalou, 2008a). Categorization can depend on a novel and familiar simulations. Each successful categorization stores a simulation on the categorized entity. If a similar entity is encountered later, it is familiar, and it is assigned to the category because the perception matches with existing memory (Barsalou, 1999). Once an entity is categorized, knowledge associated with that category provides predictions about the structure, history, ways of interaction, and behavior about the entity. Through simulation, categorical inferences can be made (Barsalou, 1999). Because categorization is dynamic, the knowledge that determines categorization and perceived entities that must be categorized are represented in the same manner (Barsalou, 1999).

2.3. Brain research

According to Barsalou, Pecher, Zeelenberg, Simmons, and Hamann (2005) the subjective experience of concepts and their properties can index the underlying brain activity. In the embodied approach it is assumed that conceptual content is distributed over sensorimotor systems (Barsalou et al., 2005; Mahon & Hickok, 2016). This means that concepts that include a visual property activate the visual cortex but potentially also other modality-specific systems. This can also be seen in blind humans (Mahon & Hickok, 2016). Different types of properties activate different patterns of modalities (Barsalou et al., 2005). Association areas near the visual system capture visual representations. Later, cross-modal association areas in the temporal, parietal and frontal lobes integrate activations from different modalities to establish multimodal representations. Once linked neurons across association areas capture modality-

specific features, they can reactivate these features later (Barsalou, 2008b). This is called the reenactment mechanism (Barsalou, 2008b). The reenactment mechanism contains two central constructs: simulators and simulations. A simulator is an organized body of knowledge that implements a concept. It produces specific simulations of a category's exemplars (Barsalou, 2008b). Spatiotemporal relations and transformations become central to concepts, because simulators partially reproduce perceptual experience (Barsalou, 1999).

2.3.1. The hub-and-spoke theory.

This study is confined by the requirement to do all research online, due to the Corona pandemic. Hence, the choice was made to investigate the difference in the presentation of concepts by using either word or pictures. To investigate the mode of presentation, only concepts were used that were classified as 'visual' by Huth et al. (2016). To get a deeper understanding of categorizing concepts it is important to know which parts of the brain are responsible for semantic representation of visual concepts, and what other parts are relevant.

The hub-and-spoke theory suggests that conceptual knowledge requires a combination of a trans-modal hub and modality-specific regions, such as the areas in the brain that process visual information (Lambon Ralph et al., 2017; Patterson, Nestor, & Rogers, 2007). These areas and the anterior temporal lobe would be important for visual concepts. The anterior temporal lobe (ATL) has the function of the semantic hub (Lambon Ralph et al., 2017; Patterson et al., 2007; Snowden et al., 2018). The ATL is also needed when the perceiving and expressing is done multimodally, by adding trans-modal representation coding (Visser, Jefferies, Embleton, & Lambon Ralph, 2012). Differentiation between entities depends on the ATL. The ATL is sensitive to differences between shared and distinctive semantic features and the specificity level of semantic information. This effect is stronger for concepts with unique distinctive features (Visser et al., 2012).

The ATL is modality independent (Visser et al., 2012). The trans-modal representation coding allows for correct mapping to be learned between modality-specific attributes and relevant concepts. Trans-modal representations allow for making semantic generalization based on conceptual similarities rather than superficial similarities. The function of the ATL can be shown by a deficit in people with semantic dementia (SD): impairment in all conceptual domains and modalities (Lambon Ralph et al., 2017). They show over- and under-generalization errors (Visser et al., 2012).

Sub-regions of the ATL are more modality dependent than the ATL. All posterior temporal regions show differences in stimulus modality (Visser et al., 2012). The superior temporal gyrus (STG) shows more activation for words than for pictures and more for abstract than concrete words. Furthermore, the anterior fusiform gyrus (AFG) shows greater activation for pictures than words and more for concrete than abstract words (Visser et al., 2012). The middle temporal gyrus (MTG) shows more activation in verbal than pictorial stimuli, but it responds significantly to both modalities. Modality specific regions can interact directly for dealing with multimodal concepts (Visser et al., 2012).

2.3.2. Huth map

Huth et al. (2016) found that there are multiple brain regions responsible for semantics. They found that specific areas are selective for visual concepts, namely: dorsolateral medial parietal cortex (MPC), lateral parietal cortex (LPC), posterior inferior prefrontal cortex (IPFC) areas in the precentral sulcus, inferior frontal sulcus, anterior middle frontal gyrus, orbitofrontal sulci, ventral temporal cortex, posterior lateral temporal cortex, and posterior superior frontal. This suggests that modal specific brain areas are involved as well in the representation of concepts, and it confirms to a large extent the hub-and-spoke theory. In the semantic system of the brain, consistent patterns across individuals can be seen. Huth et al. (2016) created a detailed semantic atlas in which can be seen that most areas in the semantic system represent information about specific semantic domains or categories of related concepts. This atlas shows that multiple brain areas are activated by one concept category, like the visual cortex and the sensorimotor cortex in case of, for example the concept ‘cap’. This is a sign that concept representation in the brain is at least partially embodied. To develop this atlas, Huth et al. (2016) let participants listen to stories. They analyzed brain activity for a large set of words in the story. Brain activity was analyzed via measurements of blood-oxygen-level-dependent (BOLD) responses which were recorded via functional magnetic resonance imaging (fMRI). Then, they used voxel-wise modelling. This approach estimates semantic selectivity for each voxel. A voxel is a small 3D element at a specific location in the brain. This study is however about activation in the brain produced by concepts, not about the use of concepts in terms of categorization by humans.

According the fMRI study of Deniz, Nunez-Elizalde, Huth, and Gallant (2019) modality does not influence representation in the semantic system. They found this result on measuring reading and listening. They did however not say anything about textual and pictorial representations of concepts. So, it does not mean that this is also true for textual and pictorial

representation modalities. According to Snowden et al. (2018) pictorial features or objects may provide sufficient information for giving a correct response in people with semantic dementia. This, however, does not account for words. This would mean that pictures and words are processed differently or at a different place in the brain. So, there might be a difference in judging and categorizing concepts as pictures versus words.

2.3. Behavioral studies on pictorial versus textual representation

There are two models from which can be concluded that stimuli from textual and pictorial modality are processed at least partly differently. One of them is about working memory and one about text and picture comprehension. This could mean that judgement and categorization of concepts relies on the difference in input modality.

2.3.1. The multicomponent model

According to the multicomponent model on working memory text and pictures share the same resources because they are processed both visually via the visuo-spatial sketchpad, as can be seen in Figure 2 (Baddeley, 2010; Schüler, Scheiter, & van Genuchten, 2011).

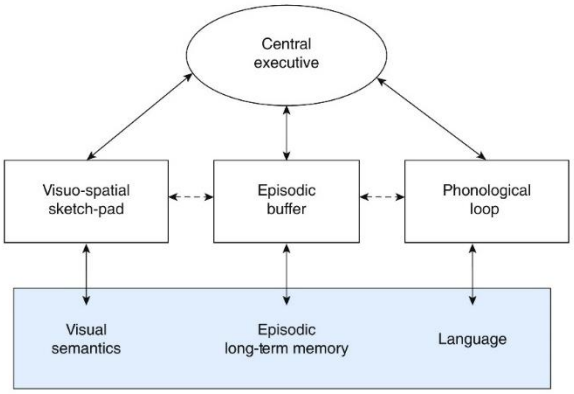

Figure 2. Multicomponent model on working memory (Baddeley, 2010).

The multicomponent model is made from a perspective on short-term memory. It has three layers. The first (top) layer is the central executive, which controls where what amount of attention goes to. When you are attending at a specific stimulus it will be stored in short term memory (second layer). There are three sub-systems for short term memory storage. The first one is the visuo-spatial sketchpad, used for visual material. Since pictures and written text are both visual you can assume that they share the same resource. Another storage system is the phonological loop, which is for verbal material, so written text is also stored in this system.

The last one is the episodic buffer. This one is multidimensional, meaning that it can combine stimuli from different modalities. It is a passive storage system, accessible through conscious awareness. Storage systems can interact with each other. The third layer is long-term memory.

Furthermore, there are views specifically based on multimedia: textual and visual information. According to Clinchant, Ah-Pine, and Csurka (2011) texts and pictures are expressed at distinct semantic levels. Pictures are represented by low-level features (e.g., forms and textures) and texts are represented by high-level features (e.g., house with a garden). It seems more difficult to describe the whole concept of a picture than the whole concept of text. Therefore, Clinchant et al. (2011) see a gap in a search query difference while using text versus pictures. In a text query only a few keywords are needed, but in a picture query all aspects of the picture are needed. This can result in a semantic mismatch. This would mean that there is a difference in judging and organizing concepts textually or pictorially.

2.3.3. The model of text and picture comprehension

Schnotz and Wagner (2018) introduced the integrated model of text and picture comprehension (ITPC). This combines different views on text and picture comprehension. It states that texts and pictures are qualitatively different forms of representations that require different forms of cognitive processing. Textual and pictorial sources are used for different purposes (Figure 3).

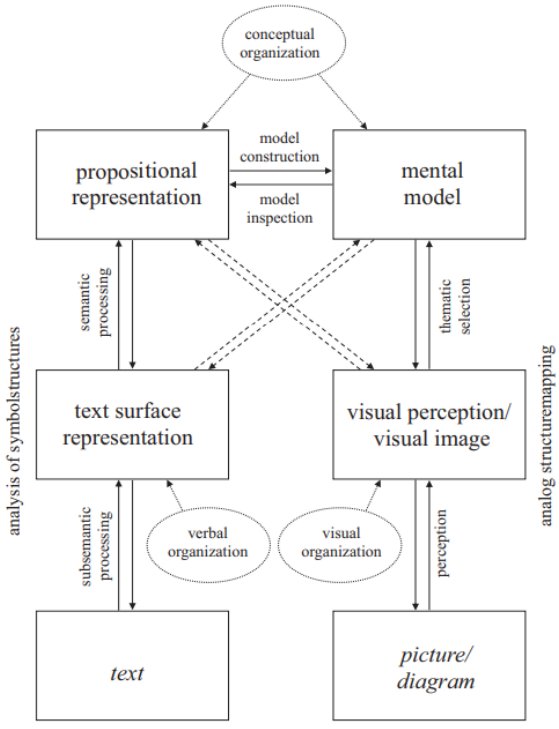

Figure 3. Integrated model of text and picture comprehension (Schnotz & Bannert, 2003).

In the ITPC the integrative processing takes place in working memory, which has limited capacity. The ITPC has two channels. One of them is the verbal channel. It involves external text, internal text surface representation and propositional representation of semantic content. The other channel is pictorial. This channel involves the external picture, internal visual image of the picture and the mental model of the concept. There are dynamic interactions between the text surface representation and perceptual representation of the picture, propositional representation, and the mental model. The interaction between propositional representation and mental model takes place via mental model construction and inspection.

There are converters between the two channels. They are at the level of semantic deep structure processing, which is with the involvement of linking conceptual structures with structural characteristics of the mental model. Because of the different processing we can combine specific advantages of both forms of representations.

Furthermore, the ITPC states that the initial construction of a mental model is context-driven (Schnotz & Wagner, 2018), and more effort is put in text comprehension or conceptual analysis (Schnotz & Wagner, 2018). There is a process of coherence formation resulting in the formation of a mental model. Unlike the construction, the adaptive elaboration of a mental model is picture-driven (Schnotz & Wagner, 2018). They allow quick and flexible access to specific task-relevant information (Schnotz & Wagner, 2018).

2.4. Summary on the issue of the symbolic versus embodied approach

It seems that there is evidence for both symbolic and embodied approaches in human cognition and behavior (Barsalou et al., 2008; Louwerse & Jeuniaux, 2008). Both seem to have important features (Barsalou, 1999). Therefore, the accurate question seems to be: ‘To what extent is the representation of concepts and their relations influenced by modal versus amodal forms of representation’ (Louwerse, 2007). Logical reasoning and mathematics tasks would be hard if there is no symbolic system and visual rotation, and spatial orientation tasks would be hard if there is no embodied system. It is more likely that they work together and play different roles in different concepts (Barsalou et al., 2008). It can differ which of the symbolic and embodied system is dominant, but they can be active together. There exist a hypothesis and a framework that combine both approaches: the symbol interdependency hypothesis and the linguistic and situation simulation system (LASS) framework.

In the symbol interdependency theory symbols are interdependent abstract systems of meaning that can be grounded in the embodied experience of the world (Louwerse, 2007;

Malhi, 2015). Symbols are built onto embodied representations and interrelations between symbols can get meaning to a larger extent (Louwerse, 2007). Language comprehension uses mostly symbolic representations, resulting in that embodied representations do not necessarily need to be fully activated (Malhi, 2015). Symbolic information is adequate for most of the meaning of words, while embodied information enables deeper understanding and is needed when having more processing demands.

In both the LASS framework and the symbol interdependency theory the symbolic factors are less precise than embodied factors (Malhi, 2015). Symbolic factors provide quicker approximate representations, refined by the perceptual system. When symbolic processing seems sufficient, embodied processing is not needed. Embodied factors tend to be more involved when deeper processing and preciseness are needed. Simulators capture statistical frequencies of properties and relations in experience. Frequency of words, associations and the relationship with syntactic structures are coded statistically (Barsalou et al., 2008).

The hub-and-spoke theory and the Huth map also do not rule out one of the approaches. Huth et al. (2016) do seem to support the idea that concepts are also represented in brain areas that support modal forms of representations and processing, since brain activation is seen at multiple places in the brain for the same concept. Concepts are also categorized in the Huth map with different other concepts, which could be an indication of situated cognition. ‘Spoon’ can for example be seen as ‘silver’ together with ‘jewelry’, but also it can be seen as an artefact that helps to eat, creating the link with food. It depends on the situation the human recalls. This does however not mean that there is no symbolic system. In the hub-and-spoke theory of Lambon Ralph et al. (2017) the hub is in favor of the symbolic approach, but the spokes could be in favor of the embodied approach.

From behavioral studies, the multicomponent model indicates that there is a difference in pictorial and textual modality (Baddeley, 2010; Clinchant et al., 2011). Furthermore, the ITPC model is in favor of the embodied approach, because it states that the mental model is context driven, and there is a difference in the representation of concepts as picture or word (Schnotz & Wagner, 2018).

To conclude, while many studies suggest that modal forms of concept representation can play a role in concept categorization, as favored by the embodied approach, the symbolic approach could still play a role in concept relations as well. This means that it is not sure to what extent modality plays a role in concept categorization.

3. The current study

While many studies suggest that modal forms of concept representation play a role in concept categorization, as favored by the embodied approach, the symbolic approach can still play a role as well. Some studies even suggest that they work together. Hence, it is not sure to what extent modality plays a role in concept categorization. It is however important to know to what extent modality plays a role and to what extent there is a difference when using textual versus pictorial modality. When is known if the input modality (textual or pictorial) is of importance in concept learning schools adjust their learning methods to in order to suit the to be learned subjects optimally to the capabilities of the pupils (Schnotz & Wagner, 2018). It can also influence the way for example technology and manuals should look like for optimal usability, since knowing this answer can indicate which modality suits our information processing.

Therefore, the purpose of this study is to gather knowledge about judgement and organization similarities and differences in textual and pictorial representation of visual concepts. The following research question arises:

To what extent are judgement and categorization of visual concepts in the brain map of Huth et al. (2016) influenced by textual versus pictorial representation of concepts?

This research question is divided in three sub questions:

1. *To what extent is there a difference in active organization by card sorting of pictures versus words?*
2. *To what extent is there a difference in active categorization between concept combinations that activate the same versus different voxels or brain areas*. If there is a difference, the following question arises:
3. *To what extent is there a difference between pictorial versus textual representation in this respect?*

Based on the literature, both symbolic and embodied processes could play a role. Hence, the expectation was that there is to some extent a difference in judgement and categorization for concepts presented as text or as picture. A difference of within versus between voxel/brain area on concept relations would suggest a relation between active categorization by card sorting with the activation of brain areas by these concepts.

3.1.Outline of the study

Huth et al. (2016) made two brain maps with concept categories: The PrAGMATIC atlas, which is based on brain areas, and voxel selectivity brain map, which is based on voxels. All concepts in both brain maps were classified in the following categories (based on the activation that was on average similar in seven subjects): body part, mental, number, outdoor, person, place, social, tactile, time, violence, and visual. Both brain maps were used in this thesis. Brain areas/voxels are activated when listening to concepts. Different concepts can activate the same brain area/voxel. For example, voxel 19,37,73 is activated by hearing the concepts: thinner, rack, diameter, bottom, holes, inches, fabric, rim, inch, steel, tops, pair, cloth, plastic, hole, top, underneath, edges, lighter, container, as can be seen in Figure 4. This does however not mean that a brain area or voxel is a category, because there is a distinction of semantics and colocation of concepts in the same brain area or voxel.

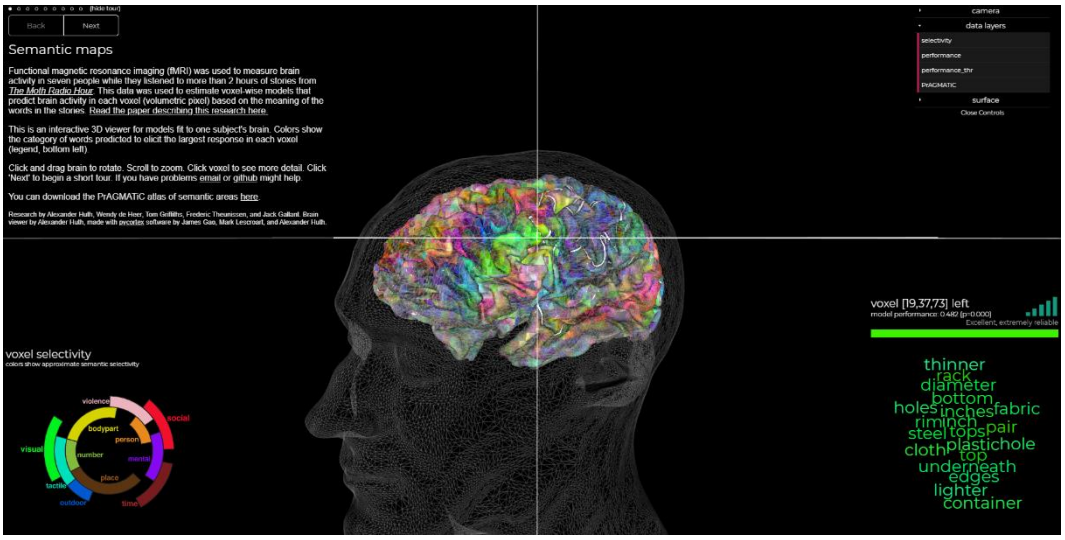

Figure 4. Selectivity semantic brain map with concepts that activate voxel 19,37,73 (Huth, Heer, Griffiths, Theunissen, & Gallant, n.d.).

Only the visual category was used, because concepts need to be visual to be able to visualize it in a picture. All visual (bright green) brain areas were selected, and a selection was made of all visual (bright green) voxels, since it was not feasible to use all voxels since there were 190 voxels counted. For the selection of voxels, the model performance should be at least 'not bad, pretty reliable' to be able to be included. The model performance is given by the statistical reliability of selective activation. This means that the selected concepts produced reliable activity in the voxels they are represented. From the voxels of at least 'not bad, pretty reliable' 26 were randomly selected.

Since the concepts from the brain maps are presented as words, ‘words’ will be used instead of ‘concepts’ for clarity. The selection of different voxels and brain areas, despite having only one category (visual) gives the ability to test whether it matters in active organization if concepts come from the same or different voxels or brain areas. Furthermore, the category ‘visual’ is broad. Using different brain areas and voxels gives the ability to know whether it matters if concepts activate the same or different voxels/brain areas.

Before the CST was performed, a set of concepts was selected from the Huth brain map, and a questionnaire was used to rate to what extent word-picture combinations do indeed represent the same concept. This is important, because a potential pitfall when using words or pictures as stimuli could be that they could activate a different concept than the intended one. This can be for both pictures and words. For example, the word ‘orange’ can be a piece of fruit or a color and a picture of a cotton tree can activate the concept ‘tree’ or the concept ‘cotton fabric’. The concept that is activated influences how it is categorized. To minimize the chance of wrong categorizations, it was first tested to what extent participants rated a combination of picture and word as the same. The CST was conducted with the word and picture combinations that were rated as highly similar. According to symbolic architectures, if picture and word activate the same concept, categorical relations would be determined with them by the activation of the same symbol. Then, there would be no difference in the CST using pictures and words.

For all words corresponding pictures were found, except for words that were hard to visualize (e.g., wears). These pictures and words were used in the card sorting study, where 24 participants had to do a card sorting with 23 pictorial and 23 textual items. This card sorting study (CST) gives an active categorization of these concepts. The categories found in the pictorial and textual card sorting were compared with each other and a comparison was made between concept combinations that activated the same or different voxels/brain areas. The data was analyzed via heatmaps and their corresponding concept ranks and concept combination scores (Jaccard scores) of concept combinations that activate the same or different voxels/brain areas.

4. Concept selection and questionnaire

A questionnaire was used to compare concepts presented as picture or text. With this questionnaire concepts were filtered by the extent to whether picture and text represent the same concept. Comparison of picture and word only could be fair if they represent the same concept. Everyone is biased and everyone has his or her own mental model which could lead to different thoughts about concepts. Therefore, a pitfall when using words or pictures as stimuli could be that they could activate a different concept than the intended one. Comparison of picture and word only could be fair if they represent the same concept. Hence, more people need to agree on that a picture and word represent the same concept.

4.1. Participants

Participants were collected via convenience sampling. Inclusion criteria were that participants needed to have access to a computer, laptop, tablet, or smartphone, since participation was online. Additionally, they must have at least knowledge of English at High School level, because the brain map of (Huth et al., 2016) is in English and it is not tested if the results of this study can be generalized to other languages. In the questionnaire five participants took part. Of them two participants were male and three were female. The oldest participant was 60 years old and the youngest was 20 years old. The mean age was 37 (SD = 15.6). The highest degree of education varied from middle level applied education to higher education bachelor. Four participants had a Dutch nationality, and one had a German nationality.

4.2. Materials: Concepts from the Huth brain map

The concepts were picked from the selectivity brain map and PrAGMATIC brain map from (Huth et al., 2016; Huth, Heer, Griffiths, Theunissen, & Gallant, n.d.). The selectivity brain map is about voxel selectivity. Voxels are 3D volume elements in the brain. A specific voxel is named by the location on the x-, y-, and z-axis (e.g., voxel [19,32,71]). Voxels should at least have a selective activation score of ‘not bad, pretty reliable’ to get involved in the voxel selection process. The PrAGMATIC brain map is about voxel selectivity by brain areas. Every area contains the place at the cortex, the left or right hemisphere, and a number to discriminate. In both brain maps concepts are categorized in to 11 main categories by semantic selectivity. All concepts used in the current study are categorized as visual by Huth et al. (2016). From the 191 visual voxels in the voxel-selectivity brain map 26 voxels were randomly selected, because using all visual voxels would not be feasible for a CST. These 26 voxels contain 116 words.

From the PrAGMATIC brain map, 13 brain areas are visual including 53 words. Some of the concepts were found in both brain maps. The found concepts are combined. Color and number concepts are left out because they do not seem to add any value. At this point, 126 concepts were included. For every concept, the Oxford Advanced Learner's Dictionary was used to make sure all definitions of a concept are included. For example, the concept 'top' can be a piece of clothing or the highest point of something. Because all the concepts used in the brain maps are presented as words, corresponding pictures are found via Google Images to be able to compare the textual and pictorial representation of concepts. During the search for pictures, an additional 17 concepts are left out, because they are difficult to visualize pictorially, like 'wears' and 'thicker'. For these concepts, it could be more likely that the participant confuses one concept with another (e.g., 'wears' could be seen as 'clothes'). All visualizable definitions of a concept are included. This resulted in 142 pairs of words and pictures, as can be seen in appendices C and D. The questionnaire contains these 142 pairs of words and pictures. With each pair, the proposition: 'The word and picture show the same concept' was given. A 7-point Likert scale was used from strongly disagree to strongly agree. An example is illustrated in Figure 5. This scale was eventually converted into grades with strongly disagree as a 1 and strongly agree as a 7.

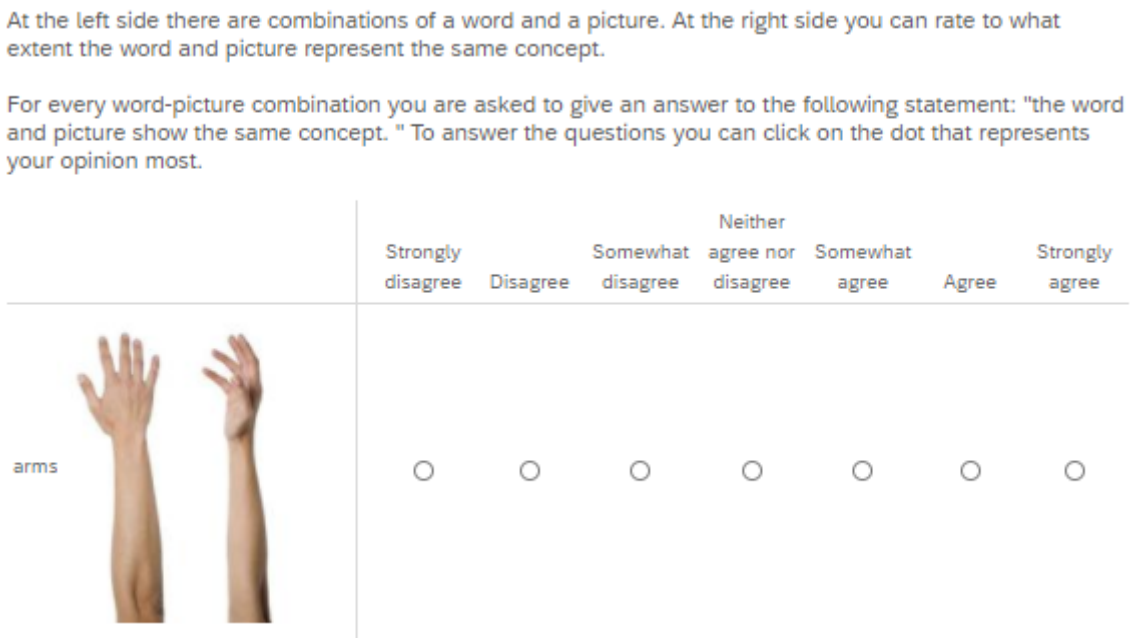

Figure 5. Example of the questionnaire

4.3. Procedure

Before the data collection could start the study was approved by the Ethical Committee from the University of Twente. The study took place online via Qualtrics. Participants got a link to the questionnaire on Qualtrics. The Qualtrics procedure for the subject can be seen in Appendix A. First the content and aim of the study and the questionnaire were explained. Thereafter, the procedure was discussed. Then, participants could read the informed consent and had to agree to go further and take part in the study as can be seen in Appendix A. Participants could only start the questionnaire by agreeing on the consent. Thereafter, four questions about demographics needed to be filled in: gender, age, nationality, and highest education. Subsequently, the questionnaire was explained. Then, the questionnaire, containing 142 picture – word pairs, started. Participants had to rate to what extent that word and picture represent the same concept, using the Likert scale presented in figure 5. Participants were asked to click on the dot that represents the answer that came closest to their opinion.

4.4. Data analysis

The maximum similarity score for a word-picture pair over all subjects (total score) was 35 and the minimum total score was 5. From the 142 pairs, the pairs that scored less than 33 on the total score were left out for the card sorting. This cut-off point was chosen because most of the pairs have relatively high scores. With this cut-off point a reasonable number of about 50 pairs for the card sorting study could be obtained (Martin & Hanington, 2012). For a given word, the word-picture pair with the highest score was selected. For example, the word uniform had three different picture items: school uniform, police uniform, and military uniform. School uniform scored 28. Since it is below 33 it was left out. Police uniform was also left out despite having a score of 33 because military uniform had a score of 34. With this procedure, a total of 45 concepts for the card sorting were found. To get an even number (for textual versus pictorial representation in the card sorting) one of the 17 pairs with a score of 32 was randomly picked and added to the concepts for the card sorting. This pair was from the concept ‘stockings’. This resulted in a total of 46 concept pairs used for card sorting.

5. Results of the questionnaire

The 46 concepts selected for the card sorting study are presented in Table 1. An overview of the word-picture pairs that made it to the card sorting can be found in Appendix B, and the pairs that did not make it to the card sorting can be seen in Appendices C and D.

In Table 2 the used brain areas from the PrAGMATIC brain map and voxels from the selectivity brain map can be seen with their corresponding concepts for items 1-23 in Table 1. The concept that occurs in the most brain areas was *cap*. *Cap* and *diameter* were often together. Most voxels have a logical set of concepts, like *boots – cap – gloves*, but some did not have a logical set of concepts: *feathers – diameter – cap – balloon* and *container – cylinder*. Lastly, 15 of the 36 voxels and brain areas contain only 1 item. Overall, it gives a usable set for the card sorting study.

In Table 3 this can be found for items 24-46 in Table 1. The concept *top* occurs most: 12 times. 13 of the 27 voxels and brain areas contain only 1 item. The words *top* and *orange* seem to occur in different meanings. *Orange* occurs together with *leaf*, but also with *hat* and *shirts*. *Top* occurs together with *slide* and *stockings*. This would mean that there was an expected difference in card sorting with the text and pictures, because with pictures only one meaning was picked. Furthermore, it is interesting that not all pieces of clothing were together in one area or voxel. There were also some not expected combinations, like: *slide-top-waist*. Overall, it gives a useful set for the card sorting study.

Tables 1, 2, and 3 were made for comparison with the categories made in the card sorting study. In appendices E and F, a combination of both can be seen, together with concepts that were not picked for this study. Appendix G shows the concepts that were selected with their corresponding voxel(s) and/or brain area(s).

Table 1

Concepts in the questionnaire.

Items 1-23		Items 24-46	
Item	Similarity score	Item	Similarity score
ball	34	hat (1)	35
balloon	35	hood	33
barrel	34	ice cream (2)	35
boots	34	jeans	35
bottle	35	jewelry	34
bowl	34	leaf	34
bra	35	millimetre	34
bread	34	orange	34
cap	35	rice	35
cents	33	sausage	35
champagne	33	shirts	35
cheese	35	shoes	34
chimney	33	slide	35
coin	35	sneakers	33
container	34	spoon	35
cylinder	33	sticks (3)	35
diameter	34	stockings	32
dollar (1)	34	top (1)	33
dough	34	trousers	33
egg	35	tunic (2)	35
feathers	35	uniform (3)	34
furniture	33	waist	34
gloves	34	wool	35

Note. A number between brackets after an item means that the word has more pictures. The number represents the place in the sequence. The similarity score is the total score from 0 to 35. The concept pairs (items) can be seen in Appendix B. The excluded pairs can be seen in appendices C and D.

Table 2

Brain areas and voxels with concepts 1-23.

Brain area/voxel	concepts
Inferior prefrontal cortex R1	cents
Inferior prefrontal cortex R5	cap; diameter
Lateral parietal cortex L2	cap; diameter
Latero-temporal cortex L10	cap; diameter
Laterotemporal cortex L2	cap; diameter
Laterotemporal cortex L3	cylinder; diameter
Ventrotemporal cortex L2	cap; cylinder
Ventrotempporal cortex L3	cap; diameter
Inferior prefrontal cortex L2	cap
Inferior prefrontal cortex L4	cap
Inferior prefrontal cortex L6	cap; cylinder; diameter
Inferior prefrontal cortex L10	cap
Inferior temporal cortex NS	feathers
5,60,68	barrel; cap; ball; diameter
6,74,74	cheese
6,77,72	cap
15,28,73	coin
15,83,62	cents; cap; dollar
15,87,36	chimney; furniture
16,23,71	container; cylinder
16,28,25	boots; cap; gloves
17,87,55	feathers; diameter; cap; balloon
17,87,60	bottle; cap; boots
19,17,56	coin; dollar; bread; dough; champagne; egg
19,19,43	container; cents; bottle
19,33,72	gloves; bottle; cap
19,33,73	cap; gloves
19,34,73	gloves; cap
19,36,72	cap; diameter
19,37,73	diameter; container
19,86,41	bowl
20,35,72	diameter
20,43,25	bra
20,72,68	bowl
21,71,26	cap
23,43,52	cents

Table 3

Brain areas and voxels with concepts 24-46.

Brain area	concepts
Inferior prefrontal cortex R5	top
Lateral parietal cortex L2	leaf; millimetre
Latero-temporal cortex L10	top
Laterotemporal cortex L2	top; millimetre; leaf
Laterotemporal cortex L3	millimetre; top
Ventrotempporal cortex L3	top
Inferior prefrontal cortex L2	leaf; orange
Inferior prefrontal cortex L4	tunic
Inferior prefrontal cortex L10	uniform; tunic; leaf; wool
Inferior temporal cortex NS	hood; tunic
5,60,68	sticks; top;
6,74,74	rice; sausage
6,75,72	stockings; shirts; tunic; uniform
6,77,72	top
10,74,26	slide
15,83,62	top
16,28,25	sneakers; stockings; shoes; trousers; jeans
17,87,60	orange; hat; shirts
19,17,56	jewelry; spoon
19,33,72	wool
19,33,73	wool
19,34,73	wool
19,37,73	top
19,86,41	top
20,35,72	millimetre
20,43,25	stockings; top
20,72,68	top; ice; wool
21,71,26	slide; top; waist

6. Method and procedure of the card sorting study

A card sorting study was performed in two different ways to compare categorization of concepts presented as picture and as word.

6.1. Information on card sorting and why it was used

Card sorting was used because it provides information about how concepts are categorized (Van der Velde, Wolf, Schmettow, & Nazareth, 2015). It is an empirical method for understanding mental models of concept domains (Schmettow & Sommer, 2016). Card sorting is a form of active categorization of concepts, based on relations between concepts (Halford et al., 2010). For example, most participants in the current study categorize all foods and drinks together. It is both qualitative and qualitative (Martin & Hanington, 2012). In card sorting participants receive a set of cards with a concept on each (Stienen, 2015). They have to make categories of those cards in a way that makes most sense to them (Wood & Wood, 2008). It can be done physically and online, which makes no difference according to Bussolon, Russi, and Missier (2006).

Card sorting can be open and closed. In open card sorting participants can organize concepts in a way that represents their best organization and in closed card sorting the categories are predefined (Wood & Wood, 2008). Open card sorting is more commonly used and advised to use, because more can be learned more from open than from closed card sorting (Spencer, 2009; Wood & Wood, 2008). Closed card sorting is advised to use when the set of categories cannot be changed, when adding something to an existing structure, and when having confidence that premade categories work well (Spencer, 2009).

Card sorting can be of one level or more levels. With multi levels there are also subcategories that can be made (Spencer, 2009). This is generally more useful, but most statistical techniques do not work with hierarchies (Spencer, 2009). Also, not every online card sorting program can handle multiple levels. Figure 6 shows an example of card sorting.

The results in a card sorting study are expressed as Jaccard scores. In one-level card sorting, the Jaccard score J(A,B) of two concepts A and B represents the number of times that A and B are placed in the same category, measured over all subjects. J(A,B) = J(B,A) and J(A,A) = n, with n as the number of subjects.

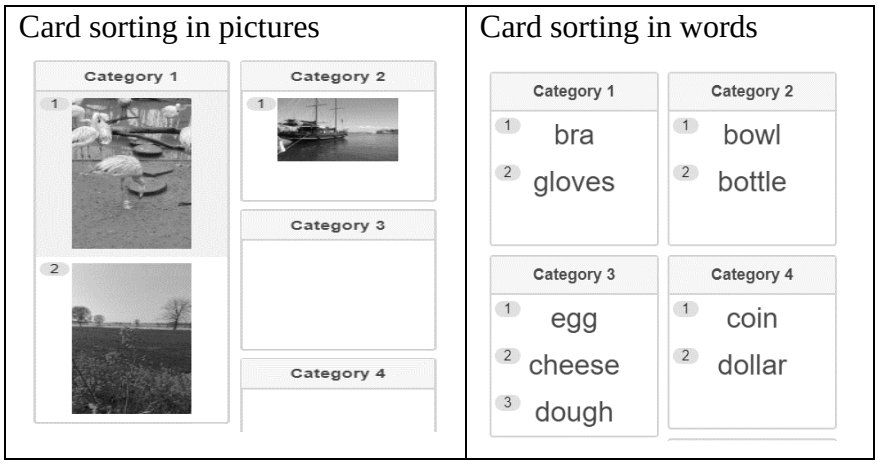

Figure 6. One level open card sorting in pictures and words.

6.2. Participants

For the card sorting study, the same inclusion criteria were used as for the questionnaire. Participants were collected via convenience sampling, and via SONA. SONA is a psychology research participation system for which students can register to participate in studies. The card sorting study included 28 participants, of which four dropped out before the end. Those four were therefore excluded from analysis. According to Wood and Wood (2008) having this number of participants can have a similar result as when having hundreds of participants. Additionally, according to Martin and Hanington (2012) diminishing returns will occur, and therefore the number of participants should be limited. 11 participants were male and 12 were female. One participant preferred not to tell the gender. The oldest participant was 66 years old and the youngest was 20 years old. The mean age was 28.4 (SD = 13.2). The highest degree of education varied from High School till Higher Education Master. The study included participants with a variety of nationalities: German (50%), Dutch (29.2%), Spanish (4.2%), Chinese (4.2%), British (4.2%), Irish (4.2%), and Romanian (4.2%). Nationality was recorded, because it can be that participants with a specific nationality think differently in the meaning of specific concepts, like it happened in the card sorting study of Schmettow and Sommer (2016). In their study, participants with German nationality categorized ‘parks’ as ‘transport’, since they thought of it as a parking lot, and Dutch participants categorized it as ‘leisure’, since they thought of it as a park.

6.3. Materials

For the card sorting Qualtrics was used. Qualtrics has the limitation that only one-level card sorting can be used. An advantage is that the recruitment of participants is easier and data analysis goes faster and classification can be better obtained (Bussolon et al., 2006).

The 46 concepts were made in cards with words or pictures. The same concepts were used for both modalities to avoid confounding differences in concepts. The concepts were divided in two groups, with the cut-off point picked at the middle in alphabetical order (between *gloves* and *hat*). Then, the order within these groups was randomized. Table 4 shows four possibilities in order and modality of the card sorting studies.

Table 4

Overview of card sorting possibilities.

	Items 1-23	Items 24-46
Participant group 1	Picture	Word
Participant group 2	Word	Picture

6.4. Procedure

For half of the participants the first 23 concepts were presented in textual modality and the other concepts were presented in pictorial modality, as shown in Table 4. For the other half of the participants the order was reversed. The concept items can be seen in Appendix B.

The information participants received per part of the session can be seen in Appendix H. A session took approximately 10 minutes on average. First, the participants received information about what the study is about. Thereafter, they received an informed consent, which they could accept and sign. They could only proceed when they agreed on the consent. Then, they had to fill in demographic questions about age, gender, nationality, and highest level of education. Thereafter, they received information about what they exactly had to do and thereafter an example was given, so they could try how the card sorting works on Qualtrics. After the example, the card sorting started.

The card sorting consisted of two tasks. The tasks itself were identical, but in one task the concepts were presented as picture and in the other task concepts were presented as a word. The order of the concept items, and which half of the items was presented as word or as picture were randomly picked for each participant. Participants were asked to place the cards into category boxes. Each task has 23 items and 16 category boxes. They were not allowed to re-arrange categories or to give names to categories. If they thought that a concept does not fit in the already made categories, they could place that concept in a new category. They did not need to use all 16 category boxes.

6.5. Data analysis

The data analysis was based on Van Der Velde (2018). The data was exported to Excel. The data was cleaned by filtering out participants who did not finish the card sorting and by cleaning the data of the open question on nationality. It was ensured that every nationality had a capital letter and that all same nationalities have the same name (e.g., for Dutch people only the value 'Dutch' instead of 'dutch', 'Nederlands' and 'Dutch'). If this is not the same, the data cannot be analyzed correctly because the system sees the intended as same values as different ones. Additionally, a new variable 'sequence' was made. This variable contained information about whether the first 23 items were presented as picture and the last 23 as word or vice versa. For every participant it was checked whether the cards sorting tasks A and B had 23 concepts each.

Four tables were made in which Jaccard scores (similarity matrices) in Excel: one for the first 23 items as text, one as picture, one for the last 23 items as text and one as picture. They can be found in Appendix I. The Jaccard scores for all participants in that specific sequence were added. The higher the score, the more the concept pair was related. At the end, the diagonal was filled in with the highest score possible, in this case 12 (the number of subjects in the study divided by two). When a table was finished, it consisted of two parts that needed to be identical around the diagonal, because J(A,B) = J(B,A) for any two concepts A and B. Both parts were compared to check if they indeed were identical. If this was not the case the number of categories containing the concept pair was counted again.

All Jaccard score tables were uploaded in R. R was used because flexible plotting and data matrices can be used. Especially flexible plotting was important in this study, since heatmaps and dendrograms needed to be constructed. A heatmap is a matrix with on each column and row the same list of concept items. The color of a heatmap represents the strength of the association between two concept items, which varies between zero in light yellow (cold) and 12 in deep red (warm) (Van der Velde et al., 2015). The more the intersection between two concepts is towards red, the stronger the similarity. A dendrogram is a hierarchical tree diagram that contains sequences of merges or splits (Schmettow, n.d.).

R can construct a heatmap and dendrogram using a vector analysis. A vector is one row or column (they are the same because of symmetry), which represents the Jaccard scores a concept has with the other concepts. The Euclidian distance of concepts (vectors) was calculated in R by calculating the difference of each pair of components of the vectors, squared, and summarized. Of that sum the square root is taken. R selected the vector pair with the lowest distance, meaning the strongest relationship between vectors, and replaced that pair with a cluster item. These steps were repeated up until no vectors were left. All clusters were produced

in the same manner, and then ordered around the diagonal from top left to bottom right. The output was an heatmap ordered around the diagonal from top left to bottom right, with a dendrogram. The clusters around the diagonal represent the concepts that are most strongly related. The top left cluster includes the concept combination with the lowest Euclidian distance. Hence, the sequence in which the concepts are ordered also provides information about the categorization. This procedure was done for each option of Table 4, so they could be compared. The syntax of the code in R can be found in Appendix J. A decision line was added in the dendrograms by hand for deciding on the clusters for having enough clusters and enough concepts within a cluster, and the same number of clusters for each heatmap to be able to compare them. Therefore, we strived for around five clusters per heatmap. However, every cluster should include at least two concepts, resulting in one having only four clusters.

Since the ordering sequence of the concepts also provides information about categorization in the card sorting task, these were analyzed. For the categorization to be the same, this means that the ranks in the heatmap also should be the same. Two tables were made: one for items 1 till 23 and one for the others. They can be found in Appendix K. Each concept was ranked by the place in the sequence in the heatmap. The concept most left got rank 1 and the one most right got rank 23, since there were 23 concept items in a heatmap. Comparing means or medians was not useful since both the textual and pictorial ranks were from 1 to 23 with all ranks occurring only once. A correlation test was used, since correlation can say something about the difference since a perfect correlation means that the ranks were identical, and a weak or negative correlation could mean that they were different. A scatterplot was made to choose a statistical test. Because of a monotonous relationship, Spearman's Rho was used.

To be able to compare active categorization by card sorting with the Huth map, it could be interesting to know whether there is a difference in Jaccard scores of concept combinations of within and between voxels/brain areas. For example, voxel 6,74,74 contains *rice* and *sausage* and voxel 19,17,56 contains *jewelry* and *spoon*. *Rice-sausage* is a within voxel combination and *rice-jewelry* is a between voxel combination. This could tell something about whether voxel/brain area activation matters for active organization. For these combinations, the corresponding Jaccard scores were used and translated into relative Jaccard scores, which were the Jaccard scores divided by the number of participants, as can be found in Appendix L. Relative scores were used because analysis is easier for data between zero and one than for between zero and twelve. Firstly, textual and pictorial data were individually used for comparison between within and between voxel/brain area combinations. Thereafter, textual and pictorial Jaccard scores were compared for within and between voxel/brain area

combinations individually. Lastly, a general comparison was made between within and between voxels/brain areas, regardless of the modality. This could be done since there was only a weak marginal difference for textual versus pictorial scores of within voxels/brain area combinations and non-significant for between voxel/brain area combinations, as can be seen section 7.3. For all five comparisons a set of two lists were made, as can be seen in in Table 5.

Table 5

Overview of what was compared in the data analysis of the relative Jaccard scores of within and between voxels/brain areas concept combinations.

Comparison	List 1	List 2	Test used
Textual within – between	Textual within	Textual between	Wilcoxon rank-sum
Pictorial within – between	Pictorial within	Pictorial between	Wilcoxon rank-sum
Within textual – pictorial	Within textual	Within pictorial	Wilcoxon signed-rank
Between textual – pictorial	Between textual	Between pictorial	Wilcoxon signed-rank
Within – between combined	Within combined	Between combined	Wilcoxon rank-sum

Note. All comparison tables can be found in Appendix L.

Concept combinations were only used when they both did not occur in more than one voxel/brain area. For the between voxel/brain area data, an additional requirement was that voxels/brain areas with one concept did not count, so when a concept was alone in its voxel and with others in another voxel, it still was included in the analysis, despite occurring in more than one voxel/brain area. The goal of all five comparisons was to test whether there was a difference. For within textual – pictorial and between textual – pictorial the data were paired, because for both lists the concept combinations that activate the same voxel/brain area different ones were used. Therefore, a paired t-test was appropriate if all assumptions were met. For the other comparisons the data were independent since they compare within voxel/brain area and between voxels/brain areas, which have different concept combinations. Therefore, a two-sample t-test was appropriate if all assumptions were met. For all data the normality assumption was tested through plotting the data and performing a Shapiro-Wilk test. For all data the normality assumption was violated. Therefore, non-parametric alternatives were used: The Wilcoxon signed rank test as alternative for the paired t-test and the Wilcoxon rank-sum test for the two sample t-test (Pagano, 2009). Since statistically significance does not tell anything about the size of the difference, the effect size was also measured using Pearson's *r* (Sullivan & Feinn, 2012). For both the Wilcoxon signed-rank and rank-sum test Pearson's *r* is appropriate (Tomczak & Tomczak, 2014).

7. Results of the card sorting study

The analysis consists of analyses of the four heatmaps with dendrograms, the comparison of ranks between textual and pictorial, and the comparison of within and between voxels/brain areas.

7.1. Analysis of the heatmaps and dendrograms: cluster analysis

Four heatmaps with dendrograms were made: a textual and pictorial one for items 1-23 and a textual and pictorial for items 24-46. These were used for identifying clusters. Global inspection of all heatmaps and dendrograms gave five clusters. First, every individual dendrogram and heatmap was inspected. The distances in the individual dendrograms, which should not be too large, and the red squares around the diagonals of the heatmaps were analyzed. Furthermore, there should be enough clusters for comparison and enough concepts within those clusters. To be able to compare the heatmaps, the number of clusters should be relatively same. After the individual and global inspections, using five clusters seems to be the most appropriate. All heatmaps will be discussed individually and will compared afterwards.

7.1.1. Concepts 1 till 23

The heatmap of Figure 7 presents concept items 1 to 23 in textual representation and Table 6 shows the five clusters identified for items 1 to 23 in textual representation. The blue lines identify the clusters in the dendrogram, the squares indicate the same clusters in the heatmap, and the ovals/circles indicate related concepts outside the cluster.

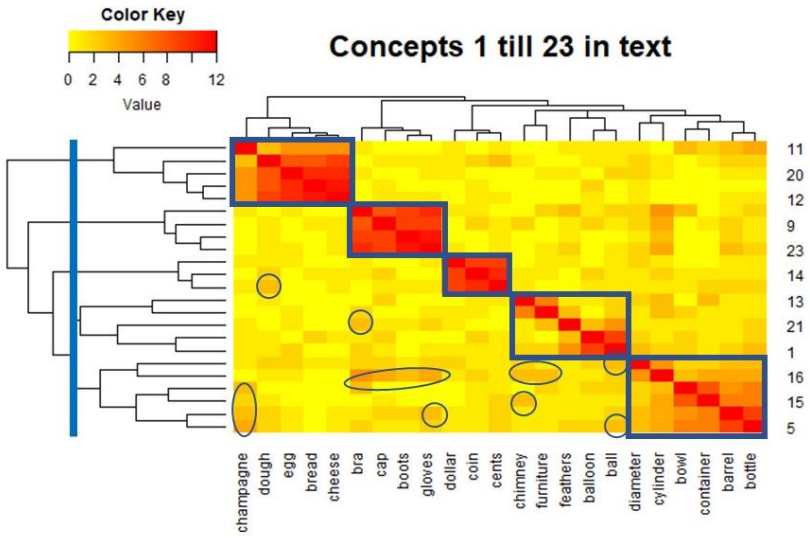

Figure 7. Heatmap of concepts 1 till 23 in textual representation.

Table 6

Clusters of concepts 1-23 in text based on the colors around the diagonals of the heatmap and decision line in the dendrogram of figure 6.

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
champagne	bra	dollar	chimney	diameter
dough	cap	coin	furniture	cylinder
egg	boots	cents	feathers	bowl
bread	gloves		balloon	container
cheese			ball	barrel
				bottle

The first cluster contains five words: *champagne, dough, egg, bread,* and *cheese*. Within this group, c*hampagne* has a brighter color and seems to have a connection with *bowl, barrel, and bottle*. *Dough* seems to have a moderate relation with *cents*. The next group contains four items: *bra, cap, boots,* and *gloves*. These are all colored dark red, which means that they are strongly related. *Cylinder* is moderate to strongly related to the whole cluster. Furthermore, *bra* is moderately related to *feathers* and *bowl,* and *gloves* with *barrel*. The next group is also dark red colored and contains *dollar, coin,* and *cents*. The next groups show weaker relationships. *Chimney, furniture, feathers, balloon,* and *ball* form a cluster. Within this cluster, *balloon* and *ball* show a strong relationship. *Chimney* and *furniture* show a somewhat strong relationship with each other but not with the rest of the cluster, except for *furniture* and *feathers*. *Feathers* shows the strongest relationship with *ball*. Chimney and furniture seem related with cylinder, and chimney also with container. Additionally, ball seems to be somewhat related to *diameter* and *bottle*. The last cluster contains *diameter, cylinder, bowl, container, barrel,* and *bottle*. Cylinder seems however even strongly related to the '*champagne, dough, egg, bread,* and *cheese* group'.

The heatmap with dendrogram of Figure 8 presents concept items 1 to 23 in pictorial representation and Table 7 gives an overview of the clusters that are formed. The blue lines identify the clusters in the dendrogram, the squares indicate the same clusters in the heatmap, and the ovals/circles indicate related concepts outside the cluster.

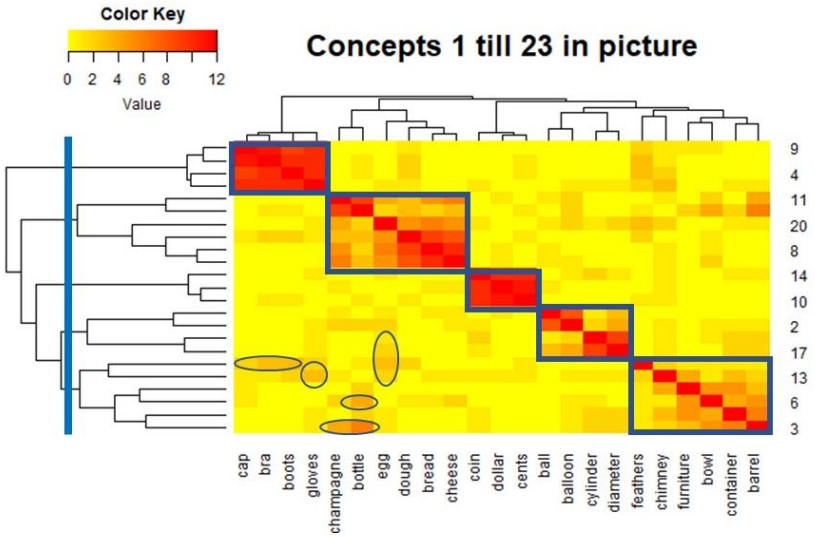

Figure 8. Heatmap of concepts 1 till 23 in pictorial representation.

Table 7

Clusters of concepts 1-23 in picture based on the colors around the diagonals of the heatmap and decision line in the dendrogram of Figure 8.

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
cap	champagne	coin	ball	feathers
bra	bottle	dollar	balloon	chimney
boots	egg	cents	cylinder	furniture
gloves	dough		diameter	bowl
	bread			container
	cheese			barrel

The first cluster contains four words: *cap, bra, boots,* and *gloves*. The next cluster contains: *Champagne, bottle, dough, bread,* and *cheese.* This cluster contains two dark red small clusters. The first one is *champagne* and *bottle* and the second one is *dough, bread,* and *cheese*. Additionally, *egg* falls in this cluster, but this correlation is somewhat weaker. The relation is stronger with *dough*, *bread*, and *cheese*. *Bottle* shows a strong relationship with *barrel* and moderate relationship with *bowl*. *Champagne* also shows a moderate relationship with *barrel*. The following cluster is again dark red and contains *coin, dollar,* and *cents. Ball, balloon, cylinder* and *diameter* form a cluster. *Diameter* is however stronger related with *ball* and *balloon* than cylinder relates to them. *Ball* and *balloon* are strongly related, and *cylinder* and *diameter* are strongly related. The last cluster contains *feathers, chimney, furniture, bowl, container,* and *barrel* when looking at the decision line in the dendrogram. *Feathers* seems to be more correlated with *boots*, *bra,* and *egg*. C*himney* and *bowl* seem not to be correlated. Some items do seem to have a relationship outside their own cluster. *Barrel* seems to be related

to *champagne* and *bottle*. *Bowl* seems also moderately correlated with *bottle*. Also, *Chimney* seems moderately correlated with *gloves*.

7.1.2. Concepts 24 till 46

The heatmap with dendrogram of Figure 9 shows concept items 24 to 46 in textual representation and Table 8 shows the clusters that are formed. The blue lines identify the clusters in the dendrogram, the squares indicate the same clusters in the heatmap, and the ovals/circles indicate related concepts outside the cluster.

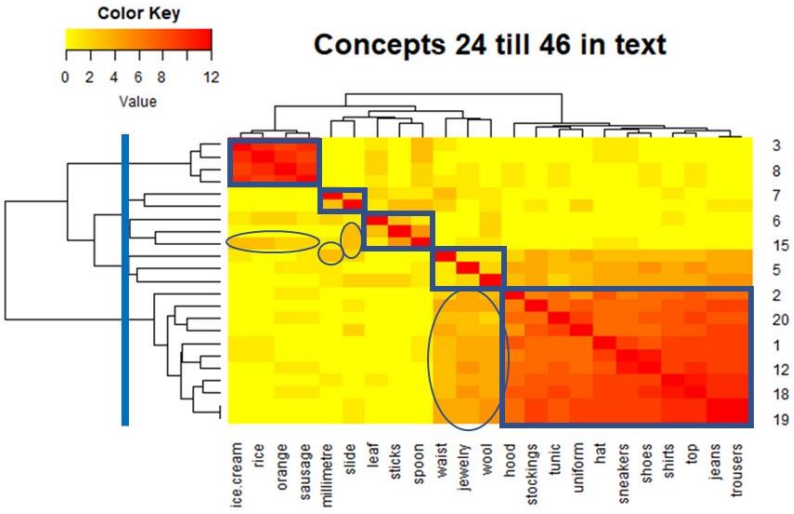

Figure 9. Heatmap of concept items 24-46 in textual representation.

Table 8

Clusters of concepts 24-46 in text based on the colors around the diagonals of the heatmap and decision line in the dendrogram of Figure 9.

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
ice cream	millimetre	leaf	waist	hood
rice	slide	sticks	jewelry	stockings
orange		spoon	wool	tunic
sausage				uniform
				hat
				sneakers
				shoes
				shirts
				top
				jeans
				trousers

The first cluster contains four items: *ice cream, rice, orange,* and *sausage*. Additionally, *spoon* seems to be correlated to this cluster. Cluster 2 contains *millimetre* and *slide. Slide* also

has a relationship with *sticks* and *spoon*. *Millimetre* has also a *relationship* with waist. The next cluster contains *leaf*, *sticks*, and *spoon*. Within this cluster *sticks* and *spoon* seem highest correlated because they are dark orange. Likewise, *sticks* and *leaf* seem correlated but less than the former. However, *leaf* and *spoon do not show strong correlation*. Cluster 4 contains *waist*, *jewelry*, and *wool*. According to the dendrogram they belong together, but when looking at the colors of the heatmap, they do not show a relationship. They all seem more related to the last cluster. The last cluster is relatively large, containing 11 concept items: *hood*, *stockings*, *tunic*, *uniform*, *hat*, *sneakers*, *shoes*, *shirts*, *top*, *jeans*, and *trousers*. All seem highly correlated showing dark red. Table 8 gives an overview of clusters of items 24 to 46 in text.

The heatmap with dendrogram in Figure 10 shows concept items 24 to 46 in pictorial representation and Table 9 shows the clusters that were formed through inspection of Figure 10. The blue lines identify the clusters in the dendrogram, the squares indicate the same clusters in the heatmap, and the ovals/circles indicate related concepts outside the cluster.

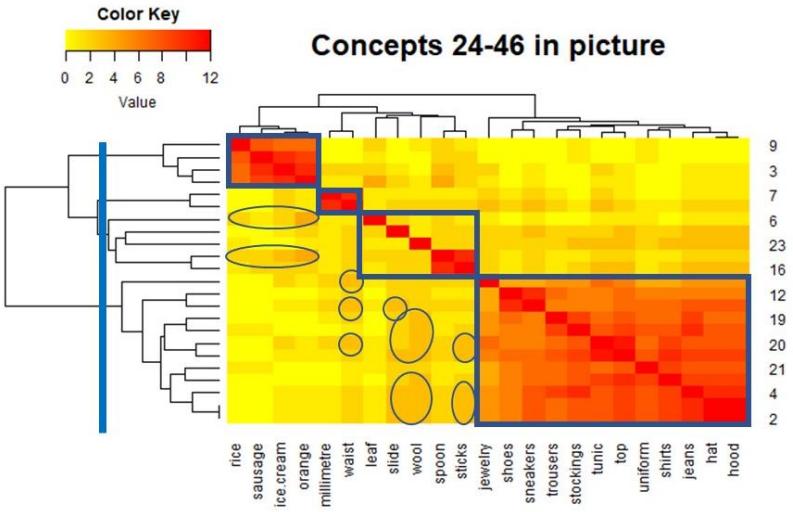

Figure 10. Heatmap of concept items 24 till 46 in pictorial representation.

Table 9

Clusters of concepts 24-46 in picture based on the colors around the diagonals of the heatmap and decision line in the dendrogram of Figure 10.

Cluster 1	Cluster 2	Cluster 3	Cluster 4
rice	millimetre	leaf	jewelry
sausage	waist	slide	shoes
ice cream		wool	sneakers
orange		spoon	trousers
		sticks	stockings
			tunic
			top
			uniform
			shirts
			jeans
			hat
			hood

The first cluster contains *rice, sausage, ice cream,* and *orange.* Additionally, *leaf* and *spoon* show some correlation with this cluster. The next cluster contains *millimetre* and *waist. Waist* also shows a moderate correlation with *jewelry*, *sneakers*, and *tunic* and weak correlation with nearly all other items. Cluster 3 contains *leaf, slide, wool, spoon,* and *sticks.* Within this cluster *spoon* and *sticks* show a high correlation. *Leaf and wool and slide and wool* show no correlation. *Slide* and *wool* have a low correlation with *spoon* and *sticks*. *Leaf* shows a higher correlation with *orange* than the concepts in cluster 3. *Slide* seems to have a moderate correlation with *sneakers, top, jeans, hat,* and *hood. Wool has a moderate correlation with most of the items of the last cluster*. *Sticks* has a moderate correlation with *top, uniform, had,* and *hood.* The last cluster contains 12 items: *jewelry, shoes, trousers, stockings, tunic, top, uniform, shirts, jeans, hat,* and *hood*. In this cluster the color varies from medium orange to dark red. *Jewelry* shows a weaker relationship with *shoes*, *sneakers*, *uniform*, and *shirts*. *Shoes* and *sneakers* are highly related, as well as *trousers* and *stockings*, *tunic* and *top*, and *jeans, hat,* and *hood*. From outside this cluster, *slide*, *wool*, and *sticks* show a moderate correlation with half of this cluster. This cluster shows no relationship with *rice* and *sausage*. The others have a weak relationship with the cluster.

7.1.3. Comparison of the textual and pictorial clusters

For items one till 23 the concept clusters *dollar, cents,* and *coin* and *bra, cap, boots,* and *gloves* are relatively the same, except for the strong correlation with *cylinder* in the textual heatmap. The cluster of *dollar, cents*, and *coin* also has the same place in both heatmaps. Only the order within the cluster varies. Within the cluster of *bra*, *cap*, *boots*, and *gloves*, *bra* and *cap* are

reversed. Furthermore, this cluster is switched with the cluster of *champagne, (bottle), egg, dough, bread, cheese*. Within that cluster *egg* and *dough* are reversed and in the pictorial heatmap *bottle* is part of this cluster, whereas this is not the case in the textual heatmap. The remaining clusters have more differences. In both heatmaps *ball* and *balloon* occur together, but they are part of clusters with different concepts. Within the textual heatmap they occur together with *chimney*, *furniture*, and *feathers*, while within the pictorial heatmap they occur together with *cylinder* and *diameter*. In both heatmaps *chimney*, *furniture* and *feathers* occur together, but they are part of different clusters with different places within the heatmap. Within the textual heatmap they occur with *ball* and *balloon* and within the pictorial heatmap they occur with *bowl*, *container*, and *barrel*. Within the textual heatmap *bowl, container*, and *barrel* also occur together in the same order. However, there they occur together with *diameter*, *cylinder*, and *bottle*.

For items 24 till 46 the heatmap of pictorial representation shows more warm spots outside diagonal areas. Both have a strong cluster of *ice cream, rice, orange,* and *sausage*. This cluster is for both heatmaps the first one. Only within this cluster there were no similarities found between the places of the concepts. *Millimetre* is at the same place in both heatmaps. *Millimetre* and *waist* are highly correlated in pictorial representation, but moderate in textual representation. In the textual heatmap they even do not form a cluster. Within the pictorial heatmap *millimetre* forms a cluster with *slide,* having a moderate correlation. These have only low correlation within the textual heatmap. *Leaf*, *sticks*, and *spoon* occur together in both heatmaps. *Leaf* is at the same place in both heatmaps. *Sticks* and *spoon* show in both the highest correlation within the cluster they are in. In both heatmaps the concepts of cluster 3 and 4 are not highly correlated, except for *spoon* and *sticks*. Of both heatmaps the last cluster contains almost the same concepts. Only *jewelry* is part of another cluster in the textual heatmap. Except for *shirts* there are no similarities between the place of the concepts within the cluster.

Overall, there were resemblances and differences seen between the textual and pictorial heatmaps and dendrograms. Most items were clustered together in both heatmaps, but a certain number of concepts were not clustered with the same concepts. Furthermore, the places of most clusters and concepts within those clusters also differ. For items one till 23 the textual heatmap shows more darker spots outside diagonal areas, while for items 24 till 46 the pictorial heatmap shows more of them.

7.2. Analysis on ranks in the heatmaps

Since the place of the items within the clusters seems to differ, it is interesting to see to what extent it differs. The place in the heatmap is based on how small the Euclidian distance is between concepts, with the concept pair with the smallest one most left and so on. Therefore, it is interesting to look at the place in the heatmap. The places were transformed into ranks, with the most left concept as rank 1 and most right one as rank 23. Ranking made the places in the heatmaps comparable. The data analysis on the ranks was based on a table of ranks of the concepts within the heatmaps of Appendix K. The textual order was the basis of the comparison, with the concept most left as rank 1 and most right as rank 23. Then the pictorial rank of the same concept was put in the next column. So, *champagne* has rank 1 in the textual heatmap and rank 5 in the pictorial heatmap. Comparing means or medians of the ranks has no use since every heatmap has a rank from 1 to 23 in which every rank occurs only once. However, analysis on association could give information on the difference between the ranks since a perfect linear relationship means that they are identical, and strong relationship could also mean that they are significantly similar. Based on the analysis of section 7.1 there is expected that the relationship is at least monotonically positive because the results of 7.1 indicated that there is a global similarity but there are also some differences.

7.2.1. Comparison of textual and pictorial of items 1-23

To test the correlation and difference between textual and pictorial ranks of clusters within the heatmaps a scatterplot was made and a test on correlation was used. The textual and pictorial ranks were plotted in a scatterplot to know whether there is a global pattern of association between the two (Figure 11).

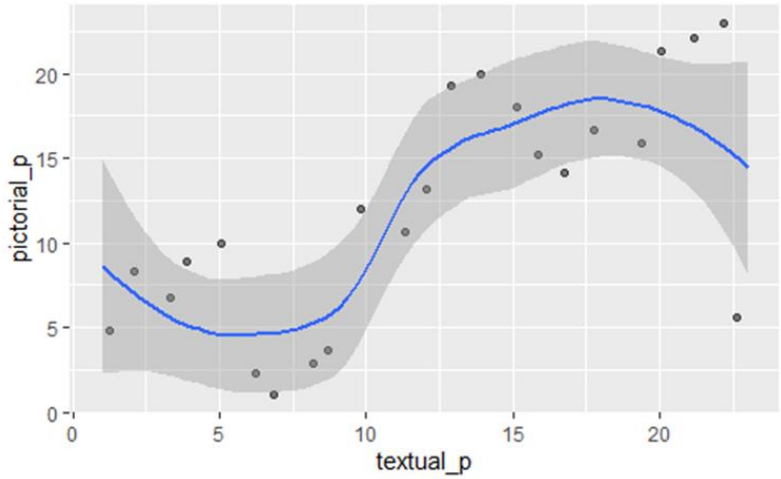

Figure 11. Scatterplot of the association of the ranks of concepts 1-23 in the textual and pictorial heatmap.

The textual ranks were placed on the x-axis and the pictorial on the y-axis. As can be seen in Figure 11, most clusters seemed relatively the same. The first two clusters were switched. The association between the ranks of concept items 1-23 was not linear. Except for rank 23 of the textual (six of the pictorial) heatmap the relationship seems somewhat monotonic. Therefore, Spearman's Rho seems most appropriate. If $R_s=0$ it would mean that the relationship is not monotonous. There is was statistically significant positive correlation between the ranks of concepts in the textual and pictorial heatmap (R_s = .694, n = 23, p <0.001) (Statstutor, n.d.).

7.2.2. Comparison of textual and pictorial of items 24-46.

For items 24-46 the same procedure was followed, and the same hypothesis was used as for 1-23. The scatterplot of Figure 12 has the same structure as the one of Figure 11. As can be seen in Figure 12, there was a monotonous association between the textual and pictorial ranks of the concepts. The association started almost linearly but the association became less clear from rank 13. This means that Spearman's Rho is the most appropriate test.

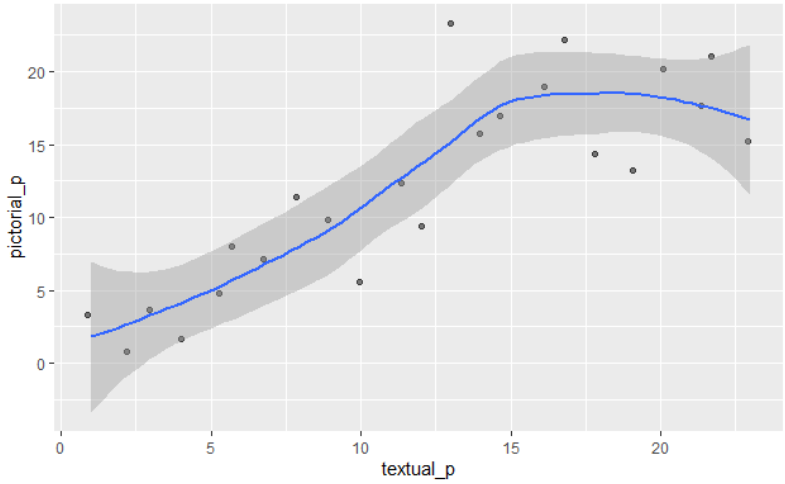

Figure 12. Scatterplot of the association between the ranks of concept items 24-46 in the textual and pictorial heatmap.

Generally, when a concept had a lower rank in one heatmap it also had a lower rank in the other one. This was strongest in the lower ranks. There is a statistically significant strong positive correlation between the ranks of the concepts in the textual and pictorial heatmap (R_s = 0.843, n = 23, p < 0.001) (Akoglu, 2018).

7.2.3. The results of the ranks combined

To conclude, there seems to be a monotonous positive relationship between ranks of concepts in the textual and pictorial heatmaps. This could mean that textual and pictorial ranks are generally the same, but there seem to be some differences as well. Therefore, no clear distinction can be made between the symbolic and the embodied view. The symbolic view would predict a perfect linear relationship (assuming the words and pictures do activate the same concepts), which could be correct for the first half of items 24 till 26, but not for the other part and for items one till 23.

7.3. Concept combinations of within and between voxels/brain areas

The analysis was performed on the differences in Jaccard scores between concept combinations that were from the same voxel/brain area versus from different voxels/brain areas. This was done because this difference can tell something about to what extent it matters if concepts were stored in the same voxels or not for the active use of concepts and if modality differs in this respect. For example, voxel 6,74,74 contains *rice* and *sausage* and voxel 19,17,56 contains *jewelry* and *spoon*. *Rice-sausage* is a within voxel combination and *rice-jewelry* is a between voxel combination. First, the relative Jaccard scores of within and between voxel/brain area combinations for textual concept representation will be compared. Thereafter, the same will be discussed for pictorial concept representation. Thirdly, the textual and pictorial representation will be compared for concept pairs within voxels/brain areas. Thereafter, the same will be done for concept pairs between voxels/brain areas. Lastly, the overall relative Jaccard scores for within and between voxels/brain areas will be discussed. All tables used for these analyses can be found in Appendix L.

7.3.1. Textual Jaccard scores of within versus between voxels/brain areas concept combinations

The first comparison was done about the textual relative Jaccard scores for within versus between voxel/brain area concept combinations. As can be seen in Table 10, the median and average of the relative Jaccard scores for textual representation were higher for within voxels/brain areas than for between. Within had a higher interquartile range and standard deviation and a higher maximum.

Table 10.

Descriptive statistics of textual relative Jaccard scores of within and between voxel/brain area.

	Within	Between
N	99	74
Median	0.17	0.08
Interquartile range	0.500	0.167
Average	0.33	0.10
Standard deviation	0.28	0.12
Minimum	0.00	0.00
Maximum	1.00	0.50

To check normality, a histogram was made, and the Shapiro Wilk test was performed. As can be seen in figure 12, the textual relative Jaccard scores of within and between voxel or brain area combinations do not follow a normal distribution. This was confirmed by the Shapiro-Wilk test ($p < .001$, W = 0.89, W = 0.79). The samples (concept combinations) were independent, and the data were at least measured at an ordinal scale. Therefore, the Wilcoxon rank-sum test was used.

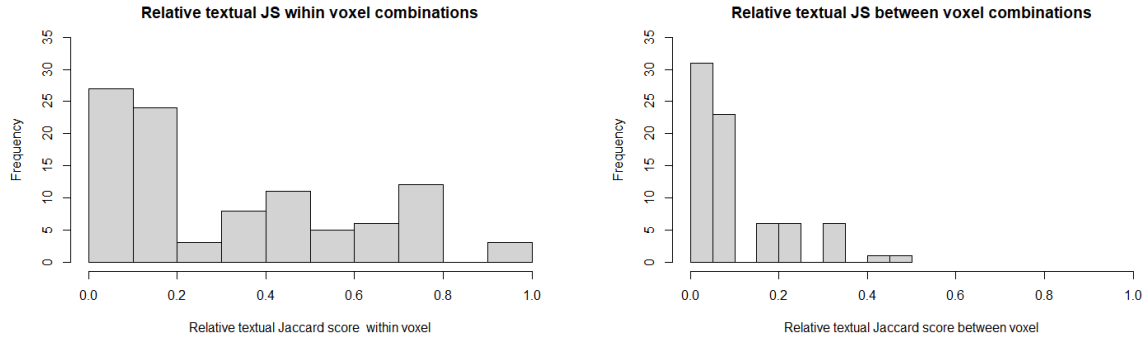

Figure 12. Histograms of relative textual Jaccard scores of within (left) and between (right) voxel/brain area combinations

There was enough evidence to reject the null hypothesis of no difference between within and between relative Jaccard scores ($p < .001$, W = 5608). The within voxel/brain area relative Jaccard scores were significantly higher than the between voxel/brain area ones. With an effect size of $r = .46$ ($z = -6.07$, N = 173), the difference of relative Jaccard scores between the medians of the within and between voxels/brain areas categorization was moderate to strong (Akoglu, 2018; Zaiontz, n.d.).

7.3.2. Pictorial Jaccard scores of within versus between voxels/brain areas concept combinations

For the comparison of pictorial relative Jaccard scores of within versus between voxels/brain areas concept combinations, the same procedure was used as for textual representation. As can be seen in Table 11, the median and average of the relative Jaccard scores for pictorial representation were higher for within voxels/brain areas than for between. Within had a higher interquartile range and standard deviation and a higher maximum.

Table 11.

Descriptive statistics of pictorial relative Jaccard scores of within and between voxel/brain area.

	Within	Between
N	99	74
Median	0.17	0.08
Interquartile range	0.583	0.167
Average	0.30	0.11
Standard deviation	0.31	0.13
Minimum	0.00	0.00
Maximum	0.92	0.67

To check normality, a histogram was made, and the Shapiro Wilk test was performed. As can be seen in figure 13, the pictorial relative Jaccard scores of within and between voxel or brain area combinations were not normally distributed. This was confirmed by the Shapiro-Wilk test ($p < .001$, W = 0.84, W = 0.80). The samples (concept combinations) were independent, and the data were at least measured at an ordinal scale. Therefore, the Wilcoxon rank-sum test was used.

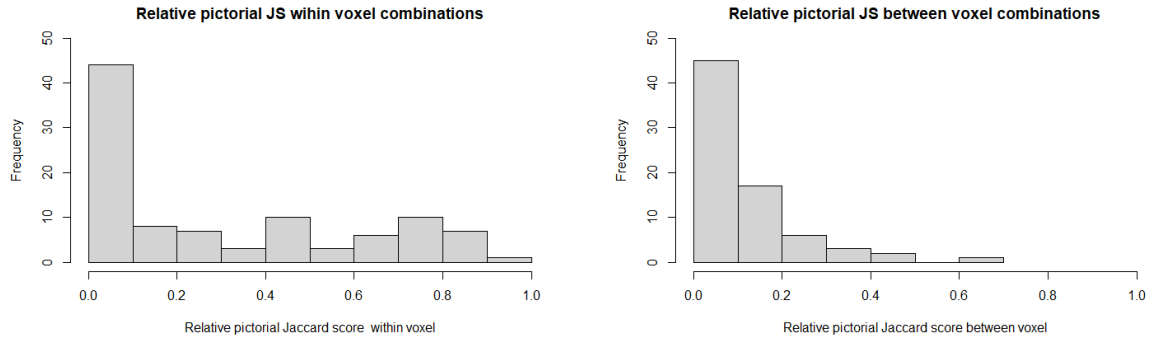

Figure 13. Histograms of relative pictorial Jaccard scores of within (left) and between (right) voxel/brain area combinations

There was enough evidence to reject the null hypothesis of no difference between within and between relative Jaccard scores ($p < .001$, W = 4762.5, n = 99). The within voxel/brain area relative Jaccard scores were significantly higher than the between voxel/brain area scores. With an effect size of $r = .26$ ($z = -3.46$, N = 173), the difference of pictorial relative Jaccard scores within and between voxels/brain areas categorization was weak to moderate (Akoglu, 2018; Zaiontz, n.d.).

7.3.3. Textual versus pictorial Jaccard scores of within voxel/brain area concept combinations

As discussed above, there seems to be a difference between within and between voxels/brain areas for both textual and pictorial representation individually. Therefore, it is interesting to know to what extent modality could matter in this respect. As can be seen in Table 12, the median, interquartile range, average and standard deviation were relatively same for the textual and pictorial representation of concept combinations. The maximum relative Jaccard score differs somewhat more.

Table 12.

Descriptive statistics of textual and pictorial relative Jaccard scores of within and between voxels/brain areas concept combinations.

	Within		Between	
	Textual	Pictorial	Textual	Pictorial
N	99	99	74	74
Median	0.17	0.17	0.08	0.08
Interquartile range	0.500	0.583	0.167	0.167
Average	0.33	0.30	0.10	0.11
Standard deviation	0.28	0.31	0.12	0.13
Minimum	0.00	0.00	0.00	0.00
Maximum	1.00	0.92	0.50	0.67

As can be seen in the left histograms of figures 12 and 13, the data was not normally distributed. The samples were paired, since for both textual and pictorial representation of concepts that activate the same voxel/brain area were used. Since the samples were paired and the data are at least measured at an ordinal scale, the Wilcoxon signed-rank test was used. There was enough evidence to reject the null hypothesis of no difference between textual and pictorial relative Jaccard scores of concept combinations within voxels/brain areas ($p = .03$, V = 2175.5,

n = 99). The textual relative Jaccard scores were significantly higher than the pictorial ones. However, with an effect size of r = .16 (z = -2.20, n = 99), the difference between the medians of the textual and pictorial categorization was weak (Akoglu, 2018).

7.3.4. Textual versus pictorial Jaccard scores of between voxels/brain areas concept combinations

For concept combinations that activated different voxels/brain areas, the same procedure was used as for within voxels/brain areas. Table 12 shows that the descriptive statistics of textual and pictorial representation of between voxel/brain area concept combinations are relatively the same.

As can be seen in the right histograms of figures 12 and 13, the data not normally distributed. Since the samples were paired, not normally distributed, and the data were at least measured at an ordinal scale, the Wilcoxon signed-rank test was used.

There was not enough evidence to reject the null hypothesis of no difference between textual and pictorial relative Jaccard scores of concept combinations between voxels/brain areas (p = .17, V = 416.5, n = 74). The pictorial relative Jaccard scores were not significantly higher than the textual ones. With an effect size of r = .11 (z = -1.37, n = 99), the difference between the medians of the textual and pictorial categorization was weak.

7.3.5. Comparison of within and between voxel/brain area concept combinations

It could also be interesting to know whether the difference between within and between voxels/brain areas concept combinations are statistically significant in general, regardless of modality. Textual and pictorial data can be combined since the difference was only marginal and weak for within voxel/brain area combinations and not significant for between voxel/brain area concept combinations. The textual and pictorial data were combined in two lists: one for concept combinations within voxels or brain areas and one for between voxels or brain areas, as can be seen in appendix L. As can be seen in Table 13, the median, interquartile range, average, standard deviation, and maximum were higher for within voxel/brain area of concept combinations than for between combinations.

Table 13.

Descriptive statistics of textual and pictorial relative Jaccard scores of within and between voxels/brain areas concept combinations.

	Within	Between
N	198	148
Median	0.17	0.08
Interquartile range	0.500	0.167
Average	0.31	0.10
Standard deviation	0.29	0.12
Minimum	0.00	0.00
Maximum	1.00	0.67

To check normality, histograms and a Shapiro-Wilk test. In figure 14 can be seen that for both within and between voxel combinations the data was right skewed, but for between the skewness seemed stronger. This assumes that the data is not normally distributed. The Shapiro-Wilk test confirmed that both the within data ($p < .0001$, W = 0.87) and the between data ($p < .0001$ (W = 0.80). Since the samples were independent and the data were at least measured at an ordinal scale, the Wilcoxon rank-sum test was used.

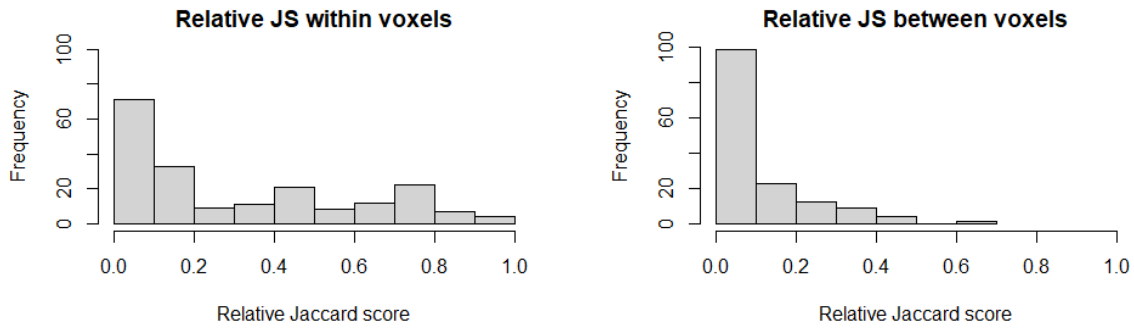

Figure 14. Histograms of relative Jaccard scores of within (left) and between (right) voxel or brain area combinations.

There was enough evidence to reject the null hypothesis of no difference between within voxel or brain area combinations and between voxel or brain area combinations relative Jaccard scores of within and between voxel/brain area concept combinations ($p < .0001$, W = 20681). With an effect size of $r = .36$ ($z = -6.68$, N = 346) the difference was moderate (Akoglu, 2018). The relative Jaccard scores within voxels/brain areas were significantly higher than those of between voxels/brain areas.

8. General discussion

This study aimed at investigate to what extent judgement and organization of visual concepts of the brain map of Huth et al. (2016) differs for textual and pictorial representation of concepts. The results indicate that there is a non-significant to marginal difference between the organization of textual versus pictorial representation of concepts. There is a positive monotonous relationship between the ranks of the concepts within the textual and pictorial CST heatmaps. This could indicate that the ranks are not significantly different, because when a rank is low in one heatmap it is also low in the other heatmap and when a rank is high in one heatmap it is also high in the other heatmap. This suggests that that the symbolic processes play a role since the relationship is strongly positive. The symbolic approach assumes that information processing is amodal. This means that there is no difference in textual and pictorial representation of concepts.

The symbolic approach would predict a 'perfect' positive relationship, if the words and pictures do activate the same concept. The questionnaire indicates that this would be the case. Hence, this could mean that other unknown processes could also play a role; whether these other processes are embodied cannot be concluded from this work.

The findings are in line with the hub-and-spoke theory, LASS framework, and the symbol interdependency theory, since they all indicate that the symbolic and other processes work together (Lambon Ralph et al., 2017; Louwerse, 2007; Malhi, 2015). The reason for the major role of the symbolic processes could be that all used concepts are concrete objects. As the hub-and-spoke theory suggests, concrete concepts are mainly processed by the ATL, which functions as hub (Lambon Ralph et al., 2017). The hub is amodal and therefore the processing is symbolic. The minor processing by the modal spokes could be the reason for the minor difference between categorization using pictures versus words. Therefore, it could be that some processes are embodied. However, more research is needed on this topic.This is also in line with the study of Goldstone, Kersten, and Carvalho (2018). They found that picture and word may trigger different representations while having overall the same core concepts..

There was only a non-significant to weakly marginal difference between textual and pictorial relative Jaccard scores. For within voxels/brain areas, the textual Jaccard scores were weakly marginally higher, and for between voxels/brain areas the pictorial Jaccard scores were non-significantly higher. The symbolic approach would predict that there is no difference since categorization would be modality independent. Since there are differences, regardless of being weakly marginal or non-significant, it means that other processes also could play a role. These

findings are again in line with the hub-and-spoke theory, LASS framework, and symbol interdependency theory (Lambon Ralph et al., 2017; Louwerse, 2007; Malhi, 2015).

The results also indicate that for both textual and visual representation the relative Jaccard scores of within voxel/brain area combinations are significantly higher than those for between voxels/brain areas. This could indicate that concept combinations that activate the same voxel or brain area are significantly more actively categorized together by humans than concept combinations that activate different voxels or brain areas. However, the Jaccard scores of within voxel/brain area combinations seem to have a relatively low average and median relative Jaccard score and the within voxel/brain area combinations have more variance than between voxel/brain area combinations. Hence, it does not mean that combinations that activate the same voxel/brain area are also categorized together by humans. This is in line with the findings of Bigga (2018), who also did a card sorting study based on the concepts from the Huth map, but with other categories. She found that there is insufficient evidence that localization of semantic concept representation in the brain can make assumptions about active use and categorization of concepts. The reason for the difference in within and between voxel/brain area combinations but still low median and variance of the within combinations could be because the active categorization is partly done by features and partly by object knowledge (Geng & Schnur, 2016). Since all concepts were categorized as visual, perceptual features are likely to play a role in categorization. Perceptual features of a concept rely on spokes while a whole concept and specific feature information rely on the hub (Chiou, Humphreys, Jung, & Lambon Ralph, 2018; Geng & Schnur, 2016).

One of the limitations is that using SONA prevents from having a representative sample of the distribution of age and educational degree of humans, because the participants selected via SONA were between 20 and 23 years old and they all had bachelor's degree or high school degree. Additionally, participants seemed to have different interpretations of the question on educational degree. Furthermore, there were no native English speakers included, which could negatively influence the results. Another limitation is that concepts were placed in part A or B of the card sorting based on alphabetical order instead of based on voxels/brain areas. This resulted in that most voxels/brain areas have split, meaning that some voxels/brain areas have only one or two concepts to compare. This could have affected the results because it makes less material to compare, especially in the part where concept combinations that activate the same versus different voxel/brain area were compared. The last limitation is that only one level card sorting was used because through the COVID-19 situation the card sorting had to be carried out online.

A strength of this study is that all participants had to sort all concepts. Furthermore, every participant had to do a card sorting task with pictures and one with words. These minimize the effects of interpersonal differences. Another strength is that the card sorting and survey are as less obtrusive as possible because of the following reasons: they were both held online, were not recorded, and participants can fill in the survey and do the card sort in their own pace and time (Babbie, 2009).

This study is a step forward in knowledge about concept categorization with respect to modality and brain activation. This study showed that concept categorization only marginally differs when using pictorial versus textual modality and it showed that there are indications that concept combinations that activate the same brain area are significantly more actively categorized together by humans than concept combinations that activate different brain areas. To know if visual and textual representation of concepts are the same or different is important because it helps towards a formal model of concept learning (Goldstone et al., 2018). Categorization and modality of concepts helps to understand the human mind, which helps in education and learning, which will have a positive impact on pedagogy. Since modality does not seem to be of great importance, the choice for modality of teaching materialis unlikely to influence concept categorization. Therefore, pictures and words can generally be used to explain the same concept. Additionally, it helps in developing technology in the sense of autonomous systems using artificial intelligence, user interfaces, and user manuals, in the sence that, based on concept organization, both pictures and text can be used.

Because of the complexity of concept learning much research still needs to be done. Future research can be done about to what extent intra- and interpersonal differences in concept organization play a role using card sorting in comparison with the Huth map. Everyone has different associations between concepts because every person is different and has his or her own experiences and history, which could lead to interpersonal differences (Barsalou, 1999; Barsalou et al., 2003; Louwerse, 2007; Mahon & Hickok, 2016). Furthermore, since symbolic processes seem to play a role together with other processes, further research is needed about what these other processes are.

9. Conclusion

This study aimed to identify to what extent there is a difference between textual and pictorial concept categorization of concepts of the brain map of Huth et al. (2016). There is an indication that there is a weak marginal difference in categorization of concepts represented in visual and textual modality for within voxel/brain area concept combinations and a non-significant difference for textual versus pictorial between voxel/brain area combinations. There are also indications that concept combinations that activate the same voxel or brain area are significantly more actively categorized together by humans than concept combinations that activate different voxels or brain areas. This however does not necessarily indicate that combinations that activate the same voxel/brain area are also categorized together by humans. The findings are in line with the hub-and-spoke theory, symbol interdependency theory, and the linguistic and situation simulation system (LASS) framework. They all include parts of the symbolic and embodied approach. Despite an error in the decision for concepts being in part A or B of the card sort that could limit the generalizability of the results, this approach provides new insights into active pictorial and textual organization of concepts and these related to location in brain activation. Further research is needed to identify which other processes than symbolic processes play a role in the use and categorization of concepts. More research is also needed to identify intra- and interpersonal differences and to what extent other processes than symbolic processes are embodied. This study helps to identify to what extent modality differs in active concept organization and to what extent localization of brain activation could play a role.

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Appendix A. Information for participants and informed consent for the questionnaire

Introduction

Welcome and thank you for participating in this study. This study is about differences in making categories of items (concepts) if they are presented as a picture or word. This questionnaire will be used for selection on pictures and words that will be used further in the study in which participants will have to make categories of concepts.

First, you will get an informed consent on the data that will be collected if you participate and how it will be handled. You can agree or not agree to participate in this study.

Then, you are asked to fill in some demographics on age, gender, nationality, and education level.

Thereafter, the questionnaire starts. This will exist of 142 combinations of words and pictures and will take approximately 30 minutes to complete. You have to rate to what extent the word and picture represent the same concept.

[next page]

Informed consent

You are being invited to participate in a research study titled 'Textual versus pictorial organization of concepts'. This study is being done by Daniëlle Dierking from the Faculty of Behavioural Management and Social Sciences at the university of Twente.

The purpose of this study is to know to what extent concepts are judged the same when they are represented as text or as a picture. This study will take you approximately 30 minutes to complete. The data will be used for making a selection on word-picture combinations for concepts.

Your participation in this study is entirely voluntary and you can withdraw at any time without giving any explanation or justification.

We believe there are no known risks associated with this research study; however, as with any online related activity the risk of a breach is always possible. To the best of our ability your answers in this study will remain confidential. We will minimize any risks by storing the data safely, making no use of any recording materials except for the answers you give in this questionnaire. There will be no questions asked from which your identity can be tracked.

For any questions or if you want a summary of the research results please contact the following email address: d.j.h.dierking@student.utwente.nl

Having read the information above, do you want to take part in this study and agree with the consent statement?

- Yes
- No

[next page]

Questions on demographics

What is your age?

Gender

What is your gender?

- Male
- Female
- I prefer not to answer

Nationality

What is your nationality?

Education level

What is your highest level of education?

- Elementary school
- High school
- Middle-level applied education
- Higher education bachelor
- Higher education master
- Higher education PhD
- Other

[next page]

Questionnaire

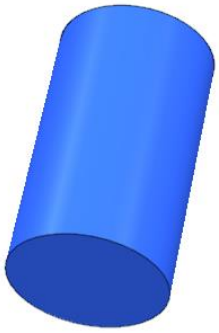
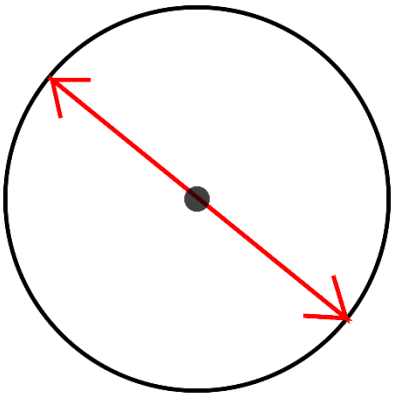
Appendix B. Concept items that made it to the card sorting

	Item nr old	Textual representation	Pictorial representation	Source of picture
1	2	ball		https://www.123rf.com/photo_77394754_stock-vector-collection-illustration-sports-balls-vector-cartoon-ball-set-for-soccer-and-tennis-rugby-basketball-.html
2	3	balloon		https://www.looksharpstore.co.nz/red-helium-filled-latex-balloon-11in/
3	4	barrel		https://www.mikesrental.com/product/whiskey-barrel/

4	10	boots		https://www.premierequine.co.uk/breacon-ladies-leather-country-boot-c2x28299933
5	11	bottle		https://www.brouwland.com/en/our-products/brewing/winter-beer/d/beer-bottle-belgium-75-cl-brown-crown-cork-26mm
6	12	bowl		https://www.walmart.com/ip/Mainstays-Gray-38-Ounce-Plastic-Bowl/294547044

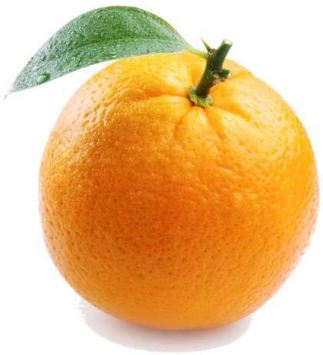
7	13	bra		https://www.walmart.ca/en/ip/g2y3110030-george-womens-t-shirt-bra-black/1255166066108
8	14	bread		https://www.browneyedbaker.com/white-bread-recipe/
9	15	cap		https://www.ebay.com/itm/100-COTTON-Burgundy-Red-Color-Blank-Plain-Baseball-Cap-Hat-Adjustable-Washed-/121147800976
10	17	cents		https://www.brusselstimes.com/all-news/eu-affairs/92342/europe-wants-to-get-rid-of-1-and-2-cents-coins-european-commission-copper-rounding-prices/
11	18	champagne		https://thevapemall.com/champagne/

12	19	cheese		https://www.midwestfarmreport.com/2020/05/24/wisconsin-cheese-markets-respond-to-reduced-covid-19-restrictions/
13	20	chimney		https://www.mychimney.com/blog/ways-reduce-chimney-fireplace-pollution/
14	24	coin		https://www.moneymetals.com/ten-dollar-us-liberty-gold-coin/30
15	28	container		https://www.portablespace.co.uk/product/20ft-x-8ft-one-trip-shipping-container-dark-green

16	30	cylinder		http://mjv.50webs.com/solids/example_09.html
17	31	diameter		https://en.wiktionary.org/wiki/diameter
18	33	dollar		https://internationalbanker.com/brokerage/us-dollar-consistently-falling-throughout-2017/
19	35	dough		https://www.taste.com.au/recipes/basic-pizza-dough-5/0fd539d3-0397-4dc4-b2cc-db2c08b181f8
20	37	egg		https://www.dietdoctor.com/an-egg-is-number-one-on-instagram

21	39	feathers		https://www.amazon.com/Coceca-180pcs-Feathers-Assorted-Catcher/dp/B078HR3VXN
22	41	furniture		https://www.pngitem.com/middle/TTwib_wooden-furniture-transparent-background-transparent-background-furniture-png/
23	44	gloves		https://www.moshi.com/en/product/touch-screen-gloves-digits/light-gray-s
24	48	hat		https://www.sportys.com/havana-hat1.html
25	52	hood		http://www.nglish.com/spanish/hood

26	58	ice cream		https://www.delish.com/cooking/recipe-ideas/a27971982/coconut-ice-cream-recipe/
27	61	jeans		https://www.levi.com/NL/nl_NL/kleding/jongens/kids-510-skinny-fit-jeans/p/864900005
28	62	jewelry		https://www.fraserhart.co.uk/c/jewellery
29	67	leaf		https://depositphotos.com/nl/stock-photos/leaf.html

30	75	millimetre		https://nl.dreamstime.com/illustration/millimeter.html + arrow self made in PowerPoint
31	77	orange		https://www.quanta.org/orange/
32	96	rice		https://www.cooksillustrated.com/recipes/10613-steamed-white-rice
33	100	sausage		https://www.southsidemarket.com/product/garlic-sausage/

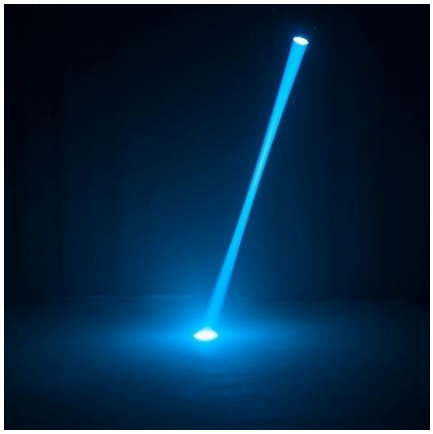
34	105	shirts		https://www.walmart.com/ip/Gildan-Men-s-short-sleeve-V-neck-assorted-color-t-shirt-up-to-2XL-5-pack/142941541
35	106	shoes		https://nl.pinterest.com/pin/597923288003460540/
36	109	slide		https://www.amazon.com/Little-Tikes-Store-Large-Slide/dp/B00B0DWCQG
37	110	sneakers		https://sneakerfits.com/a-recap-of-the-best-june-2019-nike-sneaker-releases-and-where-to-buy-them/

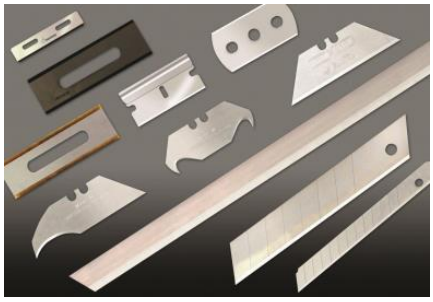
38	111	Spoon		https://www.christofle.com/eu_en/serving-spoon-malmaison-silver-plated-00018006000101.html
39	115	sticks		https://www.amazon.com/Donxote-Noodles-Kitchen-Cooking-Chopsticks/dp/B01MU8I6WY
40	119	Stockings		https://www.calzedonia.com/nl/product/diamond_and_polka_dot_patterned_hold-ups_with_tulle_top-MODA0372.html?dwvar_MODA0372_Z_COL_COLLD=019

41	126	top		https://www.agnesb.eu/en/black-clea-tank-top/black-clea-tank-top/
42	128	trousers		https://www.gaynors.co.uk/womens-c1/trousers-c70/womens-kiwi-pro-ii-trouser-p11631
43	133	tunic		https://www.ebay.co.uk/itm/Viking-Medieval-Tunic-Brown-Peasant-Thick-Cotton-Larp-Renaissance-Clothing-exp-/113640707688
44	136	uniform		https://www.amazon.co.uk/Kombat-UK-Childrens-Army-Combo/dp/B01MD2KJ65

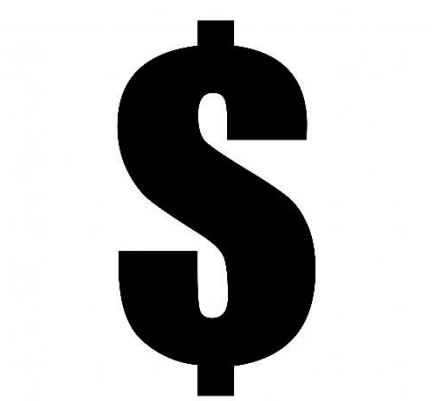
45	139	waist		https://en.wikipedia.org/wiki/Waist#/media/File:Waist.svg
46	142	wool		https://dictionary.cambridge.org/dictionary/english/wool

Appendix C. Concept pairs that did not make it to the card sorting

Item nr	Textual representation	Pictorial representation	Source of picture
1	arms		https://www.frenchpod101.com/blog/2011/02/02/french-word-of-the-day-arm-noun/
5	beads		https://www.cleverpatch.com.au/products/by-product/collage-and-craft/beads-and-jewellery-making/pony-beads-80g-pack
6	beam		https://www.researchgate.net/figure/Illustration-of-a-the-TSC-beam-and-b-the-timber-I-shape-composite-beam_fig1_324589334
7	beam		https://www.americandj.eu/en/focus-beam-led.html

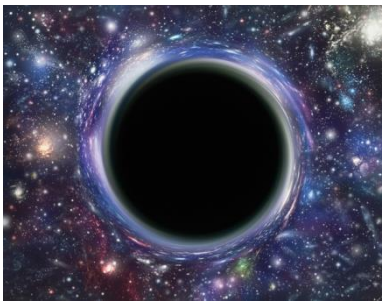
8	beam		https://www.titan.fitness/endurance/gymnastics/beams/8%27-jr.-gymnastics-balance-beam-%7C-adjustable-height/409034.html
9	blades		https://www.cadenceblades.com/capabilities/overview/razor-blades
16	cardboard		https://everytexture.com/everytexture-com-stock-paper-texture-00042/
21	cloth		https://www.thewipeshop.co.uk/index.php?cPath=79
22	clothing		https://www.123rf.com/photo_11514435_collection-of-icons-of-different-clothes-and-accessories-for-the-internet-and-banners.html

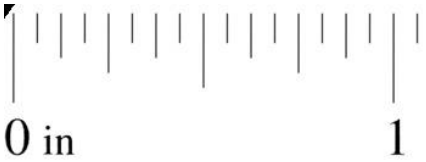
23	coat		https://www.popularmechanics.com/adventure/outdoor-gear/g3254/best-winter-coats/
25	collar (1)		https://www.dfordog.co.uk/red-dingo-dog-collar-paw-prints-red.html
26	collar (2)		https://www.fogeyunlimited.co.uk/product/double-rounded-stiff-detachable-shirt-collar/
27	coloured		https://naturalhealthcourses.com/2015/11/do-you-know-about-colour-therapy/

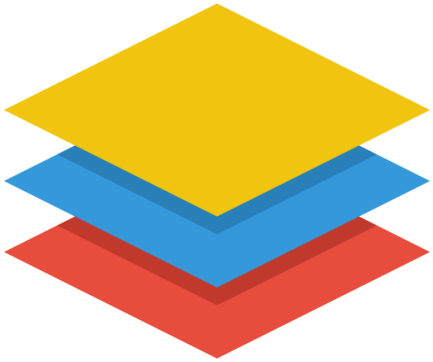
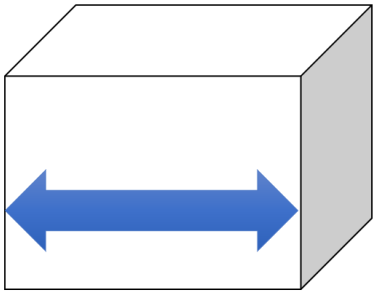
29	cotton		https://the-paper-heart.com/2019/09/17/how-to-make-your-own-cotton-flowers/
32	diamonds		https://www.miningreview.com/diamonds-gems/tango-mining-acquires-majority-share-in-liberia-diamond-project/
34	dollar (2)		https://www.publicdomainpictures.net/nl/view-image.php?image=37241&picture=dollar-sign-black
36	dried		https://www.123rf.com/photo_64211750_lemon-an-rose-flowers-tea-mix-on-turkish-market-.html

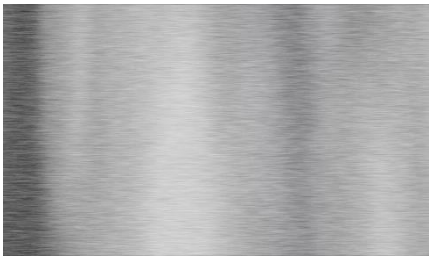
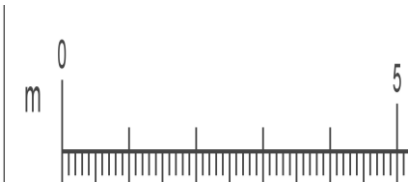
38	fabric		https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.crypton.com%2F&psig=AOvVaw2PECz2HfsqffoVqEA63rvC&ust=1593007960649000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCLDH3q6QmOoCFQAAAAAdAAAAABAJ
40	fur		https://www.cuckooland.com/brand/helen-moore/helen-moore-faux-fur-vintage-collar-scarf-in-truffle
42	garment		Same as clothing, so same picture as clothing, maybe leave one out
43	glossy		https://www.freepik.com/free-vector/plastic-glossy-balls-background_5550848.htm#page=1&query=glossy%20circle&position=32#&position=32

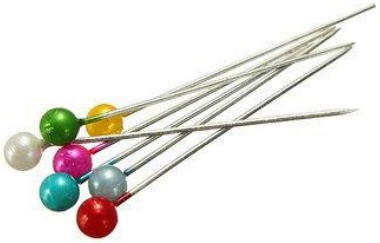
45	gloves (2)		https://www.barnes.com.au/measure-mixing-supplies/nitrile-gloves-100-bx-1480
46	gloves (3)		https://www.goodhousekeeping.com/uk/product-reviews/house-garden/g31805351/best-gardening-gloves/
47	gold		https://staffordcountymuseum.com/artifact/gold-nugget/
49	hat (2)		https://www.etsy.com/uk/listing/661627135/mens-cowboy-hat-western-genuine-leather
50	hat (3)		https://hatroom.nl/nl/herenhoeden/jaxon/hoeden-jaxon-mid-crown-top-hat-zwart/

51	hat (4)		https://www.blacks.co.uk/accessories/298469-alpine-women-s-chunky-bobble-hat-mid-grey.html
53	hole (1)		https://www.grunge.com/177025/the-truth-about-the-deepest-hole-in-the-world/
54	hole (2)		https://www.youworkforthem.com/photo/130300/golf-hole-and-flag-in-the-green-field
55	hole (3)		https://physicsworld.com/a/almost-certain-escape-from-a-black-hole/
56	horizontal		Self made in PowerPoint
57	ice cream (1)		https://beleaderly.com/ice-cream-on-a-stick-is-not-an-employee-engagement-strategy/

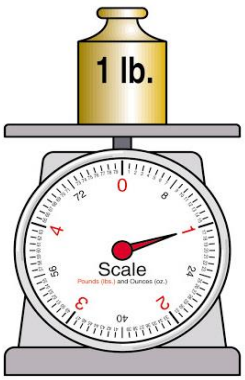
59	inch		https://www.teacherspayteachers.com/Product/Big-Printable-Inch-Ruler-Guide-590293
60	jacket		https://www.grailed.com/drycleanonly/best-mens-jacket-styles
63	lace (1)		https://www.viennemilano.com/blog/history-of-lace
64	lace (2)		https://www.fashionbeans.com/article/how-to-lace-shoes/
65	lamps		https://foir.nl/blog/gloeilampen-verschillende-soorten-maten.html

66	layers		https://www.professionalindemnity.co.uk/site/guides/excess-layer-insurance/
68	leather		https://www.polyandbark.com/products/napa-72-apartment-sofa
69	length		http://www.snowqueenandscout.com/journal/2015/4/7/100daysofwilderness-day-2 + arrows self made in PowerPoint
70	lighter		http://www.snowqueenandscout.com/journal/2015/4/7/100daysofwilderness-day-2 + arrows self made in PowerPoint
71	linen		https://www.walmart.com/ip/Linen-Fabric-60-Wide-Natural-100-Linen-By-The-Yard-White/619064009

72	maximum		https://www.freepik.com/premium-vector/speedometer-from-minimum-maximum-internet-speed-icon-gauge-flat-style_8379239.htm
73	metallic		http://lemerg.com/695813.html
74	metres		https://www.inchcalculator.com/convert/centimeter-to-meter/ Cropped in PowerPoint
76	neck		http://www.55andproud.com/staying-young/does-the-skin-on-your-hands-neck-and-chest-betray-your-youthful-spirit
78	pan		https://cookinglife.nl/masterchef-kookpan-tri-ply-cookware/
79	paper		https://blacklabelpaper.co/products/on-sale-parchment-paper-sheets-bleached-5x5-27lb-standard

80	penny		https://www.amazon.com/Lincoln-Cent-PROOF-Shield-Penny/dp/B00JF7EF2S
81	pins (1)		https://www.amazon.in/800Pcs-Round-Weddings-Corsage-Sewing/dp/B01NH0USHD
82	pins (2)	 	https://www.amazon.com/HSQYJ-Vintage-Brooches-Accessories-Clothing/dp/B07TYLMBDH
83	pins (3)		https://www.amazon.in/Plain-Bowling-Pin/dp/B01LBF9E40

84	pairs		https://www.twinkl.co.uk/resource/t-t-21122-eyfs-matching-pairs-card-game
85	plastic		https://insiderz.nl/verschil-plastic-en-kunststof/
86	pole (1)		https://www.olympicpartyhire.com.au/products/lighting/lighting-accessories/festoon-pole-non-adjustable
87	pole (2)		https://www.earthrangers.com/this-just-in/am-i-at-the-north-or-south-pole/
88	pound (1)		https://metro.co.uk/2019/09/03/pound-falling-mean-10676826/
89	pound (2)		https://www.istockphoto.com/nl/vector/weight-scale-with-a-pound-sign-gm491526792-75795465

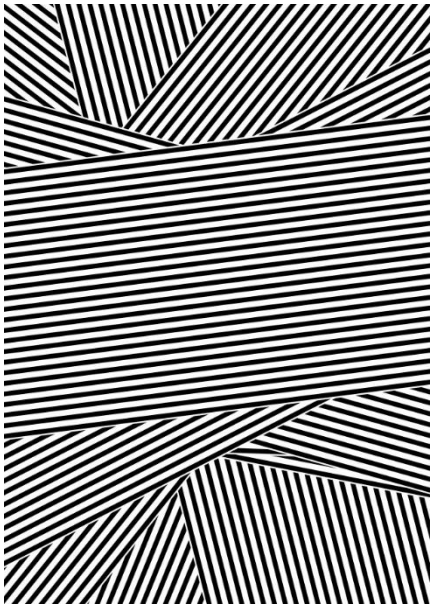
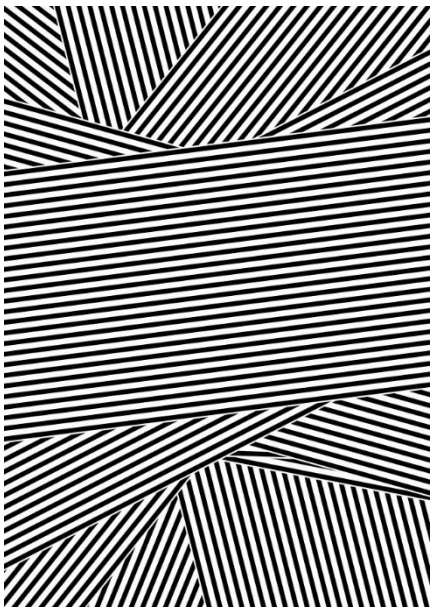
90	pound (3)		http://clipart-library.com/weight-scale-cliparts.html Copped in PowerPoint
91	powdered		http://www.nourishingmeals.com/2011/11/how-to-make-powdered-coconut-sugar.html
92	quarter (1)		https://en.wikipedia.org/wiki/America_the_Beautiful_quarters
93	quarter (2)		https://www.mathswithmum.com/telling-time-analogue-clock-quarter-past/
94	quarter (3)		https://slidemodel.com/templates/quarterly-timeline-template-powerpoint/

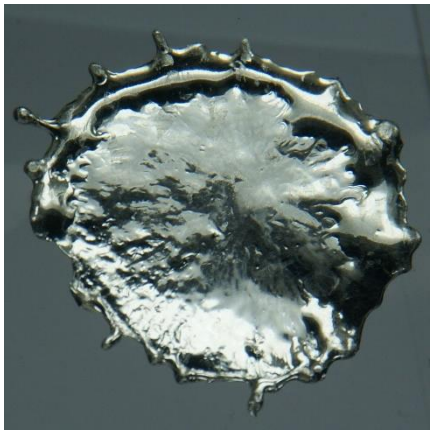
95	ribbons		https://www.amazon.co.uk/KitchenCraft-Sweetly-Ribbon-Colourful-Ribbons/dp/B00JH3XIF0
97	roofs		https://availableroofing.com/the-best-and-the-worst-roofs-for-canadian-weather/
98	rubber		https://www.researchgate.net/figure/Products-made-by-the-latex-of-Hevea-brasiliensis_fig2_323175086
99	satin		https://www.britannica.com/topic/satin
101	seed		https://www.nmda.nmsu.edu/nmda-homepage/divisions/aps/fsf/seed-2/

102	sheet		https://www.sheridanoutlet.com.au/sheridan-washed-linen-cotton-flat-sheet-o823-b130-c209-001-white.html Also, glass, iron, paper, etc.
103	shelf (1)		https://traditionalbeams.com/product/rustic-wood-floating-shelves/
104	shelf (2)		https://cgaxis.com/product/supermarket-shelf-03/
107	silver		https://economictimes.indiatimes.com/markets/stocks/news/golden-time-to-buy-silver-imports-to-rise/articleshow/63982286.cms?from=mdr
108	sleeve		https://pkvogue.com/sleeve-designs/pakistani-fashion/

112	steel		https://metalscut4u.com/rectangle-stainless-steel-1-8-brushed-3-finish-size-3x5.html Looks the same as metallic
113	sticks (1)		https://www.brushwithbamboo.com/shop/neem-chew-sticks/
114	sticks (2)		https://www.amazon.co.uk/Tiger-5A-Maple-Drumsticks-Wooden/dp/B005HH130W
116	sticks (4)		https://fashion-history.lovetoknow.com/fashion-accessories/canes-walking-sticks

117	sticks (5)		https://www.amazon.co.uk/Giant-Lollipop-Sticks-Natural-Choice/dp/B07BNQRQSX
118	stick (6)		https://www.bax-shop.nl/keuzehulp/usb-sticks
120	straps		https://www.shopsocialthreads.com/products/guitar-bag-strap-available-in-camo-leopard-rainbow-stripe-embroidered-bee-floral?utm_source=pinterest&utm_medium=social&variant=21998097072210

121	striped		https://www.freepik.com/free-vector/black-white-abstract-striped-design-background_5396809.htm Remove stripes or striped
122	stripes		Remove stripes or striped
123	tan		https://beauty-cocoon.nl/behandelingen/spray-tan/

124	tin (1)		https://investorintel.com/sectors/technology-metals/technology-metals-intel/banging-tin-can-north-americas-tin-vulnerability/
125	tin (2)		https://en.wikipedia.org/wiki/Tin#/media/File:Tin-2.jpg
127	top (2)		https://www.aliexpress.com/i/32919874609.html
129	tube (1)		https://www.materials.sandvik/en/products/tube-pipe-fittings-and-flanges/tubular-products/muffle-tubes/

130	tube (2)		https://www.clsmith.com/packaging-solutions/squeeze-tubes/
131	tube (3)		https://www.machinery.co.uk/machinery-news/siemens-tube-train-order-win-will-secure-goole-sites-realisation-brings-supply-chain-benefits
132	tunic (1)		https://www.roetgerink.nl/dames/blouses/tunieken/vero-moda-vmdicthe-3-4-tunic-exp-ga_groen_179541.html
134	uniform (1)		https://www.workgearcompany.co.nz/blogs/news/school-uniform

135	uniform (2)		https://nl.pinterest.com/pin/423197696210492026/
137	upwards		https://www.what-buddha-said.net/going-upwards/
138	vertical		Self made via PowerPoint
140	wings		https://www.amazon.com/FashionWings-Black-Costume-Feather-Unisex/dp/B008I6TIK6

141	wire		https://dictionary.cambridge.org/dictionary/english/wire

Appendix D. Items that were excluded for the CST

Item	Score
arms	31
beads	31
beam (1)	28
beam (2)	24
beam (3)	29
blades	32
cardboard	32
cloth	24
clothing	32
coat	31
collar (1)	26
collar (2)	32
coloured	32
cotton	31
diamonds	31
dollar (2)	31
dried	28
fabric	31
fur	32
garment	28
glossy	25
gloves (2)	33
gloves (3)	33
gold	31
hat (2)	34
hat (3)	34
hat (4)	34
hole (1)	31
hole (2)	29
hole (3)	24
horizontal	26
ice cream	31
inch	30
jacket	27
lace (1)	29
lace (2)	26
lamps	32
layers	26
leather	26
length	28
lighter	27
linen	29
maximum	32
metallic	26
metres	25
neck	31
pan	32
paper	32
penny	32
pins (1)	32
pins (2)	25
pins (3)	27
pairs	16
plastic	29
pole (1)	25
pole (2)	26

pound (1)	24
pound (2)	24
pound (3)	29
powdered	31
quarter (1)	31
quarter (2)	32
quarter (3)	31
ribbons	31
roofs	31
rubber	27
satin	32
seed	31
sheet	31
shelf (1)	28
shelf (2)	26
silver	32
sleeve	25
steel	28
sticks (1)	34
sticks (2)	34
sticks (4)	31
sticks (5)	31
sticks (6)	25
straps	30
striped	24
stripes	27
tan	26
tin (1)	26
tin (2)	29
top (2)	21
tube (1)	30
tube (2)	31
tube (3)	25
tunic (1)	31
uniform (1)	28
uniform (2)	33
upwards	25
vertical	28
wings	32
wire	35

Appendix E. Brain areas with concepts

Brain area	Picked/not picked	concepts
Inferior prefrontal cortex R1	Picked	quarter; inch; pound; cents; coat; stripes
	Not picked	roughly; tops; brown; pounds; topped
Inferior prefrontal cortex R5	Picked	lighter; inch; leather; coat; top; cloth; cap; stripes; sleeves; diameter; ribbons
	Not picked	thinner; coloured; thin; worn; edges; inches; thick
Lateral parietal cortex L2	Picked	vertical; diameter; leather; inch; stripes; coat; leaf; millimetre; cap; glossy; horizontal
	Not picked	yellow; inches; coloured; blue; edges; tops; underneath
Latero-temporal cortex L10	Picked	glossy; lighter; pair; inch; strips; layers; top; diameter; cap; stripes
	Not picked	thicker; coloured; thin; edges; tops; thinner; layer; inches
Laterotemporal cortex L2	Picked	cylinder; strips; top; inch; lighter; millimetre; diameter; sheet; cap; leaf; stripes; glossy; metallic; vertical
	Not picked	coloured; stops; coloured; edges; inches
Laterotemporal cortex L3	Picked	vertical; beam; millimetre; sheet; diameter; horizontal; pins; cylinder; top; inch; wire; upwards; maximum, length
	Not picked	surface; depending; each; edges; layer; inches
Ventrotemporal cortex L2	Picked	ribbons; stripes; sleeve; inch; glossy; leather; cap; coat; beads; sleeve; plastic; cloth; lighter
	Not picked	shaped; thin; coloured; thinner; thicker
Ventrotempporal cortex L3	Picked	metallic; diameter; lighter; inch; stripes; glossy; tops; thin; cap; strips; cloth; sleeve
	Not picked	coloured; tops; thin; thinner; thick; thicker; sleeve; inches
Inferior prefrontal cortex L2	Picked	strips; gold; satin; coat; stripes; glossy; leaf; cap; silver; orange; striped; leather
	Not picked	colour; blue; yellow; coloured; red; brown
Inferior prefrontal cortex L4	Picked	ribbons; sleeve; glossy; satin; strips; gold; cap; silver; striped; stripes; tunic; inch; leather
	Not picked	colour; coloured; red; brown; yellow; thinner

Inferior prefrontal cortex L6	Picked	plastic; glossy; strips; layers; sheet; cap; inch; lighter; cloth; layers; diameter; metallic; cylinder; leather
	Not picked	thinner; edges; coloured; thinner; thicker
Inferior prefrontal cortex L10	Picked	uniform; glossy; stripes; strips; tunic; leaf; cloth; cap; wool; powdered; coat; metallic; leather
	Not picked	yellow; colour; coloured; brown; powder
Inferior temporal cortex NS	Picked	ribbons; hood; tunic; striped; coat; leather; stripes; tan; lace; satin; arms; collar; feathers
	Not picked	brown; coloured; white; black; wears; red; ribbon

Appendix F. Voxels with their picked and not picked concepts

Voxel	Picked/not picked	Concepts
5,60,68	Picked;	Blade; barrel; inch; sticks; tube; hole; cap; top; ball; blades; diameter; pins; metal; beads; plastic
	Not picked	Shaped; inches; shaft; rope; bottom
6,74,74	Picked	Cheese; rice; pan; sausage
	Not picked	Chopped; pudding; French; label; sour; cups; brand; cream; American; cup; jelly; curry; brown; pitcher; breast; substitute
6,75,72	Picked	Stockings; shirts; tunic; uniform; tan; stripes; ribbon; colored
	Not picked	Black; cowboy; shirt; blond; outfit; wig; white; breast; baggy; brown; pink; wears; muscular
6,77,72	Picked	Neck; rubber; cap; top; inch; wings; sheets
	Not picked	Underneath; sand; covered; thick; feet; blue; inches; tail; mud; legs; thinner; tops; yellow
10,74,26	Picked	Vertical; horizontal; edge; length; slide; blades; inch; tube; blades
	Not picked	Reaches; tightly; sliding; edges; rim; evenly; surface; heavier; downward; bottom
15,28,73	Picked	Beads; strips; pound; seed; coins; pieces
	Not picked	Hundred; cups; weigh; thinner; items; packs; ink; weight; cards; item; ten; pounds; excess; amount
15,83,62	Picked	Gold; top; cent; cap; silver; inch; quarter; dollar
	Not picked	Topped; million; four; six; three; per; ten; eight; tops; year; five; cup
15,87,36	Picked	Chimney; leather; coat; roofs; lamps; cloth; furniture
	Not picked	Underneath; exterior; floors; roof; lamp; glass; damp; wood; walls; feet; strewn; covered; stained
16,23,71	Picked	Container; wire; plastic; cylinder
	Not picked	Equipment; pad; item; amount; sturdy; bulky; cost; per; items; rack; boxes; extra; expensive; weights; excess; folding
16,28,25	Picked	Sneakers; boots; cap; stockings; coat; gloves; pair; clothing shoe; jacket; trousers; jeans;
	Not picked	Wore; tie; worn; suit; shorts; outfit; jackets; t-shirt

17,23,70	Picked	Pole, length, beam, metres; maximum; upwards; horizontal
	Not picked	Downward; reaches; climb; below; reach; feet; distance; speed; distances
17,87,55	Picked	Feather; diameter; colored; lighter; inch; cap; wings; upwards; striped; balloon
	Not picked	Blue; yellow; bare; fly; tail; tops; shiny; inches; purple; heavier
17,87,60	Picked	Orange; bottle; plastic; hat; jacket; cloth; coat; cap; shirts; boots; lighter
	Not picked	Bottles; hose; pipe, blue; red; underneath; tops; yellow; purple
19,17,56	Picked	Pound; penny; coin; jewelry; dollar; slice; bread; coin; dough; spoon; strips; champagne; gold; pieces; egg; powdered
	Not picked	item; pearls; cups, cup
19,19,43	Picked	Shelf; sheet; container; cents; paper; bottle;
	Not picked	Plates; receipt; packed; per; item; extra; rack; boxes; cups; items; stacked; deposit; purchase
19,33,72	picked	Gloves; lighter; bottle; leather; beads; wool; coat; plastic; fur; cap; powdered; fabric; pieces; sleeves; colored
	Not picked	Wax; thick; thin; powder
19,33,73	Picked	Cardboard; cotton; cap; fur; cloth; steel; dried; leather; coat; plastic; rubber; inch; lighter; wool; gloves; colored
	Not picked	Sturdy; thick; powder; thin
19,34,73	Picked	Gloves; lighter; rubber; strap; leather; fabric; plastic; inch; wool; cloth; linen; cap; cardboard; clothing
	Not picked	Thicker; thin; bulky; thinner; thick; powder
19,36,72	Picked	Upwards; inch; cap; lighter; diameter; vertical
	Not picked	Glittering; underneath; clad; beneath; visible; tall; glow; blue; floating; glowing; bright; light; deck
19,37,73	Picked	Diameter; fabric; hole; inch; steel; pair; plastic; hole; cloth; top; edge; lighter; container
	Not picked	Thinner; rack; bottom; inches; rim; underneath
19,86,41	Picked	Pound; quarter; shelf; bowl; top; sheets
	Not picked	Packed; extra; piles; ten; half; stacked; tie; tops; pack; per; cups; lower; evenly; inches

20,35,72	Picked	Layer; lighter; inch; millimetre; hole; diameter; blades
	Not picked	Sealed; stacked; evenly; thinner; heavier; thin; surface; thick; inches; heavier; deck; blade; holes
20,43,25	Picked	Stockings; linen; inch; beads; bra; top; pound; pieces; cloth; sheets; garment
	Not picked	Thick; nearly; six; half; forty; roughly; ten; stacked
20,72,68	Picked	Top; fur; ice; bowl; silver; wool; cotton; gold
	Not picked	Thinner; sparkling; iron; powder; cups; cup; salt; sugar; cream; brown; dipped
21,71,26	Picked	Blades; inch; slide; top; pair; cap; waist; length; pins; pole
	Not picked	Inches; tight; tie; round; pin; rack; bottom; wrist; shorter; squeeze
23,43,52	Picked	Silver; tin; cent; gold; diamonds
	Not picked	Containing; tribute; pink; version; sold; recorded; tiger; records; blue; released; vol; produced; cover; edition; brown

Appendix G. Concepts with their voxels and brain areas

Concept	Voxel from selectivity map	Area from PrAGMATIC map
arms		ITC L NS
ball	5,60,68	
balloon	17,87,55	
barrel	5,60,68	
beads	5,60,68; 15;28;73; 19,33,72; 20;43;25	VTC L2
beam	17,23,70	LTC L3
blades	5,60,68; 10,74,26; 20,35,72; 21,71,26	
boots	16,28,25; 17,87,60	
bottle	17,87,60; 19,19,43; 19,33,72	
bowl	19,86,41; 20,72,68	
bra	20,43,25	
bread	19,17,56	
cap	5,60,68; 6,77,72; 16,28,25; 17,87,55; 19,33,72; 19,34,73; 19,36,72; 20,72,68; 21,71,26	IPFC L2; IPFC L6; IPFC L10; LPC L2; LPC L10; LTC L2; VTC L2; VTCL3; IPFC R5
cardboard	19,33,73; 19,34,73	
cents	15,83,62; 19,19,43; 23,43,52	IPFC R1
champagne	19,17,56	
cheese	6,74,74	
chimney	15,87,36	
cloth	15,87,36; 19,37,73; 20,43,25	IPFC L6; IPFC L10; VTC L2; VTC L3; IPFC R5;
clothing	16,28,25; 19,34,73	
coat	15,87,36; 16,28,25; 17,87,60; 19,33,72; 19,33,73	IPFC L2; IPFC L10; ITC L NS; LPC L2; VTC L2; IPFC R1; IPFC R5
coin	15,28,73; 19,17,56	
collar		ITC L NS
coloured	6,75,74; 17,87,55; 19,33,72; 19,33,73	IPFC L2; IPFC L4;IPFC L10; IPFC L10; ITC L NS; LPC L2; LPC L10; LTC L2; VTC L2; VTC L3; IPFC R5
container	16,23,71; 19,19,43; 19,37,73	
cotton	6,73,75; 19,33,73; 20,72,68	
cylinder	16,23,71	IPFC L6; LTC L2; LTC L3;
diameter	5,60,68; 17,87,55; 19,36,72; 19,37,73; 20,35,72	IPFC L 6; LPC L2; LPC L10; LTC L2; LTC L3; VTC L3; IPFC R5
diamonds	23,43,52	
dollar	15,83,62; 19,17,56	

dough	19,17,56	
dried	19,33,73	
egg	19,17,56	
fabric	19,33,72; 19,34,73; 19,37,73	
feathers	17,87,55	ITC L NS
fur	19,33,72; 19,33,73; 20,72,68	
furniture	15,87,36	
garment	20,43,25	
glossy		IPFC L4; IPFC L6; IPFC L10; LPC L10
gloves	16,28,25; 19,33,72; 19,33,73; 19,34,73	
gold	15,83,62; 19,17,56; 20,72,68. 23,43,52	IPFC L2; IPFC L4
hat	17,87,60	
hole	5,60,68; 19,37,73; 20;35;72	
hood		ITC L NS
horizontal	10,74,26; 17,23,70	LPC L2; LTC L3
ice cream	20,72,68	
inch	5,60,68; 6,77,72; 15,83,62; 17,87,55; 19,33,73; 19,34,73; 19,36,72; 19,37,73; 19,86,41; 20,35,72; 20,43,25; 21,71,26	IPFC L4; IPFC L6; LPC L2; LPC L10; LTC L2; LTC L3; VTC L2; VTC L3; IPFC R1; IPFC R5
jacket	16,28,25; 17,87,60	
jeans	16,28,25	
jewelry	19,17,56	
lace		ITC L NS
lamps	15,87,36	
layers	20,35,72	IPFC L6; LPC L10; LTC L3
leaf		IPFC L2; IPFC L10; LPC L2; LTC L2
leather	15,87,36; 19,33,72; 19,33,73; 19,34,73	IPFC L2; IPFC L4; IPFC L6; IPFC L10; ITC L NS; LPC L2; VTC L2; IPFC R5
length	10,74,26; 17,23,70; 21,71,26	LTC L3
lighter	17,87,55; 17,87,60; 19,27,73; 19,33,72; 19,33,73; 19,34,73; 19,36,72; 20,35,72	LPC L10; LTC L2; IPFC R5
linen	19,34,73; 20,43,25	
maximum	17,23,70	LTC L3
metallic		IPFC L6; IPFC L10; LTC L2; VTC L3
metres	17,23,70	
millimetre	20,35,72	LPC L2; LTC L2; LTC L3
neck	6,77,72	
orange	17,87,60	IPFC L2

pairs	16,28,25; 19,37,73; 21,71,26	LPC L10
pan	6,74,74	
paper	19,19,43;	
penny	19,17,56	
pins	5,60,68; 21,71,26	LTC L3
plastic	5,60,68; 16,23,71; 17,87,60; 19,33,72; 19,33,73; 19,34,73; 19,37,73	IPFC L6; VTC L2
pole	17,23,70; 21,71,26	
pound	15,28,73; 19,17,56; 19,86,41; 20,43,25	IPFC R1
powdered	19,17,56; 19,33,72; 19,33,73; 19,34,73; 20,72,68	IPFC L10
quarter	15,83,62; 19,86,41	IPFC R1
ribbons	6,75,74	IPFC L4; ITC L NS; VTC L2; IPFC R5
rice	6,73,75; 6,74,74	
roofs	15,87,36	
rubber	6,77,72; 19,33,73; 19,34,73	
satin		IPFC L2; IPFC L4; ITC L NS
sausage	6,74,74	
seed	15,28,73	
sheet	6,77,72; 19,19,43; 19,86,41; 20,43,25	IPFC L6; LTC L2; LTC L3
shelf	19,86,41	
shirts	6,75,74; 16,28,25; 17,87,60	
shoes	16,28,25	
silver	15,83,62; 20,72,68; 23,43,52	IPFC L2; IPFC L4
sleeve	19,33,72	IPFC L4; VTC L2; VTC L3; IPFC R5
slide	10,74,26; 21,71,26	
sneakers	16,28,25	
spoon	19,17,56	
steel	19,33,73; 19,37,73	
sticks	5,60,68	
stockings	6,75,74; 16,28,25; 20,43,25	
straps	19,34,73	
striped	17,87,55	IPFC L2; IPFC L4; ITC L NS
stripes	6,75,74	IPFC L2; IPFC L4; LPC L2; ITC L NS; LPC L10; LTC L2; VTC L2; VTC L3; IPFC R1 ;IPFC R5
tan	6,75,74	ITC L NS
tin	23,43,52	

	5,60,68; 6,77,72; 15,83,62; 17,87,55;	
top	17,87,60; 19,37,73; 19,86,41;	LPC L2; LPC L10; LTC L2; LTC L3; VTC L3;
	20,43,25; 20,72,68; 21,71,26	IPFC R1; IPFC R5
trousers	16,28,25	
tube	5,60,68; 10,74,26	
tunic	6,75,74	IPFC L4; IPFC L10; ITC L NS
uniform	6,75,74	IPFC L10
upwards	17,23,70; 17,87,55; 19,36,72	LTC L3
vertical	10,74,26; 19,36,72	LPC L2; LTC L2; LTC L3
waist	21,71,26	
wings	6,77,72; 17,87,55	
wire	16,23,71	LTC L3
wool	19,33,72; 19,33,73; 19,34,73; 20,72,68	IPFC L10

Appendix HD. Information about the card sorting study for participants

Introduction

Welcome and thank you for participating in this study. This study is about differences in making categories of items (concepts) if they are presented as a picture or word.

First, you will get an informed consent on the data that will be collected if you participate and how it will be handled. You can agree or not agree to participate in this study. If you do not agree, the participation will end there. If you agree you are able to go further.

Then, you are asked to fill in some demographics on age, gender, nationality, and education level. This is asked because there may be potential differences in responses when demographics differ.

Thereafter, the card sorting tasks will be explained and an example will be given.

After the example the card sorting starts. This will consist of two tasks with 23 concepts each. In the card sorting you are asked to categorize the concepts.

[next page]

Informed consent

You are being invited to participate in a research study titled 'Textual versus pictorial organization of concepts'. This study is part of a master thesis being done by Daniëlle Dierking from master Human Factors and Engineering Psychology at the University of Twente.

The purpose of this study is to know to what extent concepts are judged the same when they are represented as text or as a picture. This study will take you approximately 25 minutes to complete. The data will be used to compare categorization of concepts when they are represented as a word with when they are represented as a picture.

Your participation in this study is entirely voluntary and you can withdraw at any time without giving any explanation or justification.

We believe there are no known risks associated with this research study; however, as with any online related activity the risk of a breach is always possible. To the best of our ability your answers in this study will remain confidential. We will minimize any risks by storing the data safely, making no use of any recording materials except for the answers you give in this card sorting. There will be no questions asked from which your identity can be tracked.

This study is approved by the ethics committee of Behavioural Management and Social sciences of the University of Twente.

For any questions or if you want a summary of the research results please contact the following email address: d.j.h.dierking@student.utwente.nl

- Having read the information above, do you want to take part in this study and agree with the consent statement?
- Yes
- No

[next page]

Questions on demographics

What is your age?

Gender

What is your gender?

- Male
- Female
- I prefer not to answer

Nationality

What is your nationality?

Education level

What is your highest level of education?

- Elementary school
- High school
- Middle-level applied education
- Higher education bachelor
- Higher education master
- Higher education PhD
- Other

[next page]

Explanation

This card sorting study consists of two tasks. At one of the tasks the concepts are presented as a word and at the other task the concepts are presented as a picture. It is randomly chosen if you start with words or pictures.

At the left side you can see concept items as pictures or words. At the right side you can see boxes. Each box is one category. With your mouse or finger you can drag the concept to the category box of your choice. In the categories you can cluster concepts which you think belong together. Make the categories in a way that makes most sense to you. Please note that there is no right or wrong in here.

There are a few rules:
1. You are NOT allowed to re-arrange groups
2. You can use all category group boxes, but you do not have to
3. You can place as many concepts in a category as you want

At the next page you can see an example.

[Next page]

Example

Here is an example. Please drag the concepts to a category.

Items


×


×


×

Category 1

Category 2

Category 3

End of introduction

If you are ready you can go to the next page, where the first task of the card sorting will start. Good luck!

[next page]

Card sorting task 1

Appendix I. Similarity matrices

Similarity matrix textual items 1-23

ball	balloon	barrel	boots	bottle	bowl	bra	bread	cap	cents	champag	cheese	chimney	coin	container	cylinder	diameter	dollar	dough	egg	feathers	furniture	gloves
1	9	2	0	3	2	2	0	1	1	1	0	2	1	1	2	3	1	1	2	5	2	1
9	1	1	0	2	2	1	2	2	1	1	1	1	2	1	1	2	0	1	0	3	0	0
2	1	1	2	9	5	1	0	2	2	3	1	1	1	6	4	3	1	2	1	1	1	3
0	0	2	1	1	0	9	0	9	1	0	1	0	0	0	3	1	0	1	0	1	0	1
3	2	9	1	1	6	2	0	1	2	4	1	1	1	6	4	3	1	2	1	2	1	2
2	2	5	0	6	1	3	0	0	1	3	0	0	1	8	3	2	0	0	0	1	2	0
2	1	1	9	2	3	1	0	8	0	1	0	0	1	0	5	2	1	0	1	3	2	1
0	2	0	0	0	0	0	1	1	0	5	1	0	1	0	0	1	0	8	1	0	0	0
1	2	2	9	1	0	8	1	1	1	0	1	2	2	1	4	2	0	1	0	1	0	9
1	1	2	1	2	1	0	0	1	1	1	1	1	1	2	1	1	9	3	0	0	0	1
1	1	3	0	4	3	1	5	0	1	1	5	0	0	2	0	1	1	3	5	1	0	0
0	1	1	1	1	0	0	1	1	1	5	1	0	1	0	0	1	0	9	1	0	0	1
2	1	1	0	1	0	0	0	2	1	0	0	1	1	3	3	2	0	1	0	1	6	0
1	2	1	0	1	1	1	1	2	1	0	1	1	1	1	2	1	9	2	0	0	1	0
1	1	6	0	6	8	0	0	1	2	2	0	3	1	1	4	2	0	1	0	1	1	0
2	1	4	3	4	3	5	0	4	1	0	0	3	2	4	1	5	1	1	1	1	3	4
3	2	3	1	3	2	2	1	2	1	1	1	2	1	2	5	1	2	2	2	1	1	2
1	0	1	0	1	0	1	0	0	9	1	0	0	9	0	1	2	1	1	1	1	1	1
1	1	2	1	2	0	0	8	1	3	3	9	1	2	1	1	2	1	1	8	0	0	1
2	0	1	0	1	0	1	1	0	0	5	1	0	0	0	1	2	1	8	1	1	1	1
5	3	1	1	2	1	3	0	1	0	1	0	1	0	1	1	1	1	0	1	1	3	2
2	0	1	0	1	2	2	0	0	0	0	0	6	1	1	3	1	1	0	1	3	1	1
1	0	3	1	2	0	1	0	9	1	0	1	0	0	0	4	2	1	1	1	2	1	1

Similarity matrix pictorial items 1-23

ball	balloon	barrel	boots	bottle	bowl	bra	bread	cap	cents	champag	cheese	chimney	coin	container	cylinder	diameter	dollar	dough	egg	feathers	furniture	gloves
1	8	0	0	0	0	0	1	0	0	1	1	0	0	0	1	3	1	0	1	0	0	0
8	1	1	0	2	1	0	0	0	0	2	1	1	1	1	2	4	0	0	2	0	0	1
0	1	1	0	6	5	0	0	0	0	4	0	2	1	6	2	2	0	0	1	1	3	1
0	0	0	1	1	0	1	0	9	1	0	0	2	0	0	0	0	0	2	0	3	0	1
0	2	6	1	1	4	1	2	0	1	9	3	0	0	2	0	0	0	3	2	1	2	0
0	1	5	0	4	1	0	1	1	0	2	2	1	0	4	1	0	0	1	0	1	5	0
0	0	0	1	1	0	1	0	1	1	0	0	1	0	0	0	0	0	2	0	3	0	1
1	0	0	0	2	1	0	1	0	0	5	1	1	0	0	0	0	1	9	6	0	0	0
0	0	0	9	0	1	1	0	1	0	0	0	1	0	0	0	0	0	1	0	2	1	1
0	0	0	1	1	0	1	0	0	1	0	0	1	1	0	0	0	1	1	0	1	0	0
1	2	4	0	9	2	0	5	0	0	1	6	1	0	0	0	0	1	3	4	0	0	0
1	1	0	0	3	2	0	1	0	0	6	1	1	0	0	0	0	1	8	5	0	0	0
0	1	2	2	0	1	1	1	1	1	1	1	1	1	3	1	1	1	0	2	2	4	3
0	1	1	0	0	0	0	0	0	1	0	0	1	1	1	2	1	1	0	1	0	0	1
0	1	6	0	2	4	0	0	0	0	0	0	3	1	1	2	2	0	0	1	1	5	1
1	2	2	0	0	1	0	0	0	0	0	0	1	2	2	1	9	0	0	1	0	0	1
3	4	2	0	0	0	0	0	0	0	0	0	1	1	2	9	1	0	0	2	0	0	1
1	0	0	0	0	0	0	1	0	1	1	1	1	1	0	0	0	1	0	0	0	0	0
0	0	0	2	3	1	2	9	1	1	3	8	0	0	0	0	0	0	1	5	2	0	1
1	2	1	0	2	0	0	6	0	0	4	5	2	1	1	1	2	0	5	1	3	0	1
0	0	1	3	1	1	3	0	2	1	0	0	2	0	1	0	0	0	2	3	1	1	2
0	0	3	0	2	5	0	0	1	0	0	0	4	0	5	0	0	0	0	0	1	1	0
0	1	1	1	0	0	1	0	1	0	0	0	3	1	1	1	1	0	1	1	2	0	1

Similarity matrix textual items 24-46

hat	hood	ice	jeans	jewelry	leaf	millimetr	orange	rice	sausage	shirts	shoes	slide	sneakers	spoon	sticks	stockings	top	trousers	tunic	uniform	waist	wool
1	8	1	9	4	0	0	0	1	0	9	8	0	9	1	0	7	9	9	7	7	3	4
8	1	0	7	4	0	0	1	0	1	7	7	0	6	0	0	6	8	7	7	5	2	3
1	0	1	0	0	1	0	9	1	1	0	0	0	1	3	0	0	0	0	0	0	1	0
9	7	0	1	4	0	0	0	0	0	1	9	1	9	0	0	9	1	1	8	9	4	5
4	4	0	4	1	0	1	1	0	1	4	5	0	4	1	0	4	5	4	3	3	1	2
0	0	1	0	0	1	2	2	2	1	1	0	1	0	1	3	0	0	0	0	0	0	2
0	0	0	0	1	2	1	0	0	0	1	0	3	0	1	1	0	0	0	0	0	3	1
0	1	9	0	1	2	0	1	1	1	0	1	0	0	2	0	0	1	0	1	0	0	0
1	0	1	0	0	2	0	1	1	9	0	0	0	1	3	0	0	0	0	0	0	0	0
0	1	1	0	1	1	0	1	9	1	0	1	0	0	2	0	0	1	0	1	0	1	0
9	7	0	1	4	1	1	0	0	0	1	9	0	9	0	0	8	1	1	8	8	3	4
8	7	0	9	5	0	0	1	0	1	9	1	0	1	0	0	7	1	9	8	7	3	4
0	0	0	1	0	1	3	0	0	0	0	0	1	0	3	3	1	0	1	0	2	2	1
9	6	1	9	4	0	0	0	1	0	9	1	0	1	1	0	7	9	9	7	7	3	4
1	0	3	0	1	1	1	2	3	2	0	0	3	1	1	5	0	0	0	0	0	0	1
0	0	0	0	0	3	0	0	0	0	0	0	3	0	5	1	0	0	0	0	0	0	2
7	6	0	9	4	0	0	0	0	0	8	7	1	7	0	0	1	8	9	7	8	4	4
9	8	0	1	5	0	0	1	0	1	1	1	0	9	0	0	8	1	1	9	8	3	4
9	7	0	1	4	0	0	0	0	0	1	9	1	9	0	0	9	1	1	8	9	4	5
7	7	0	8	3	0	0	1	0	1	8	8	0	7	0	0	7	9	8	1	9	3	2
7	5	0	9	3	0	0	0	0	0	8	7	2	7	0	0	8	8	9	9	1	4	3
3	2	1	4	1	0	3	0	0	1	3	3	2	3	0	0	4	3	4	3	4	1	1
4	3	0	5	2	2	1	0	0	0	4	4	2	4	1	2	4	4	5	2	3	1	1

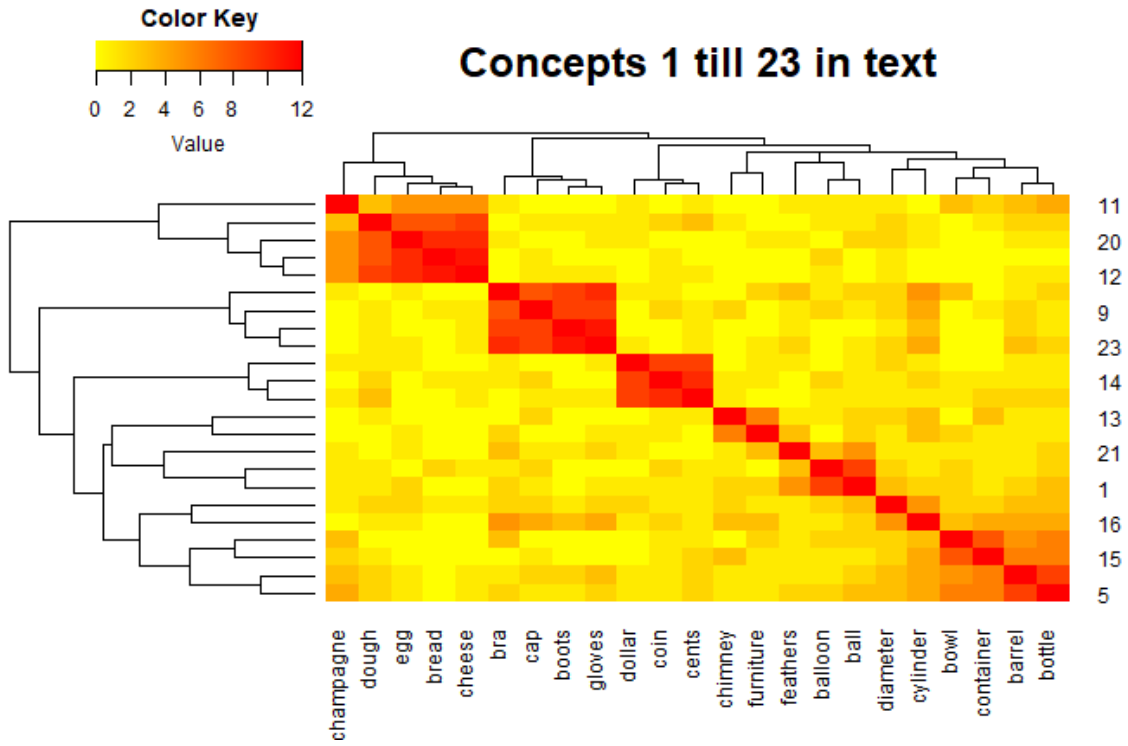
Similarity matrix pictorial items 24-46

hat	hood	ice	jeans	jewelry	leaf	millimetr	orange	rice	sausage	shirts	shoes	slide	sneakers	spoon	sticks	stockings	top	trousers	tunic	uniform	waist	wool
1	1	1	1	5	1	1	1	0	0	9	6	3	8	2	3	8	9	7	8	8	2	3
1	1	1	1	5	1	1	1	0	0	9	6	3	8	2	3	8	9	7	8	8	2	3
1	1	1	1	2	2	2	1	7	1	0	0	1	1	3	2	0	1	0	2	0	2	0
1	1	1	1	5	1	1	1	0	0	9	6	3	8	2	3	1	9	9	8	8	2	3
5	5	2	5	1	1	2	1	0	0	4	4	2	4	2	2	5	6	5	7	4	3	2
1	1	2	1	1	1	1	4	2	1	0	0	2	1	2	1	0	1	0	1	1	1	1
1	1	2	1	2	1	1	1	0	0	0	1	1	2	1	1	0	1	1	2	0	1	1
1	1	1	1	1	4	1	1	7	9	0	0	2	1	4	2	0	1	0	1	0	1	1
0	0	7	0	0	2	0	7	1	8	0	0	0	0	2	1	1	0	0	0	1	0	1
0	0	1	0	0	1	0	9	8	1	0	0	0	0	2	2	1	0	0	0	1	0	0
9	9	0	9	4	0	0	0	0	0	1	6	2	7	1	2	8	1	7	9	9	1	3
6	6	0	6	4	0	1	0	0	0	6	1	2	1	1	1	6	7	7	6	6	2	2
3	3	1	3	2	2	1	2	0	0	2	2	1	3	2	2	2	3	2	2	2	2	1
8	8	1	8	4	1	2	1	0	0	7	1	3	1	2	2	6	7	6	6	7	3	2
2	2	3	2	2	2	1	4	2	2	1	1	2	2	1	1	1	2	1	2	1	2	2
3	3	2	3	2	1	1	2	1	2	2	1	2	2	1	1	2	3	1	3	1	2	2
8	8	0	1	5	0	0	0	1	1	8	6	2	6	1	2	1	9	9	8	8	1	3
9	9	1	9	6	1	1	1	0	0	1	7	3	7	2	3	9	1	8	1	8	2	3
7	7	0	9	5	0	1	0	0	0	7	7	2	6	1	1	9	8	1	7	7	2	3
8	8	2	8	7	1	2	1	0	0	9	6	2	6	2	3	8	1	7	1	7	3	3
8	8	0	8	4	1	0	0	1	1	9	6	2	7	1	1	8	8	7	7	1	1	2
2	2	2	2	3	1	1	1	0	0	1	2	2	3	2	2	1	2	2	3	1	1	2
3	3	0	3	2	1	1	1	1	0	3	2	1	2	2	2	3	3	2	3	2	2	1

Appendix J. Syntax R

Textual representation of items 1 to 23

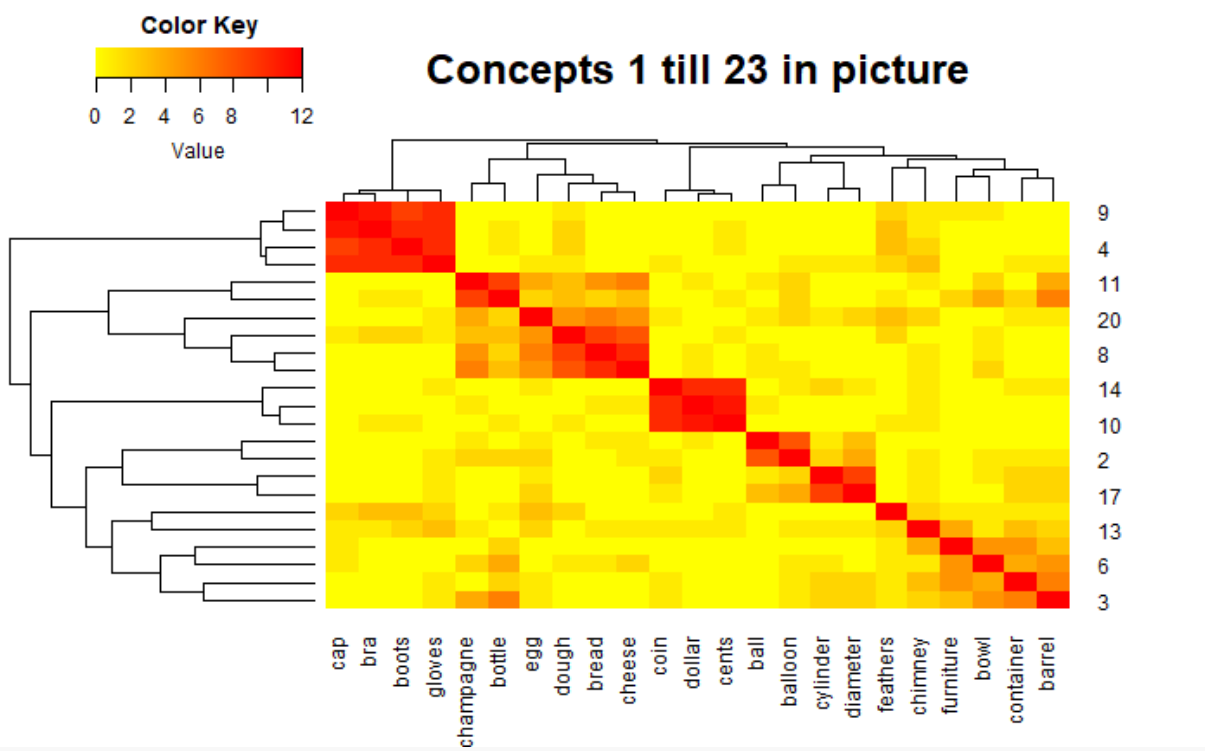
```
#   R   script   to   generate    a   heatmap based   on   concepts    from
Huth    et  al. (2016)
#   Call    these   libraries.  They    need    to  be  installed   as  pa
ckages
library(gplots)

library(RColorBrewer)
#   Read    the data    file    (.csv   format)
data    <- read.csv("C:/Users/danie/Desktop/Utwente/Master/1. Thesis/Data
analysis/Jaccard scores text 1-23.csv")
#   Transform data  in  numerical   format
mat_data    <- data.matrix(data[,1:ncol(data)])

#   Define  colors  of  heatmap:    red for high    numbers
my_palette  <- colorRampPalette(c("yellow","red"))(n    =   299)

#   Call    heatmap function    (from   gplots),    with    these   argume
nts
heatmap.2(mat_data, col =   my_palette, density.info="none",    trace="non
e",
                                        revC    =   TRUE,   main="Concepts
1 till 23 in text")
```




```
#Export figure (png or pdf) from Plots screen (bottom-right   panel)
```

Pictorial representation of items 1 to 23

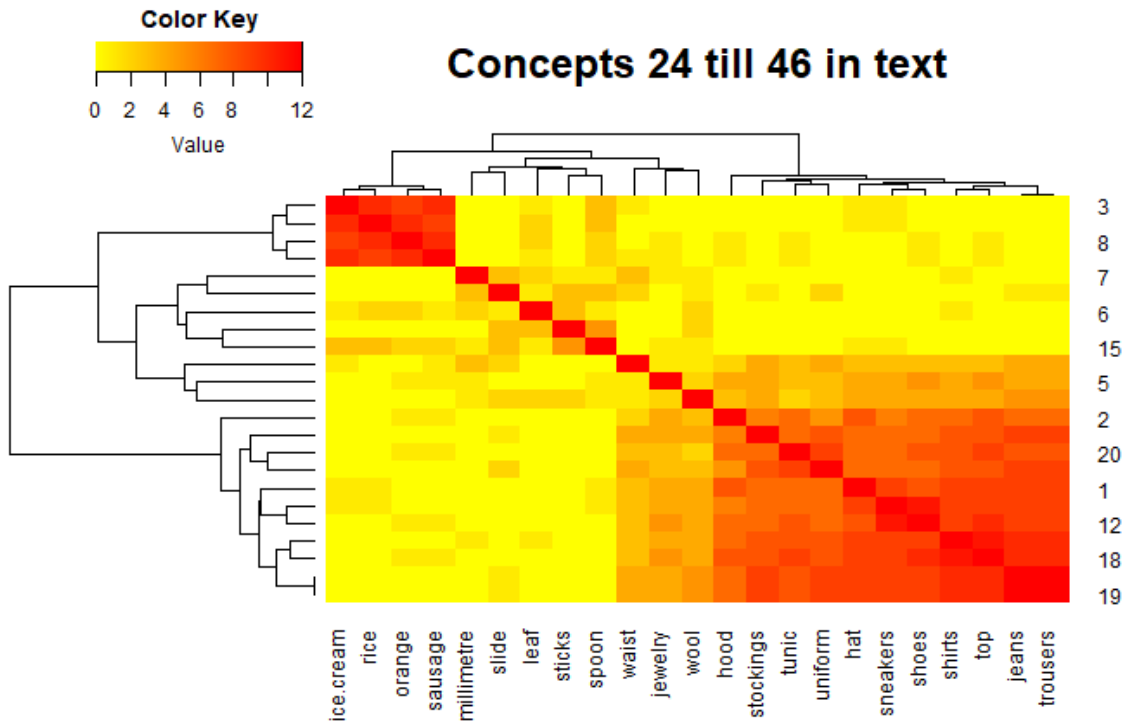
```
#   R   script to generate    a   heatmap based   on concepts    from    H
uth    et al. (2016)
#   Call    these   libraries.  They    need    to be installed   as packa
ges
library(gplots)

library(RColorBrewer)
#   Read    the data    file    (.csv   format)
data    <- read.csv("C:/Users/danie/Desktop/Utwente/Master/1. Thesis/Data
analysis/JC picture 1-23.csv")
#   Transform data  in  numerical   format
mat_data    <- data.matrix(data[,1:ncol(data)])


#   Define  colors  of  heatmap:    red for high    numbers
my_palette  <- colorRampPalette(c("yellow","red"))(n    =   299)
heatmap.2(mat_data, col =   my_palette, density.info="none",    trace="non
e",
                                        revC    =   TRUE,   main="Concepts
1 till 23 in picture")
```




```
#Export figure (png or pdf) from Plots screen (bottom-right   panel)
```

Textual representation of items 24-46

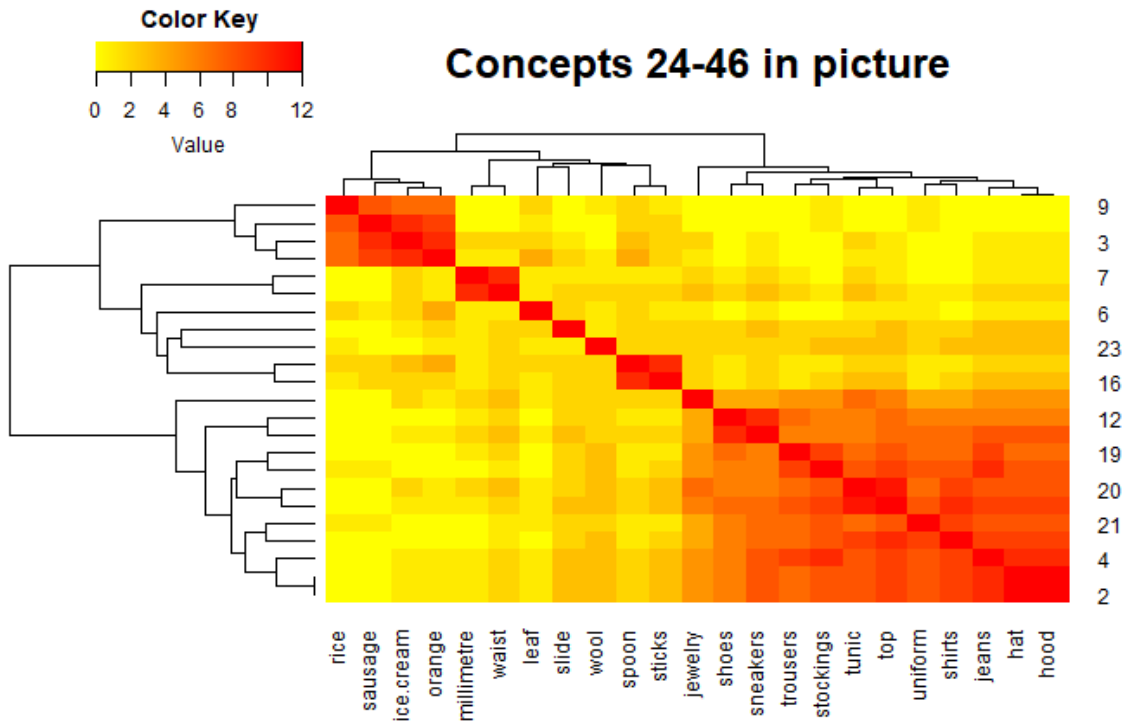
```
#   R   script to generate    a   heatmap based   on concepts    from    H
uth    et al. (2016)
library(gplots)

library(RColorBrewer)
#   Read    the data    file    (.csv   format)
data    <- read.csv("C:/Users/danie/Desktop/Utwente/Master/1. Thesis/Data
analysis/Jaccard scores text 24-46.csv")
#   Transform data  in  numerical   format
mat_data    <- data.matrix(data[,1:ncol(data)])


#   Define  colors  of  heatmap:    red for high    numbers
my_palette  <- colorRampPalette(c("yellow","red"))(n    =   299)
heatmap.2(mat_data, col =   my_palette, density.info="none",    trace="non
e",
                                        revC    =   TRUE,   main="Concepts
24 till 46 in text")
```




```
#Export figure (png or pdf) from Plots screen (bottom-right panel)
```

Pictorial representation of items 24-46

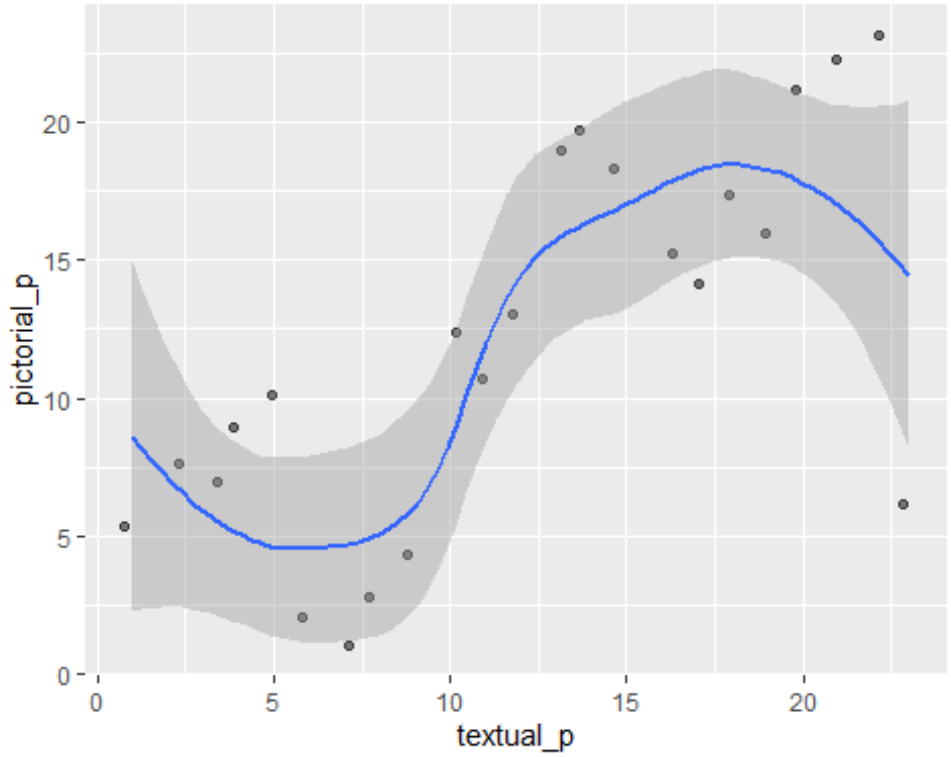
```
#   R   script to generate    a   heatmap based   on concepts    from    H
uth    et al. (2016)
library(gplots)

library(RColorBrewer)
#   Read    the data    file    (.csv   format)
data    <- read.csv("C:/Users/danie/Desktop/Utwente/Master/1. Thesis/Data
analysis/Jaccard scores pictures 24-46.csv")
#   Transform data  in  numerical   format
mat_data    <- data.matrix(data[,1:ncol(data)])


#   Define  colors  of  heatmap:    red for high    numbers
my_palette  <- colorRampPalette(c("yellow","red"))(n    =   299)
heatmap.2(mat_data, col =   my_palette, density.info="none",    trace="non
e",
                                        revC    =   TRUE,   main="Concepts
24-46 in picture")
```




```
#Export figure (png or pdf) from Plots screen (bottom-right   panel)
```

Spearman's Rho items 1-23

```
Dataset_A <-
  read_csv("C:/Users/danie/Desktop/Utwente/Master/1. Thesis/Data analysis/
Places in heatmap items 1 till 23.csv")

## Parsed with column specification:
## cols(
##   Concept = col_character(),
##   textual_p = col_double(),
##   pictorial_p = col_double()
## )

#textual_p <- Dataset[,2]
#pictorial_p <- Dataset[,3]
print(Dataset_A)

## # A tibble: 23 x 3
##    Concept   textual_p pictorial_p
##    <chr>         <dbl>       <dbl>
##  1 champagne         1           5
##  2 dough             2           8
##  3 egg               3           7
##  4 bread             4           9
##  5 cheese            5          10
##  6 bra               6           2
##  7 cap               7           1
##  8 boots             8           3
##  9 gloves            9           4
## 10 dollar           10          12
## # ... with 13 more rows

summary(Dataset_A)

##    Concept            textual_p     pictorial_p
##  Length:23          Min.   : 1.0   Min.   : 1.0
##  Class :character   1st Qu.: 6.5   1st Qu.: 6.5
##  Mode  :character   Median :12.0   Median :12.0
##                     Mean   :12.0   Mean   :12.0
##                     3rd Qu.:17.5   3rd Qu.:17.5
##                     Max.   :23.0   Max.   :23.0

Dataset_A %>%
  #filter(Dataset_A$textual_p <= 22) %>%
  ggplot(aes(x = textual_p, y = pictorial_p)) +
  geom_jitter(alpha = .5) +
  geom_smooth(se = T)

## `geom_smooth()` using method = 'loess' and formula 'y ~ x'
```




```
help(geom_smooth)
```

```
## starting httpd help server ...
```

```
## done
```

```
#H0: Ranks of concepts in textual representation = ranks of concepts in pi
ctorial representation.
#H1: Ranks of concepts in textual representation != ranks of concepts in p
ictorial representation.
#one-sided test
res_A <- cor.test(Dataset_A$textual_p, Dataset_A$pictorial_p, method = "sp
earman", alternative = "greater", SE = "T")
```

```
res_A
```

```
##
## Spearman's rank correlation rho
##
## data:  Dataset_A$textual_p and Dataset_A$pictorial_p
## S = 618, p-value = 0.0001697
## alternative hypothesis: true rho is greater than 0
## sample estimates:
##      rho
## 0.694664
```

```
#For items 1-23 there is a moderate-strong positive correlation between th
e ranks of concepts in the textual and pictorial heatmap, which was statis
tically significant (Rs = .694, n = 23, p <0.001)
```

Spearman's Rho items 24-46

```
Dataset_B <-
 read_csv("C:/Users/danie/Desktop/Utwente/Master/1. Thesis/Data analysis/P
laces in heatmaps 24-26.csv")
```

```
## Parsed with column specification:
## cols(
##   textual_p = col_double(),
##   pictorial_p = col_double()
## )
```

```
#textual_p <- Dataset[,2]
#pictorial_p <- Dataset[,3]
print(Dataset_B)
```

```
## # A tibble: 23 x 2
##    textual_p pictorial_p
##        <dbl>       <dbl>
##  1         1           3
##  2         2           1
##  3         3           4
##  4         4           2
##  5         5           5
##  6         6           8
##  7         7           7
##  8         8          11
##  9         9          10
## 10        10           6
## # ... with 13 more rows
```

```
summary(Dataset_B)
```

```
##    textual_p     pictorial_p
##  Min.   : 1.0   Min.   : 1.0
##  1st Qu.: 6.5   1st Qu.: 6.5
##  Median :12.0   Median :12.0
##  Mean   :12.0   Mean   :12.0
##  3rd Qu.:17.5   3rd Qu.:17.5
##  Max.   :23.0   Max.   :23.0
```

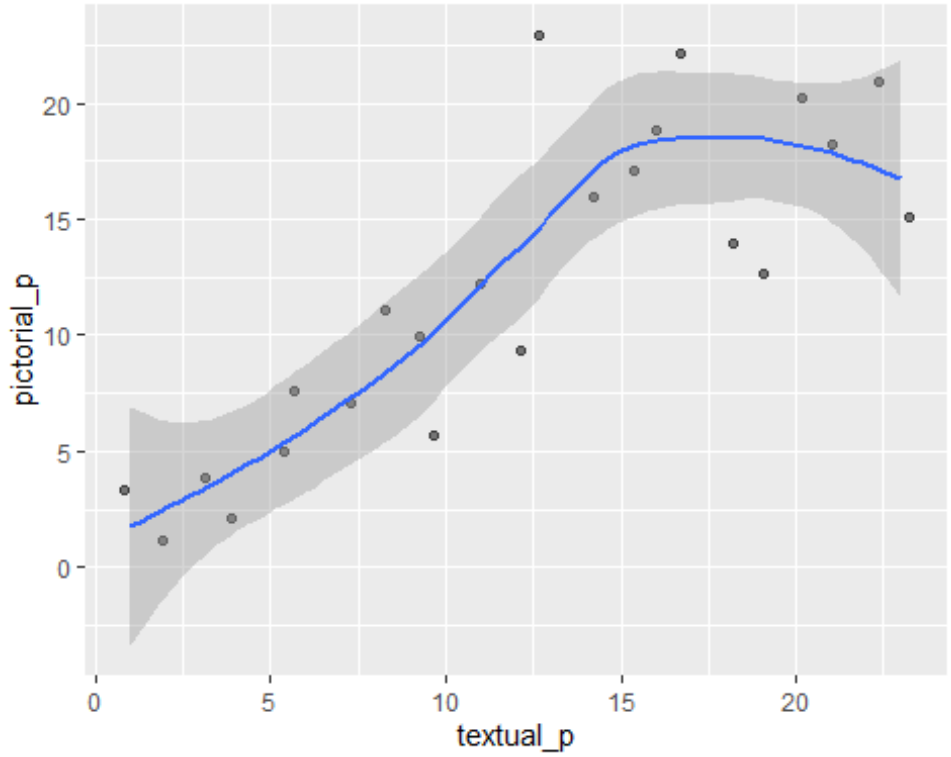
```
#H0: Ranks of concepts in textual representation = ranks of concepts in pi
ctorial representation.
#H1: Ranks of concepts in textual representation != ranks of concepts in p
ictorial representation.
#one-sided test
#Paird sample because the rank numbers of the dataset only belong to one o
f the concepts.
#confidence level of 0.95
```

```
wilcox.test(Dataset_B$textual_p,Dataset_B$pictorial_p, mu=0,alt="two.sided
", conf.int = T, conf.level = 0.95,paired = T, correct = T)
```

```
## Warning in wilcox.test.default(Dataset_B$textual_p, Dataset_B$pictorial
_p, :
## cannot compute exact p-value with ties
```

```
## Warning in wilcox.test.default(Dataset_B$textual_p, Dataset_B$pictorial
_p, :
## cannot compute exact confidence interval with ties

## Warning in wilcox.test.default(Dataset_B$textual_p, Dataset_B$pictorial
_p, :
## cannot compute exact p-value with zeroes

## Warning in wilcox.test.default(Dataset_B$textual_p, Dataset_B$pictorial
_p, :
## cannot compute exact confidence interval with zeroes

##
## Wilcoxon signed rank test with continuity correction
##
## data:  Dataset_B$textual_p and Dataset_B$pictorial_p
## V = 107, p-value = 0.9551
## alternative hypothesis: true location shift is not equal to 0
## 95 percent confidence interval:
##  -1.999986  1.999950
## sample estimates:
## (pseudo)median
##   5.906847e-05
```

```
#To be able to use Spearman's Rho, one of the assumptions is that there mu
st be a monotonic relationship. Therefore, a jitterplot is plotted. There
can be seen that the relationship is not monotonic. Therefore, not all ass
umptions are met, so Spearmans Rho cannot be used.
Dataset_B %>%
  ggplot(aes(x = textual_p, y = pictorial_p)) +
  geom_jitter(alpha = .5) +
  geom_smooth(se = T)

## `geom_smooth()` using method = 'loess' and formula 'y ~ x'
```




```
#https://biostats.w.uib.no/comparing-two-variables-spearmans-correlation/
res_B <- cor.test(Dataset_B$textual_p, Dataset_B$pictorial_p, method = "sp
earman", alternative = "greater")

res_B

##
## Spearman's rank correlation rho
##
## data:  Dataset_B$textual_p and Dataset_B$pictorial_p
## S = 318, p-value = 8.661e-07
## alternative hypothesis: true rho is greater than 0
## sample estimates:
##       rho
## 0.8428854

#For items 24-46 there is a strong positive correlation between the ranks
of the concepts in the textual and pictorial heatmap, which was statistica
lly significant (Rs = 0.843, n = 23, p < 0.001).
```

Wilcoxon signed rank and rank sum test on within and between voxels/brain areas

```
## -- Attaching packages ---------------------- tidyverse 1.3.0 --

## v ggplot2 3.3.0     v purrr   0.3.4
## v tibble  3.0.1     v dplyr   0.8.5
## v tidyr   1.0.3     v stringr 1.4.0
## v readr   1.3.1     v forcats 0.5.0

## -- Conflicts ------------------------- tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()

library(devtools)

## Loading required package: usethis

library(mvtnorm)
library(dplyr)
library(tidyverse)
library(rstanarm)


## Loading required package: Rcpp

## rstanarm (Version 2.19.3, packaged: 2020-02-11 05:16:41 UTC)

## - Do not expect the default priors to remain the same in future rstanar
m versions.

## Thus, R scripts should specify priors explicitly, even if they are just
the defaults.

## - For execution on a local, multicore CPU with excess RAM we recommend
calling

## options(mc.cores = parallel::detectCores())

## - bayesplot theme set to bayesplot::theme_default()

##    * Does _not_ affect other ggplot2 plots

##    * See ?bayesplot_theme_set for details on theme setting

##Stating hypotheses

##Stating hypotheses
#H0=there is no significant difference between the relative jaccard scores
of textual concept combinations within and between clusters/brain areas.
#H1=there is a significant difference between the relative jaccard scores
of textual concept combinations within and between clusters/brain areas.

##Stating hypotheses
#H0=there is no significant difference between the relative jaccard scores
of pictorial concept combinations within and between clusters/brain areas.
#H1=there is a significant difference between the relative jaccard scores
of pictorial concept combinations within and between clusters/brain areas.
```

```
#H0=there is no significant difference between the relative jaccard scores
of textual and pictorial concept combinations within voxels/brain areas.
#H1=there is a significant difference between the relative jaccard scores
of textual and pictorial concept combinations within voxels/brain areas.

#H0=there is no significant difference between the relative jaccard scores
of textual and pictorial concept combinations between voxels/brain areas.
#H1=there is a significant difference between the relative jaccard scores
of textual and pictorial concept combinations between voxels/brain areas.

#H0=there is no significant difference between the relative jaccard scores
of concept combinations between voxels/brain areas.
#H1=there is a significant difference between the relative jaccard scores
of concept combinations between voxels/brain areas.

## Checking the assumptions for a t-test.
#One of the assumptions for a t-test is normality. Normality will be check
ed by plotting a histogram and performing the Shapiro Wilk test.
# Check for within voxels relative JS for the textual data of items 1-23



#### Within versus between in textual and pictorial individually

#import datasets
Textual_Dataset <- read_csv("C:/Users/danie/Desktop/Utwente/Master/1. Thes
is/Data analysis/Textual within versus between.csv")

## Parsed with column specification:
## cols(
##   Text_Within = col_character(),
##   JS_T_Within = col_double(),
##   Rel_JS_T_Within = col_double(),
##   Text_Between = col_character(),
##   JS_T_Between = col_double(),
##   Rel_JS_T_Between = col_double()
## )

Pictorial_Dataset <- read_csv("C:/Users/danie/Desktop/Utwente/Master/1. Th
esis/Data analysis/Pictorial within versus between.csv")

## Parsed with column specification:
## cols(
##   Pictorial_Within = col_character(),
##   JS_P_Within = col_double(),
##   Rel_JS_P_Within = col_double(),
##   Pictorial_Between = col_character(),
##   JS_P_Between = col_double(),
##   Rel_JS_P_Between = col_double()
## )

Between_voxels <- read_csv("C:/Users/danie/Desktop/Utwente/Master/1. Thesi
s/Data analysis/Danielle Dierking concept pairs between clusters in Huth.c
sv")
```

```
## Parsed with column specification:
## cols(
##   Text = col_character(),
##   JS_T = col_double(),
##   Rel_JS_T = col_double(),
##   Picture = col_character(),
##   JS_P = col_double(),
##   Rel_JS_P = col_double()
## )
```

```
summary(Textual_Dataset)
```

```
##  Text_Within         JS_T_Within     Rel_JS_T_Within   Text_Between
##  Length:99          Min.   : 0.000   Min.   :0.00000   Length:99
##  Class :character   1st Qu.: 1.000   1st Qu.:0.08333   Class :character
##  Mode  :character   Median : 2.000   Median :0.16667   Mode  :character
##                     Mean   : 3.939   Mean   :0.32828
##                     3rd Qu.: 7.000   3rd Qu.:0.58333
##                     Max.   :12.000   Max.   :1.00000
##
##   JS_T_Between   Rel_JS_T_Between
##  Min.   :0.000   Min.   :0.00000
##  1st Qu.:0.000   1st Qu.:0.00000
##  Median :1.000   Median :0.08333
##  Mean   :1.189   Mean   :0.09910
##  3rd Qu.:2.000   3rd Qu.:0.16667
##  Max.   :6.000   Max.   :0.50000
##  NA's   :25      NA's   :25
```

```
summary (Pictorial_Dataset)
```

```
##  Pictorial_Within    JS_P_Within     Rel_JS_P_Within  Pictorial_Between
##  Length:99          Min.   : 0.000   Min.   :0.0000   Length:99
##  Class :character   1st Qu.: 0.000   1st Qu.:0.0000   Class :character
##  Mode  :character   Median : 2.000   Median :0.1667   Mode  :character
##                     Mean   : 3.626   Mean   :0.3022
##                     3rd Qu.: 7.000   3rd Qu.:0.5833
##                     Max.   :11.000   Max.   :0.9167
##
##   JS_P_Between   Rel_JS_P_Between
##  Min.   :0.000   Min.   :0.00000
##  1st Qu.:0.000   1st Qu.:0.00000
##  Median :1.000   Median :0.08333
##  Mean   :1.324   Mean   :0.11036
##  3rd Qu.:2.000   3rd Qu.:0.16667
##  Max.   :8.000   Max.   :0.66667
##  NA's   :25      NA's   :25
```

```
sd(Textual_Dataset$Rel_JS_T_Within)
```

```
## [1] 0.2763388
```

```
sd(Between_voxels$Rel_JS_T)
```

```
## [1] 0.1207817
```

```
sd(Pictorial_Dataset$Rel_JS_P_Within)
```

```
## [1] 0.307361
```

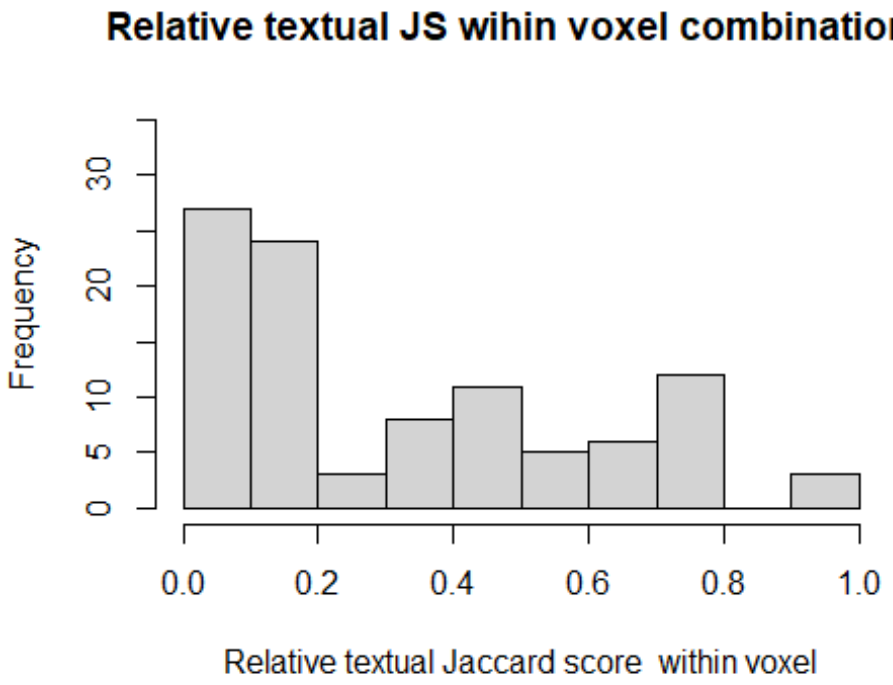
```
sd(Between_voxels$Rel_JS_P)
```

```
## [1] 0.12725
```

```
### Textual
## Checking the assumptions for a t-test.
#One of the assumptions for a t-test is normality. Normality will be check
ed by plotting a histogram and performing the Shapiro Wilk test.
# Check for within voxels relative JS for the textual data
Textual_Dataset
```

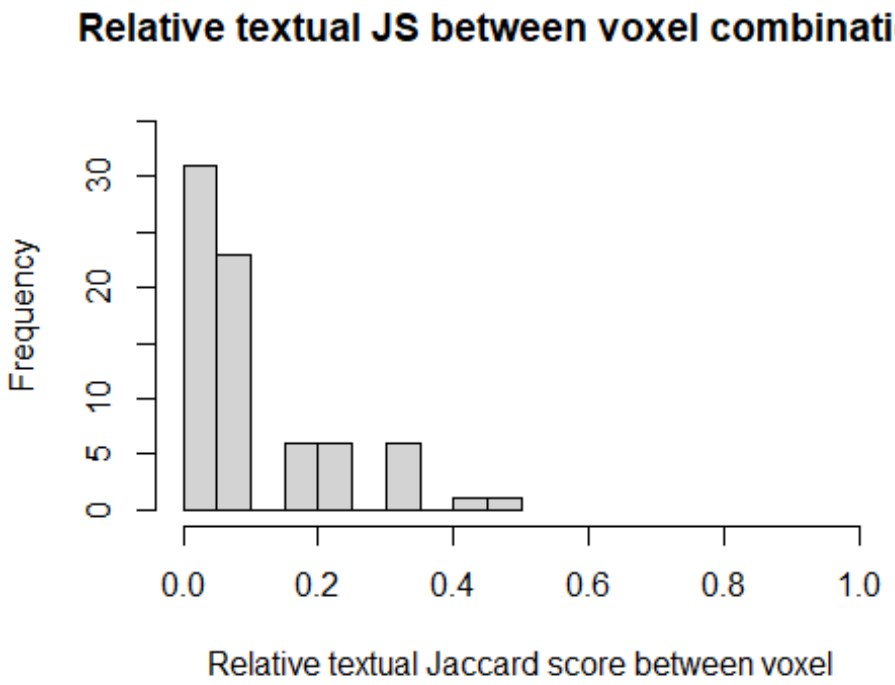
```
## # A tibble: 99 x 6
##    Text_Within JS_T_Within Rel_JS_T_Within Text_Between JS_T_Between
##    <chr>             <dbl>           <dbl> <chr>                <dbl>
##  1 cap-diamet~           2           0.167 ball-chimney             2
##  2 cap-diamet~           2           0.167 ball-furnit~             2
##  3 cap-diamet~           2           0.167 ball-feathe~             4
##  4 cap-diamet~           2           0.167 ball-balloon             6
##  5 cylinder-d~           5           0.417 ball-coin                1
##  6 cap-cylind~           4           0.333 ball-bread               0
##  7 cap-diamet~           2           0.167 ball-dough               1
##  8 cap-cylind~           4           0.333 ball-champa~             0
##  9 cap-diamet~           2           0.167 ball-egg                 2
## 10 cap-cylind~           4           0.333 barrel-chim~             2
## # ... with 89 more rows, and 1 more variable: Rel_JS_T_Between <dbl>
```

```
  hist(main="Relative textual JS wihin voxel combinations", Textual_Datase
t$Rel_JS_T_Within, xlim = c(0,1), ylim = c(0,35), xlab = "Relative textual
Jaccard score  within voxel") #adjusted y-limit and x-label.
```




```
  #The histogram is not bell shaped so there is no normal distribution.
  shapiro.test(Textual_Dataset$Rel_JS_T_Within)#The distribution is not no
rmal because p<0.001< alpha = 0.05.

##
##  Shapiro-Wilk normality test
##
## data:  Textual_Dataset$Rel_JS_T_Within
## W = 0.89073, p-value = 5.916e-07

## Checking the assumptions for a t-test.
#One of the assumptions for a t-test is normality. Normality will be check
ed by plotting a histogram and performing the Shapiro Wilk test.
# Check for between voxels relative JS for the textual data
Textual_Dataset

## # A tibble: 99 x 6
##    Text_Within JS_T_Within Rel_JS_T_Within Text_Between JS_T_Between
##    <chr>             <dbl>           <dbl> <chr>                <dbl>
##  1 cap-diamet~           2           0.167 ball-chimney             2
##  2 cap-diamet~           2           0.167 ball-furnit~             2
##  3 cap-diamet~           2           0.167 ball-feathe~             4
##  4 cap-diamet~           2           0.167 ball-balloon             6
##  5 cylinder-d~           5           0.417 ball-coin                1
##  6 cap-cylind~           4           0.333 ball-bread               0
##  7 cap-diamet~           2           0.167 ball-dough               1
##  8 cap-cylind~           4           0.333 ball-champa~             0
##  9 cap-diamet~           2           0.167 ball-egg                 2
## 10 cap-cylind~           4           0.333 barrel-chim~             2
## # ... with 89 more rows, and 1 more variable: Rel_JS_T_Between <dbl>
```

```
  hist(main="Relative textual JS between voxel combinations", Textual_Data
set$Rel_JS_T_Between, xlim = c(0,1), ylim = c(0,35), xlab = "Relative text
ual Jaccard score between voxel") #adjusted y-limit and x-label.
```




```
  #The histogram is not bell shaped so there is no normal distribution.
  shapiro.test(Textual_Dataset$Rel_JS_T_Between)#The distribution is not n
ormal because p<0.001< alpha = 0.05.

##
##  Shapiro-Wilk normality test
##
## data:  Textual_Dataset$Rel_JS_T_Between
## W = 0.78628, p-value = 5.331e-09

##The Wilcoxon Rank Sum test for textual data within versus between voxels
/brain areas
#Since the data are not normally distributed an alternative of the t-test
needs to be used. Since the samples are independent and the data are at le
ast measured at an ordinal scale the Wilcoxon Rank Sum test is a suitable
test.
# Wilcoxon Rank Sum test for within voxels
#p = 0.00016 < 0.05(W = 5608) therefore,there is enough evidence to reject
H0. There is a significant difference for textual relative Jaccard scores
between within voxels/brain areas (Median = 0.17, IQR = 0.50, n = 99) and
between voxels/brain areas (Median = 0.08,iQR = 0.17, n = 74).

Model_Textual_Dataset <- wilcox.test(Textual_Dataset$Rel_JS_T_Within, Text
ual_Dataset$Rel_JS_T_Between,mu=0, alt="two.sided", conf.int = T, conf.lev
el = 0.95,paired = F, correct = F)
print(Model_Textual_Dataset)
```

```
##
##  Wilcoxon rank sum test
##
## data:  Textual_Dataset$Rel_JS_T_Within and Textual_Dataset$Rel_JS_T_Bet
ween
## W = 5608, p-value = 1.29e-09
## alternative hypothesis: true location shift is not equal to 0
## 95 percent confidence interval:
##  0.0833652 0.2499732
## sample estimates:
## difference in location
##              0.1666254
```

```
#https://www.datanovia.com/en/lessons/wilcoxon-test-in-r/#:~:text=Calculat
e%20and%20report%20Wilcoxon%20test,%2Fsqrt(N)%20).&text=Note%20that%20N%20
corresponds%20to,pairs%20for%20paired%20samples%20test.

# Measuring effect size
Zstat <- qnorm(Model_Textual_Dataset$p.value/2)
print(Zstat)
```

```
## [1] -6.068662
```

```
abs(Zstat/sqrt(173))
```

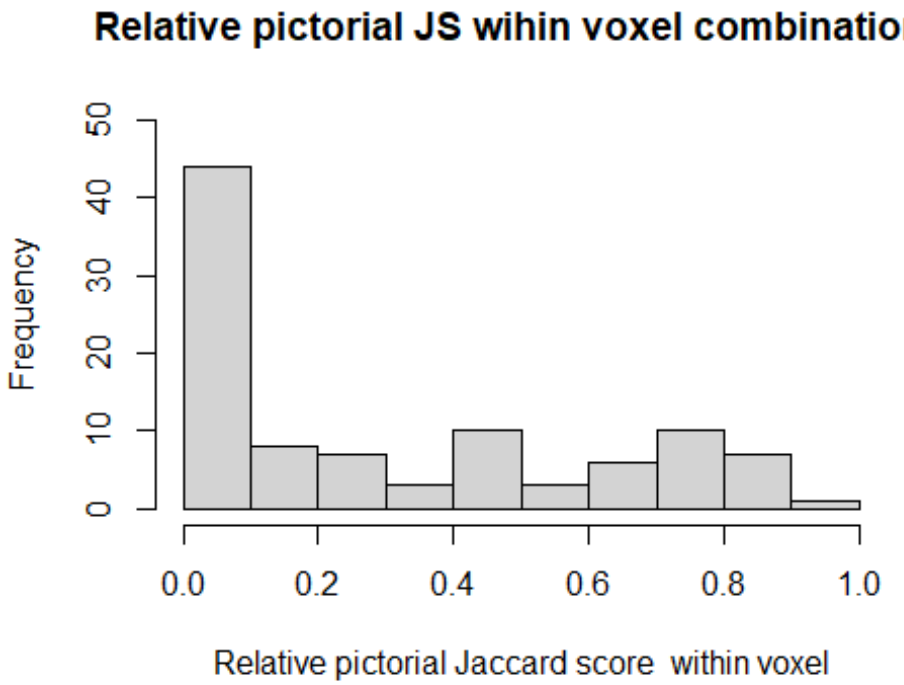
```
## [1] 0.4613918
```

```
#effectsize = absolut Z-statistic/sqrt(N)
#with r = 0.46, the difference is relatively strong https://www.peterstati
stics.com/CrashCourse/4-TwoVarPair/OrdOrd/OrdOrdPair3.html

## Checking the assumptions for a t-test.
#One of the assumptions for a t-test is normality. Normality will be check
ed by plotting a histogram and performing the Shapiro Wilk test.
# Check for within voxels relative JS for the pictorial data
Pictorial_Dataset
```

```
## # A tibble: 99 x 6
##    Pictorial_Within JS_P_Within Rel_JS_P_Within Pictorial_Betwe~ JS_P_B
etween
##    <chr>                  <dbl>           <dbl> <chr>
<dbl>
##  1 cap-diameter               0           0     ball-chimney
0
##  2 cap-diameter               0           0     ball-furniture
0
##  3 cap-diameter               0           0     ball-feathers
0
##  4 cap-diameter               0           0     ball-balloon
8
##  5 cylinder-diamet~           5           0.417 ball-coin
0
##  6 cap-cylinder               0           0     ball-bread
1
##  7 cap-diameter               0           0     ball-dough
```

```
1
##  8 cap-cylinder               0           0     ball-champagne
1
##  9 cap-diameter               0           0     ball-egg
1
## 10 cap-cylinder               0           0     barrel-chimney
2
## # ... with 89 more rows, and 1 more variable: Rel_JS_P_Between <dbl>
```

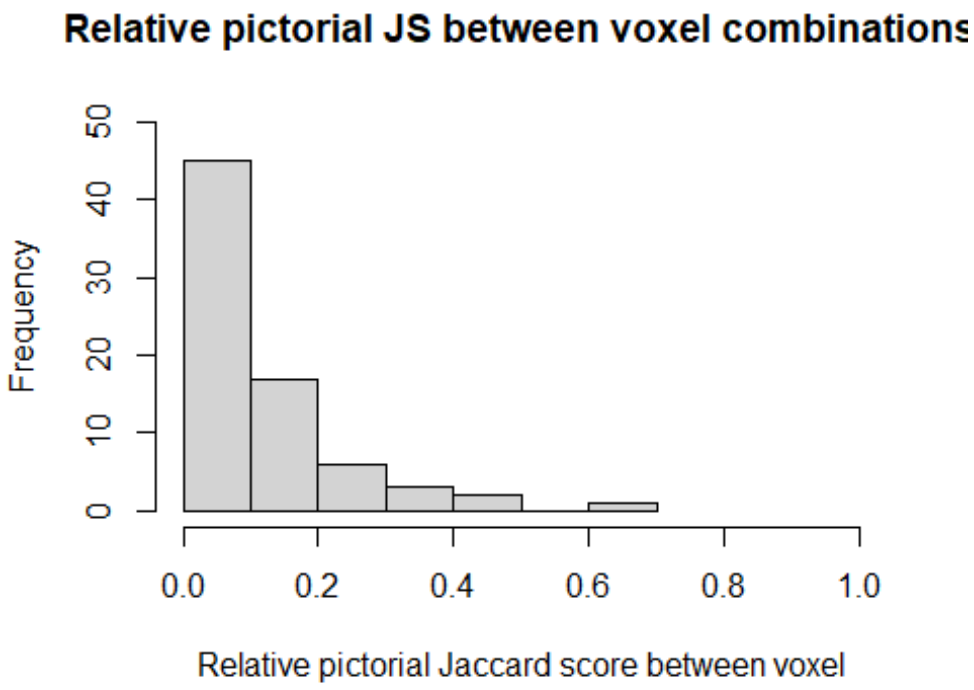
```
  hist(main="Relative pictorial JS wihin voxel combinations", Pictorial_Da
taset$Rel_JS_P_Within, xlim = c(0,1), ylim = c(0,50),xlab = "Relative pict
orial Jaccard score  within voxel") #adjusted y-limit and x-label.
```




```
  #The histogram is not bell shaped so there is no normal distribution.
  shapiro.test(Pictorial_Dataset$Rel_JS_P_Within)#The distribution is not
normal because p<0.001< alpha = 0.05.

##
##  Shapiro-Wilk normality test
##
## data:  Pictorial_Dataset$Rel_JS_P_Within
## W = 0.83734, p-value = 4.723e-09

## Checking the assumptions for a t-test.
#One of the assumptions for a t-test is normality. Normality will be check
ed by plotting a histogram and performing the Shapiro Wilk test.
# Check for between voxels relative JS for the pictorial data
Textual_Dataset

## # A tibble: 99 x 6
##    Text_Within JS_T_Within Rel_JS_T_Within Text_Between JS_T_Between
```

```
##    <chr>              <dbl>           <dbl> <chr>                <dbl>
##  1 cap-diamet~            2           0.167 ball-chimney             2
##  2 cap-diamet~            2           0.167 ball-furnit~             2
##  3 cap-diamet~            2           0.167 ball-feathe~             4
##  4 cap-diamet~            2           0.167 ball-balloon             6
##  5 cylinder-d~            5           0.417 ball-coin                1
##  6 cap-cylind~            4           0.333 ball-bread               0
##  7 cap-diamet~            2           0.167 ball-dough               1
##  8 cap-cylind~            4           0.333 ball-champa~             0
##  9 cap-diamet~            2           0.167 ball-egg                 2
## 10 cap-cylind~            4           0.333 barrel-chim~             2
## # ... with 89 more rows, and 1 more variable: Rel_JS_T_Between <dbl>
```

```
  hist(main="Relative pictorial JS between voxel combinations", Pictorial_
Dataset$Rel_JS_P_Between, xlim = c(0,1), ylim = c(0,50),xlab = "Relative p
ictorial Jaccard score between voxel") #adjusted y-limit and x-label.
```




```
  #The histogram is not bell shaped so there is no normal distribution.
  shapiro.test(Pictorial_Dataset$Rel_JS_P_Between)#The distribution is not
normal because p<0.001< alpha = 0.05.

##
##  Shapiro-Wilk normality test
##
## data:  Pictorial_Dataset$Rel_JS_P_Between
## W = 0.80197, p-value = 1.399e-08

##The Wilcoxon Rank Sum test for pictorial data of within versus voxels/br
ain areas
#Since the data are not normally distributed an alternative of the t-test
needs to be used. Since the samples are independent and the data are at le
```

```
ast measured at an ordinal scale the Wilcoxon Rank Sum test is a suitable
test.
# Wilcoxon Rank Sum test for within voxels
#p = 0.0005 (W = 4762.5) therefore,there is enough evidence to reject H0.
There is a significant difference for textual relative Jaccard scores betw
een within voxels/brain areas (Median = 0.17, IQR = 0.58, n = 99) and betw
een voxels/brain areas (Median = 0.08,iQR = 0.17, n = 74).

Model_Pictorial_Dataset <- wilcox.test(Pictorial_Dataset$Rel_JS_P_Within,
Pictorial_Dataset$Rel_JS_P_Between,mu=0, alt="two.sided", conf.int = T, co
nf.level = 0.95,paired = F, correct = F)
print(Model_Pictorial_Dataset)

##
##  Wilcoxon rank sum test
##
## data:  Pictorial_Dataset$Rel_JS_P_Within and Pictorial_Dataset$Rel_JS_P
_Between
## W = 4762.5, p-value = 0.0005425
## alternative hypothesis: true location shift is not equal to 0
## 95 percent confidence interval:
##  1.052671e-06 1.667148e-01
## sample estimates:
## difference in location
##             0.08338219

#https://www.datanovia.com/en/lessons/wilcoxon-test-in-r/#:~:text=Calculat
e%20and%20report%20Wilcoxon%20test,%2Fsqrt(N)%20).&text=Note%20that%20N%20
corresponds%20to,pairs%20for%20paired%20samples%20test.

# Measuring effect size
Zstat <- qnorm(Model_Pictorial_Dataset$p.value/2)
print(Zstat)

## [1] -3.458834

abs(Zstat/sqrt(173))

## [1] 0.2629703

#effectsize = absolut Z-statistic/sqrt(N)
#with r = 0.26, the difference is moderate https://www.peterstatistics.com
/CrashCourse/4-TwoVarPair/OrdOrd/OrdOrdPair3.html
```

```
####Within versus between voxels, textual compared with pictorial

In_voxels <- read_csv("C:/Users/danie/Desktop/Utwente/Master/1. Thesis/Dat
a analysis/Danielle Dierking relative jaccard scores of concept combinatio
ns from Huth.csv")

## Parsed with column specification:
## cols(
##   Text = col_character(),
##   JS_T = col_double(),
##   Rel_JS_T = col_double(),
##   Picture = col_character(),
##   JS_P = col_double(),
##   REL_JS_P = col_double()
## )

#Load datasets of within voxel and between voxel
In_voxels <- read_csv("C:/Users/danie/Desktop/Utwente/Master/1. Thesis/Dat
a analysis/Danielle Dierking relative jaccard scores of concept combinatio
ns from Huth.csv")

## Parsed with column specification:
## cols(
##   Text = col_character(),
##   JS_T = col_double(),
##   Rel_JS_T = col_double(),
##   Picture = col_character(),
##   JS_P = col_double(),
##   REL_JS_P = col_double()
## )

Between_voxels <- read_csv("C:/Users/danie/Desktop/Utwente/Master/1. Thesi
s/Data analysis/Danielle Dierking concept pairs between clusters in Huth.c
sv")

## Parsed with column specification:
## cols(
##   Text = col_character(),
##   JS_T = col_double(),
##   Rel_JS_T = col_double(),
##   Picture = col_character(),
##   JS_P = col_double(),
##   Rel_JS_P = col_double()
## )

summary(In_voxels)

##      Text                JS_T           Rel_JS_T         Picture
##  Length:99          Min.   : 0.000   Min.   :0.00000   Length:99
##  Class :character   1st Qu.: 1.000   1st Qu.:0.08333   Class :character
##  Mode  :character   Median : 2.000   Median :0.16667   Mode  :character
##                     Mean   : 3.939   Mean   :0.32828
##                     3rd Qu.: 7.000   3rd Qu.:0.58333
##                     Max.   :12.000   Max.   :1.00000
##       JS_P           REL_JS_P
```

```
##  Min.   : 0.000   Min.   :0.0000
##  1st Qu.: 0.000   1st Qu.:0.0000
##  Median : 2.000   Median :0.1667
##  Mean   : 3.616   Mean   :0.3013
##  3rd Qu.: 7.000   3rd Qu.:0.5833
##  Max.   :11.000   Max.   :0.9167
```

```
summary(Between_voxels)
```

```
##      Text                JS_T          Rel_JS_T         Picture
##  Length:74          Min.   :0.000   Min.   :0.00000   Length:74
##  Class :character   1st Qu.:0.000   1st Qu.:0.00000   Class :character
##  Mode  :character   Median :1.000   Median :0.08333   Mode  :character
##                     Mean   :1.189   Mean   :0.09910
##                     3rd Qu.:2.000   3rd Qu.:0.16667
##                     Max.   :6.000   Max.   :0.50000
##       JS_P          Rel_JS_P
##  Min.   :0.000   Min.   :0.00000
##  1st Qu.:0.000   1st Qu.:0.00000
##  Median :1.000   Median :0.08333
##  Mean   :1.324   Mean   :0.11036
##  3rd Qu.:2.000   3rd Qu.:0.16667
##  Max.   :8.000   Max.   :0.66667
```

```
In_voxels
```

```
## # A tibble: 99 x 6
##    Text               JS_T Rel_JS_T Picture            JS_P REL_JS_P
##    <chr>             <dbl>    <dbl> <chr>             <dbl>    <dbl>
##  1 cap-diameter          2    0.167 cap-diameter          0    0
##  2 cap-diameter          2    0.167 cap-diameter          0    0
##  3 cap-diameter          2    0.167 cap-diameter          0    0
##  4 cap-diameter          2    0.167 cap-diameter          0    0
##  5 cylinder-diameter     5    0.417 cylinder-diameter     5    0.417
##  6 cap-cylinder          4    0.333 cap-cylinder          0    0
##  7 cap-diameter          2    0.167 cap-diameter          0    0
##  8 cap-cylinder          4    0.333 cap-cylinder          0    0
##  9 cap-diameter          2    0.167 cap-diameter          0    0
## 10 cap-cylinder          4    0.333 cap-cylinder          0    0
## # ... with 89 more rows
```

```
#The histogram is not bell shaped so there is no normal distribution.
#The distribution is not normal because p<0.001< alpha = 0.05.

# Check for within voxels relative JS for the pictorial data of items 1-23
In_voxels
```

```
## # A tibble: 99 x 6
##    Text               JS_T Rel_JS_T Picture            JS_P REL_JS_P
##    <chr>             <dbl>    <dbl> <chr>             <dbl>    <dbl>
##  1 cap-diameter          2    0.167 cap-diameter          0    0
##  2 cap-diameter          2    0.167 cap-diameter          0    0
##  3 cap-diameter          2    0.167 cap-diameter          0    0
##  4 cap-diameter          2    0.167 cap-diameter          0    0
```

```
##  5 cylinder-diameter     5    0.417 cylinder-diameter     5    0.417
##  6 cap-cylinder          4    0.333 cap-cylinder          0    0
##  7 cap-diameter          2    0.167 cap-diameter          0    0
##  8 cap-cylinder          4    0.333 cap-cylinder          0    0
##  9 cap-diameter          2    0.167 cap-diameter          0    0
## 10 cap-cylinder          4    0.333 cap-cylinder          0    0
## # ... with 89 more rows

#The distribution is not normal because p<0.01< alpha = 0.05.

# Check for between voxels relative JS for the textual data.
Between_voxels

## # A tibble: 74 x 6
##    Text            JS_T Rel_JS_T Picture         JS_P Rel_JS_P
##    <chr>          <dbl>    <dbl> <chr>          <dbl>    <dbl>
##  1 ball-chimney       2   0.167  ball-chimney       0   0
##  2 ball-furniture     2   0.167  ball-furniture     0   0
##  3 ball-feathers      4   0.333  ball-feathers      0   0
##  4 ball-balloon       6   0.5    ball-balloon       8   0.667
##  5 ball-coin          1   0.0833 ball-coin          0   0
##  6 ball-bread         0   0      ball-bread         1   0.0833
##  7 ball-dough         1   0.0833 ball-dough         1   0.0833
##  8 ball-champagne     0   0      ball-champagne     1   0.0833
##  9 ball-egg           2   0.167  ball-egg           1   0.0833
## 10 barrel-chimney     2   0.167  barrel-chimney     2   0.167
## # ... with 64 more rows

#The histogram is not bell shaped so there is no normal distribution.

#The distribution is not normal because p<0.001< alpha = 0.05.

# Check for between voxels relative JS for the pictorial data.
Between_voxels

## # A tibble: 74 x 6
##    Text            JS_T Rel_JS_T Picture         JS_P Rel_JS_P
##    <chr>          <dbl>    <dbl> <chr>          <dbl>    <dbl>
##  1 ball-chimney       2   0.167  ball-chimney       0   0
##  2 ball-furniture     2   0.167  ball-furniture     0   0
##  3 ball-feathers      4   0.333  ball-feathers      0   0
##  4 ball-balloon       6   0.5    ball-balloon       8   0.667
##  5 ball-coin          1   0.0833 ball-coin          0   0
##  6 ball-bread         0   0      ball-bread         1   0.0833
##  7 ball-dough         1   0.0833 ball-dough         1   0.0833
##  8 ball-champagne     0   0      ball-champagne     1   0.0833
##  9 ball-egg           2   0.167  ball-egg           1   0.0833
## 10 barrel-chimney     2   0.167  barrel-chimney     2   0.167
## # ... with 64 more rows

#The histogram is not bell shaped so there is no normal distribution.

#The distribution is not normal because p<0.001< alpha = 0.05.

##The Wilcoxon Rank Sum test for within voxels/brain areas
#Since the data are not normally distributed an alternative of the t-test
```

```
needs to be used. Since the samples are independent and the data are at le
ast measured at an ordinal scale the Wilcoxon Rank Sum test is a suitable
test.
# Wilcoxon Rank Sum test for within voxels
Model_In_voxels <- wilcox.test(In_voxels$Rel_JS_T, In_voxels$REL_JS_P,mu=0
, alt="two.sided", conf.int = T, conf.level = 0.95,paired = T, correct = F
)
print(Model_In_voxels)#p = 0.03 < 0.05, therefore,there is enough evidence
to reject H0. There is a significant difference between textual (Median =
0.17, IQR = 0.450, n = 99) and pictorial (Median = 0.17,iQR = 0.583, n = 9
9) relative jaccard scores of concept combinations not clustered together
in the Huth map (V = 2,175.5)

##
##  Wilcoxon signed rank test
##
## data:  In_voxels$Rel_JS_T and In_voxels$REL_JS_P
## V = 2175.5, p-value = 0.02784
## alternative hypothesis: true location shift is not equal to 0
## 95 percent confidence interval:
##  2.020787e-05 8.332476e-02
## sample estimates:
## (pseudo)median
##     0.04165472

# Measuring effect size
Zstat <- qnorm(Model_In_voxels$p.value/2)
print(Zstat)

## [1] -2.199574

abs(Zstat/sqrt(198))

## [1] 0.1563169

#effectsize = absolut Z-statistic/sqrt(N)
#with r = 0.16, the difference is weak. https://www.peterstatistics.com/Cr
ashCourse/4-TwoVarPair/OrdOrd/OrdOrdPair3.html

## Wilcoxon Rank Sum test for between voxels/brain areas
Model_Between_voxels <- wilcox.test(Between_voxels$Rel_JS_T, Between_voxel
s$Rel_JS_P,mu=0, alt="two.sided", conf.int = T, conf.level = 0.95,paired =
T, correct = F)

## Warning in wilcox.test.default(Between_voxels$Rel_JS_T,
## Between_voxels$Rel_JS_P, : cannot compute exact p-value with ties

## Warning in wilcox.test.default(Between_voxels$Rel_JS_T,
## Between_voxels$Rel_JS_P, : cannot compute exact confidence interval wit
h ties

## Warning in wilcox.test.default(Between_voxels$Rel_JS_T,
## Between_voxels$Rel_JS_P, : cannot compute exact p-value with zeroes
```

```
## Warning in wilcox.test.default(Between_voxels$Rel_JS_T,
## Between_voxels$Rel_JS_P, : cannot compute exact confidence interval wit
h zeroes
```

```
print(Model_Between_voxels)#p>0.05, therefore, H0 cannot be rejected. Ther
e is no significant difference between textual (Median = 0.67,n = 74) and
pictorial (Median = 0.67, n = 74) relative jaccard scores of concept combi
nations between voxels/brain areas, W = 2573.5, p = 0.51.
```

```
##
##  Wilcoxon signed rank test
##
## data:  Between_voxels$Rel_JS_T and Between_voxels$Rel_JS_P
## V = 416.5, p-value = 0.1716
## alternative hypothesis: true location shift is not equal to 0
## 95 percent confidence interval:
##  -8.328980e-02  6.219804e-05
## sample estimates:
## (pseudo)median
##  -3.463033e-06
```

```
# Measuring effect size
Zstat <- qnorm(Model_Between_voxels$p.value/2)
print(Zstat)
```

```
## [1] -1.367196
```

```
abs(Zstat/sqrt(148))
```

```
## [1] 0.1123828
```

```
#effectsize = absolut Z-statistic/sqrt(N)
#with r = 0.11, the difference is negligible to weak. https://www.petersta
tistics.com/CrashCourse/4-TwoVarPair/OrdOrd/OrdOrdPair3.html
```

```
##Wilcoxon Rank Sum test for within versus between voxels/brain areas.
Comparison_Dataset <- read_csv("C:/Users/danie/Desktop/Utwente/Master/1. T
hesis/Data analysis/Within versus between relative jaccard scores.csv")
```

```
## Parsed with column specification:
## cols(
##   Text = col_character(),
##   JS_In = col_double(),
##   Rel_JS_In = col_double(),
##   Between_voxels = col_character(),
##   JS_Between = col_double(),
##   Rel_JS_Between = col_double()
## )
```

```
summary(Comparison_Dataset)
```

```
##      Text                JS_In          Rel_JS_In       Between_voxels
##  Length:198         Min.   : 0.000   Min.   :0.00000   Length:198
##  Class :character   1st Qu.: 1.000   1st Qu.:0.08333   Class :character
##  Mode  :character   Median : 2.000   Median :0.16667   Mode  :character
##                     Mean   : 3.778   Mean   :0.31481
```

```
##                     3rd Qu.: 7.000   3rd Qu.:0.58333
##                     Max.   :12.000   Max.   :1.00000
##
##    JS_Between    Rel_JS_Between
##  Min.   :0.000   Min.   :0.00000
##  1st Qu.:0.000   1st Qu.:0.00000
##  Median :1.000   Median :0.08333
##  Mean   :1.257   Mean   :0.10473
##  3rd Qu.:2.000   3rd Qu.:0.16667
##  Max.   :8.000   Max.   :0.66667
##  NA's   :50      NA's   :50
```

```
sd(Comparison_Dataset$Rel_JS_In)
```

```
## [1] 0.291967
```

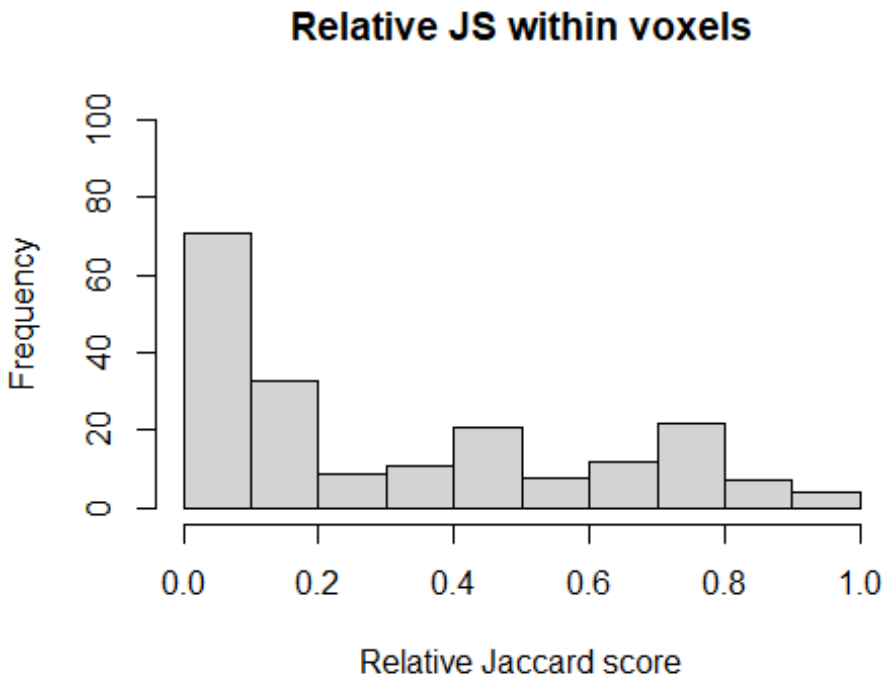
```
sd(Comparison_Dataset$Rel_JS_Between, na.rm = T)
```

```
## [1] 0.1237643
```

```
# Check for normality within voxels
Comparison_Dataset
```

```
## # A tibble: 198 x 6
##    Text              JS_In Rel_JS_In Between_voxels JS_Between Rel_JS_B
etween
##    <chr>             <dbl>     <dbl> <chr>               <dbl>
<dbl>
##  1 cap-diameter          2     0.167 ball-chimney            2
0.167
##  2 cap-diameter          2     0.167 ball-furniture          2
0.167
##  3 cap-diameter          2     0.167 ball-feathers           4
0.333
##  4 cap-diameter          2     0.167 ball-balloon            6
0.5
##  5 cylinder-diameter     5     0.417 ball-coin               1
0.0833
##  6 cap-cylinder          4     0.333 ball-bread              0
0
##  7 cap-diameter          2     0.167 ball-dough              1
0.0833
##  8 cap-cylinder          4     0.333 ball-champagne          0
0
##  9 cap-diameter          2     0.167 ball-egg                2
0.167
## 10 cap-cylinder          4     0.333 barrel-chimney          2
0.167
## # ... with 188 more rows
```

```
  hist(main="Relative JS within voxels", Comparison_Dataset$Rel_JS_In, yli
m=c(0,100), xlab = "Relative Jaccard score") #adjust y limit for easier co
mparison with between voxels.
```




```
  #The histogram is not bell shaped so there is no normal distribution.
  shapiro.test(Comparison_Dataset$Rel_JS_In)#The distribution is not norma
l because p<0.0001< alpha = 0.05.
```

```
##
##  Shapiro-Wilk normality test
##
## data:  Comparison_Dataset$Rel_JS_In
## W = 0.87175, p-value = 6.562e-12
```

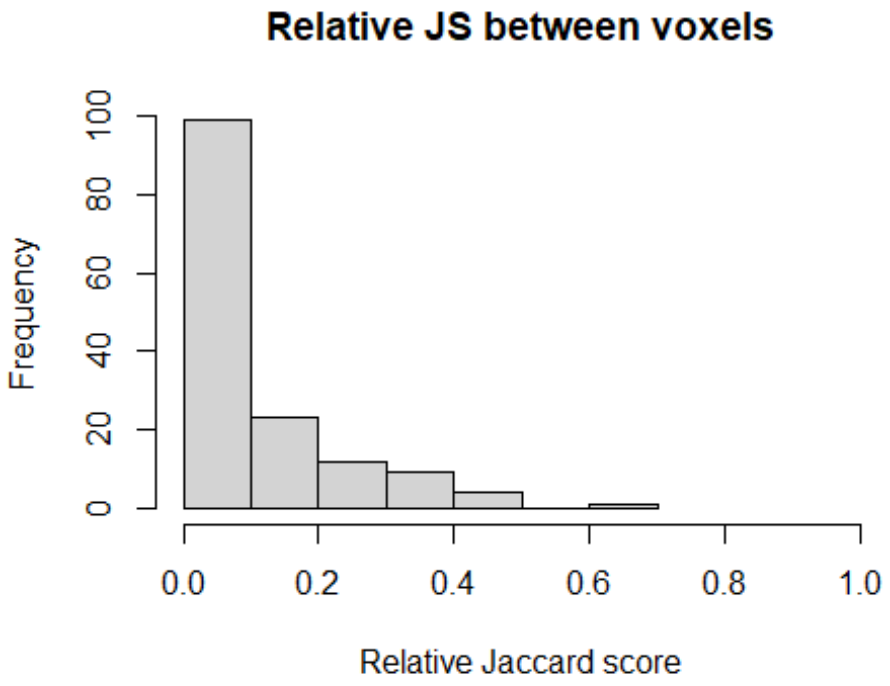
```
## starting httpd help server ... done
```

```
# Check for normality between voxels
Comparison_Dataset
```

```
## # A tibble: 198 x 6
##    Text              JS_In Rel_JS_In Between_voxels JS_Between Rel_JS_B
etween
##    <chr>             <dbl>     <dbl> <chr>               <dbl>
<dbl>
##  1 cap-diameter          2     0.167 ball-chimney            2
0.167
##  2 cap-diameter          2     0.167 ball-furniture          2
0.167
##  3 cap-diameter          2     0.167 ball-feathers           4
0.333
##  4 cap-diameter          2     0.167 ball-balloon            6
0.5
##  5 cylinder-diameter     5     0.417 ball-coin               1
0.0833
##  6 cap-cylinder          4     0.333 ball-bread              0
```

```
0
##  7 cap-diameter          2     0.167 ball-dough              1
0.0833
##  8 cap-cylinder          4     0.333 ball-champagne          0
0
##  9 cap-diameter          2     0.167 ball-egg                2
0.167
## 10 cap-cylinder          4     0.333 barrel-chimney          2
0.167
## # ... with 188 more rows
```

```
  hist(main="Relative JS between voxels", Comparison_Dataset$Rel_JS_Betwee
n, xlim = c(0,1), xlab = "Relative Jaccard score") #adjust x-scale for eas
ier comparison with within voxels
```




```
  #The histogram is not bell shaped so there is no normal distribution.
  shapiro.test(Comparison_Dataset$Rel_JS_Between)#The distribution is not
normal because p<0.0001< alpha = 0.05.

##
##  Shapiro-Wilk normality test
##
## data:  Comparison_Dataset$Rel_JS_Between
## W = 0.8025, p-value = 7.452e-13

# Wilcoxon Rank Sum test for within and between voxels/brain areas
#H0=there is no difference between the relative jaccards scores of the wit
hin and between voxel/brain area concept pairs.
#H1=there is a difference between the relative jaccard scores of the withi
n and between voxel/brain area concept pairs.
Model_In_Between <- wilcox.test(Comparison_Dataset$Rel_JS_In, Comparison_D
```

```
ataset$Rel_JS_Between,mu=0, alt="two.sided", conf.int = T, conf.level = 0.
95,paired = F, correct = F)
print(Model_In_Between)
```

```
##
##  Wilcoxon rank sum test
##
## data:  Comparison_Dataset$Rel_JS_In and Comparison_Dataset$Rel_JS_Betwe
en
## W = 20681, p-value = 2.362e-11
## alternative hypothesis: true location shift is not equal to 0
## 95 percent confidence interval:
##  0.08335439 0.16667844
## sample estimates:
## difference in location
##              0.1666553
```

```
Zstat <- qnorm(Model_In_Between$p.value/2)
print(Zstat)
```

```
## [1] -6.681705
```

```
abs(Zstat/sqrt(346))
```

```
## [1] 0.3592107
```

```
#p<0.0001 and r = 0.36, therefore, there is enough evidence to reject H0.T
here is significant medium difference between the relative Jaccard scores
of the within voxel/brain area pairs (Median = 0.17,IQR = 0.25, n = 85) be
tween voxel/brain area pairs (Median = 0.08, IQR = 0.16, n = 148) relative
Jaccard scores of concept combinations clustered together in both the Huth
map and textual and pictorial card sorts, W = 12322, p<0.0001.So, the rela
tive Jaccard scores of the within voxels/brain areas are significantly hig
her than those of the between voxel/brain area. This could indicate that v
oxel/brain area differences in the brain map of Huth is correlated with ca
rd sorting.
```

Appendix K. Ranks of concept items in the heatmaps

Ranks

Items 1-23			Items 24-46		
Concept	textual_p	pictorial_p	Concept	Textual_P	Pictorial_P
champagne	1	5	ice cream	1	3
dough	2	8	rice	2	1
egg	3	7	orange	3	4
bread	4	9	sausage	4	2
cheese	5	10	millimetre	5	5
bra	6	2	slide	6	8
cap	7	1	leaf	7	7
boots	8	3	sticks	8	11
gloves	9	4	spoon	9	10
dollar	10	12	waist	10	6
coin	11	11	jewelry	11	12
cents	12	13	wool	12	9
chimney	13	19	hood	13	23
furniture	14	20	stockings	14	16
feathers	15	18	tunic	15	17
balloon	16	15	uniform	16	19
ball	17	14	hat	17	22
diameter	18	17	sneakers	18	14
cylinder	19	16	shoes	19	13
bowl	20	21	shirts	20	20
container	21	22	top	21	18
barrel	22	23	jeans	22	21
bottle	23	6	trousers	23	15

Appendix L. Relative Jaccard scores

Within versus between relative Jaccard scores of textual concept combinations

Text_ Within	JS_T_ Within	Rel_JS_ T_Within	Text_ Between	JS_T_ Between	Rel_JS_ T_Between
cap-diameter	2	0.166667	ball-chimney	2	0.166667
cap-diameter	2	0.166667	ball-furniture	2	0.166667
cap-diameter	2	0.166667	ball-feathers	4	0.333333
cap-diameter	2	0.166667	ball-balloon	6	0.5
cylinder-diameter	5	0.416667	ball-coin	1	0.083333
cap-cylinder	4	0.333333	ball-bread	0	0
cap-diameter	2	0.166667	ball-dough	1	0.083333
cap-cylinder	4	0.333333	ball-champagne	0	0
cap-diameter	2	0.166667	ball-egg	2	0.166667
cap-cylinder	4	0.333333	barrel-chimney	2	0.166667
cap-diameter	2	0.166667	barrel-furniture	1	0.083333
cylinder-diameter	5	0.416667	barrel-feathers	1	0.083333
barrel-cap	1	0.083333	barrel-balloon	1	0.083333
barrel-ball	2	0.166667	barrel-coin	1	0.083333
barrel-diameter	3	0.25	barrel-bread	0	0
cap-ball	1	0.083333	barrel-dough	2	0.166667
cap-diameter	2	0.166667	barrel-champagne	3	0.25
ball-diameter	2	0.166667	barrel-egg	1	0.083333
cents-cap	1	0.083333	chimney-feathers	1	0.083333
cents-dollar	6	0.5	chimney-balloon	1	0.083333
chimney-furniture	6	0.5	chimney-coin	1	0.083333
container-cylinder	4	0.333333	chimney-bread	0	0
boots-cap	6	0.5	chimney-dough	1	0.083333
boots-gloves	11	0.916667	chimney-champagne	0	0
cap-gloves	9	0.75	chimney-egg	0	0
feathers-diameter	1	0.083333	furniture-feathers	3	0.25
feathers-cap	0	0	furniture-balloon	0	0
feathers-balloon	3	0.25	furniture-coin	1	0.083333
diameter-cap	2	0.166667	furniture-bread	0	0

diameter-balloon	1	0.083333	furniture-dough	0	0
cap-balloon	2	0.166667	furniture-champagne	0	0
bottle-cap	1	0.083333	furniture-egg	1	0.083333
bottle-boots	1	0.083333	feathers-coin	0	0
cap-boots	6	0.5	feathers-bread	0	0
coin-dollar	9	0.75	feathers-dough	0	0
coin-bread	1	0.083333	feathers-champagne	1	0.083333
coin-champagne	0	0	feathers-egg	1	0.083333
coin-egg	0	0	balloon-coin	1	0.083333
dollar-bread	0	0	balloon-bread	2	0.166667
dollar-dough	1	0.083333	balloon-dough	1	0.083333
dollar-champagne	1	0.083333	balloon-champagne	1	0.083333
dollar-egg	1	0.083333	balloon-egg	0	0
bread-dough	8	0.666667	rice-sneakers	0	0
bread-champagne	4	0.333333	rice-shoes	0	0
bread-egg	7	0.583333	rice-trousers	0	0
dough-champagne	2	0.166667	rice-jeans	0	0
dough-egg	5	0.416667	rice-jewelry	0	0
champagne-egg	4	0.333333	rice-spoon	3	0.25
container-cents	2	0.166667	rice-slide	0	0
container-bottle	6	0.5	rice-waist	0	0
cents-bottle	2	0.166667	sausage-sneakers	0	0
gloves-bottle	2	0.166667	sausage-shoes	1	0.083333
gloves-cap	6	0.5	sausage-trousers	0	0
bottle-cap	1	0.083333	sausage-jeans	0	0
cap-gloves	6	0.5	sneakers-jewelry	4	0.333333
cap-gloves	6	0.5	sneakers-spoon	1	0.083333
cap-diameter	2	0.166667	sneakers-slide	0	0
diameter-container	2	0.166667	sneakers-waist	3	0.25
leaf-millemetre	2	0.166667	shoes-jewelry	5	0.416667
top-millimetre	0	0	shoes-spoon	0	0
leaf-millimetre	2	0.166667	shoes-slide	0	0

millimetre-top	0	0	shoes-waist	3	0.25
leaf-orange	2	0.166667	trousers-jewelry	4	0.333333
uniform-tunic	9	0.75	trousers-spoon	0	0
uniform-leaf	0	0	trousers-slide	1	0.083333
uniform-wool	4	0.333333	trousers-waist	4	0.333333
tunic-leaf	0	0	jeans-jewelry	4	0.333333
tunic-wool	2	0.166667	jeans-spoon	0	0
leaf-wool	2	0.166667	jeans-slide	1	0.083333
hood-tunic	7	0.583333	jeans-waist	4	0.333333
sticks-top	0	0	jewelry-slide	0	0
rice-sausage	9	0.75	jewelry-waist	1	0.083333
stockings-shirts	8	0.666667	spoon-slide	3	0.25
stockings-tunic	7	0.583333	spoon-waist	0	0
stockings-uniform	8	0.666667			
shirts-tunic	8	0.666667			
shirts-uniform	8	0.666667			
tunic-uniform	9	0.75			
sneakers-stockings	7	0.583333			
sneakers-shoes	11	0.916667			
sneakers-trousers	9	0.75			
sneakers-jeans	9	0.75			
stockings-shoes	7	0.583333			
stockings-trousers	9	0.75			
stockings-jeans	9	0.75			
shoes-trousers	9	0.75			
shoes-jeans	9	0.75			
trousers-jeans	12	1			
orange-hat	0	0			
orange-shirts	0	0			
hat-shirts	9	0.75			
jewelry-spoon	1	0.083333			
stockings-top	8	0.666667			
top-ice	0	0			

top-wool	4	0.333333
ice-wool	0	0
slide-top	0	0
slide-waist	2	0.166667
top-waist	3	0.25

Within versus between relative Jaccard scores of pictorial concept combinations

Pictorial_ Within	JS_P_ Within	Rel_JS_ P_Within	Pictorial_ Between	JS_P_ Between	Rel_JS_ P_Between
cap-diameter	0	0	ball-chimney	0	0
cap-diameter	0	0	ball-furniture	0	0
cap-diameter	0	0	ball-feathers	0	0
cap-diameter	0	0	ball-balloon	8	0.666667
cylinder-diameter	5	0.416667	ball-coin	0	0
cap-cylinder	0	0	ball-bread	1	0.083333
cap-diameter	0	0	ball-dough	1	0.083333
cap-cylinder	0	0	ball-champagne	1	0.083333
cap-diameter	0	0	ball-egg	1	0.083333
cap-cylinder	0	0	barrel-chimney	2	0.166667
cap-diameter	0	0	barrel-furniture	3	0.25
cylinder-diameter	5	0.416667	barrel-feathers	1	0.083333
barrel-cap	0	0	barrel-balloon	1	0.083333
barrel-ball	0	0	barrel-coin	1	0.083333
barrel-diameter	2	0.166667	barrel-bread	0	0
cap-ball	0	0	barrel-dough	0	0
cap-diameter	0	0	barrel-champagne	4	0.333333
ball-diameter	3	0.25	barrel-egg	1	0.083333
cents-cap	0	0	chimney-feathers	2	0.166667
cents-dollar	11	0.916667	chimney-balloon	1	0.083333
chimney-furniture	6	0.5	chimney-coin	1	0.083333
container-cylinder	2	0.166667	chimney-bread	1	0.083333
boots-cap	9	0.75	chimney-dough	0	0
boots-gloves	10	0.833333	chimney-champagne	1	0.083333
cap-gloves	10	0.833333	chimney-egg	2	0.166667
feathers-diameter	0	0	furniture-feathers	1	0.083333
feathers-cap	2	0.166667	furniture-balloon	0	0
feathers-balloon	0	0	furniture-coin	0	0
diameter-cap	0	0	furniture-bread	0	0
diameter-balloon	4	0.333333	furniture-dough	0	0

cap-balloon	0	0	furniture-champagne	0	0
bottle-cap	0	0	furniture-egg	0	0
bottle-boots	1	0.083333	feathers-coin	0	0
cap-boots	9	0.75	feathers-bread	0	0
coin-dollar	9	0.75	feathers-dough	2	0.166667
coin-bread	0	0	feathers-champagne	0	0
coin-champagne	0	0	feathers-egg	3	0.25
coin-egg	1	0.083333	balloon-coin	1	0.083333
dollar-bread	1	0.083333	balloon-bread	0	0
dollar-dough	0	0	balloon-dough	0	0
dollar-champagne	1	0.083333	balloon-champagne	2	0.166667
dollar-egg	0	0	balloon-egg	2	0.166667
bread-dough	9	0.75	rice-sneakers	0	0
bread-champagne	5	0.416667	rice-shoes	0	0
bread-egg	6	0.5	rice-trousers	0	0
dough-champagne	3	0.25	rice-jeans	0	0
dough-egg	5	0.416667	rice-jewelry	0	0
champagne-egg	4	0.333333	rice-spoon	2	0.166667
container-cents	0	0	rice-slide	0	0
container-bottle	2	0.166667	rice-waist	0	0
cents-bottle	1	0.083333	sausage-sneakers	0	0
gloves-bottle	0	0	sausage-shoes	0	0
gloves-cap	10	0.833333	sausage-trousers	0	0
bottle-cap	0	0	sausage-jeans	0	0
cap-gloves	10	0.833333	sneakers-jewelry	4	0.333333
cap-gloves	10	0.833333	sneakers-spoon	2	0.166667
cap-diameter	0	0	sneakers-slide	3	0.25
diameter-container	2	0.166667	sneakers-waist	3	0.25
leaf-millemetre	1	0.083333	shoes-jewelry	4	0.333333
top-millimetre	1	0.083333	shoes-spoon	1	0.083333
leaf-millimetre	1	0.083333	shoes-slide	2	0.166667
millimetre-top	1	0.083333	shoes-waist	2	0.166667

leaf-orange	4	0.333333	trousers-jewelry	5	0.416667
uniform-tunic	7	0.583333	trousers-spoon	1	0.083333
uniform-leaf	1	0.083333	trousers-slide	2	0.166667
uniform-wool	2	0.166667	trousers-waist	2	0.166667
tunic-leaf	1	0.083333	jeans-jewelry	5	0.416667
tunic-wool	3	0.25	jeans-spoon	2	0.166667
leaf-wool	1	0.083333	jeans-slide	3	0.25
hood-tunic	8	0.666667	jeans-waist	2	0.166667
sticks-top	3	0.25	jewelry-slide	2	0.166667
rice-sausage	8	0.666667	jewelry-waist	3	0.25
stockings-shirts	8	0.666667	spoon-slide	2	0.166667
stockings-tunic	8	0.666667	spoon-waist	2	0.166667
stockings-uniform	8	0.666667			
shirts-tunic	9	0.75			
shirts-uniform	9	0.75			
tunic-uniform	7	0.583333			
sneakers-stockings	6	0.5			
sneakers-shoes	10	0.833333			
sneakers-trousers	6	0.5			
sneakers-jeans	8	0.666667			
stockings-shoes	6	0.5			
stockings-trousers	9	0.75			
stockings-jeans	10	0.833333			
shoes-trousers	7	0.583333			
shoes-jeans	6	0.5			
trousers-jeans	9	0.75			
orange-hat	1	0.083333			
orange-shirts	0	0			
hat-shirts	9	0.75			
jewelry-spoon	2	0.166667			
stockings-top	9	0.75			
top-ice	1	0.083333			
top-wool	3	0.25			

ice-wool	0	0
slide-top	3	0.25
slide-waist	2	0.166667
top-waist	3	0.25

Relative Jaccard scores within voxels text versus picture

Text	JS_T	Rel_JS_T	Picture	JS_P	REL_JS_P
cap-diameter	2	0.166667	cap-diameter	0	0
cap-diameter	2	0.166667	cap-diameter	0	0
cap-diameter	2	0.166667	cap-diameter	0	0
cap-diameter	2	0.166667	cap-diameter	0	0
cylinder-diameter	5	0.416667	cylinder-diameter	5	0.416667
cap-cylinder	4	0.333333	cap-cylinder	0	0
cap-diameter	2	0.166667	cap-diameter	0	0
cap-cylinder	4	0.333333	cap-cylinder	0	0
cap-diameter	2	0.166667	cap-diameter	0	0
cap-cylinder	4	0.333333	cap-cylinder	0	0
cap-diameter	2	0.166667	cap-diameter	0	0
cylinder-diameter	5	0.416667	cylinder-diameter	5	0.416667
barrel-cap	1	0.083333	barrel-cap	0	0
barrel-ball	2	0.166667	barrel-ball	0	0
barrel-diameter	3	0.25	barrel-diameter	2	0.166667
cap-ball	1	0.083333	cap-ball	0	0
cap-diameter	2	0.166667	cap-diameter	0	0
ball-diameter	2	0.166667	ball-diameter	3	0.25
cents-cap	1	0.083333	cents-cap	0	0
cents-dollar	6	0.5	cents-dollar	11	0.916667
chimney-furniture	6	0.5	chimney-furniture	6	0.5
container-cylinder	4	0.333333	container-cylinder	2	0.166667
boots-cap	6	0.5	boots-cap	9	0.75
boots-gloves	11	0.916667	boots-gloves	10	0.833333
cap-gloves	9	0.75	cap-gloves	10	0.833333
feathers-diameter	1	0.083333	feathers-diameter	0	0
feathers-cap	0	0	feathers-cap	2	0.166667
feathers-balloon	3	0.25	feathers-balloon	0	0
diameter-cap	2	0.166667	diameter-cap	0	0
diameter-balloon	1	0.083333	diameter-balloon	4	0.333333
cap-balloon	2	0.166667	cap-balloon	0	0
bottle-cap	1	0.083333	bottle-cap	0	0
bottle-boots	1	0.083333	bottle-boots	1	0.083333
cap-boots	6	0.5	cap-boots	9	0.75
coin-dollar	9	0.75	coin-dollar	9	0.75
coin-bread	1	0.083333	coin-bread	0	0
coin-champagne	0	0	coin-champagne	0	0
coin-egg	0	0	coin-egg	1	0.083333

dollar-bread	0	0	dollar-bread	1	0.083333
dollar-dough	1	0.083333	dollar-dough	0	0
dollar-champagne	1	0.083333	dollar-champagne	1	0.083333
dollar-egg	1	0.083333	dollar-egg	0	0
bread-dough	8	0.666667	bread-dough	9	0.75
bread-champagne	4	0.333333	bread-champagne	5	0.416667
bread-egg	7	0.583333	bread-egg	6	0.5
dough-champagne	2	0.166667	dough-champagne	3	0.25
dough-egg	5	0.416667	dough-egg	5	0.416667
champagne-egg	4	0.333333	champagne-egg	4	0.333333
container-cents	2	0.166667	container-cents	0	0
container-bottle	6	0.5	container-bottle	2	0.166667
cents-bottle	2	0.166667	cents-bottle	1	0.083333
gloves-bottle	2	0.166667	gloves-bottle	0	0
gloves-cap	6	0.5	gloves-cap	10	0.833333
bottle-cap	1	0.083333	bottle-cap	0	0
cap-gloves	6	0.5	cap-gloves	10	0.833333
cap-gloves	6	0.5	cap-gloves	10	0.833333
cap-diameter	2	0.166667	cap-diameter	0	0
diameter-container	2	0.166667	diameter-container	2	0.166667
leaf-millemetre	2	0.166667	leaf-millemetre	1	0.083333
top-millimetre	0	0	top-millimetre	1	0.083333
leaf-millimetre	2	0.166667	leaf-millimetre	1	0.083333
millimetre-top	0	0	millimetre-top	1	0.083333
leaf-orange	2	0.166667	leaf-orange	4	0.333333
uniform-tunic	9	0.75	uniform-tunic	7	0.583333
uniform-leaf	0	0	uniform-leaf	1	0.083333
uniform-wool	4	0.333333	uniform-wool	2	0.166667
tunic-leaf	0	0	tunic-leaf	1	0.083333
tunic-wool	2	0.166667	tunic-wool	3	0.25
leaf-wool	2	0.166667	leaf-wool	1	0.083333
hood-tunic	7	0.583333	hood-tunic	8	0.666667
sticks-top	0	0	sticks-top	3	0.25
rice-sausage	9	0.75	rice-sausage	8	0.666667
stockings-shirts	8	0.666667	stockings-shirts	8	0.666667
stockings-tunic	7	0.583333	stockings-tunic	8	0.666667
stockings-uniform	8	0.666667	stockings-uniform	8	0.666667
shirts-tunic	8	0.666667	shirts-tunic	9	0.75
shirts-uniform	8	0.666667	shirts-uniform	9	0.75
tunic-uniform	9	0.75	tunic-uniform	7	0.583333

sneakers-stockings	7	0.583333	sneakers-stockings	6	0.5
sneakers-shoes	11	0.916667	sneakers-shoes	10	0.833333
sneakers-trousers	9	0.75	sneakers-trousers	6	0.5
sneakers-jeans	9	0.75	sneakers-jeans	8	0.666667
stockings-shoes	7	0.583333	stockings-shoes	6	0.5
stockings-trousers	9	0.75	stockings-trousers	9	0.75
stockings-jeans	9	0.75	stockings-jeans	10	0.833333
shoes-trousers	9	0.75	shoes-trousers	7	0.583333
shoes-jeans	9	0.75	shoes-jeans	6	0.5
trousers-jeans	12	1	trousers-jeans	9	0.75
orange-hat	0	0	orange-hat	1	0.083333
orange-shirts	0	0	orange-shirts	0	0
hat-shirts	9	0.75	hat-shirts	9	0.75
jewelry-spoon	1	0.083333	jewelry-spoon	2	0.166667
stockings-top	8	0.666667	stockings-top	9	0.75
top-ice	0	0	top-ice	1	0.083333
top-wool	4	0.333333	top-wool	3	0.25
ice-wool	0	0	ice-wool	0	0
slide-top	0	0	slide-top	3	0.25
slide-waist	2	0.166667	slide-waist	2	0.166667
top-waist	3	0.25	top-waist	2	0.166667

Relative Jaccard scores between voxels text versus picture

Text	JS_T	Rel_JS_T	Picture	JS_P	Rel_JS_P
ball-chimney	2	0.166667	ball-chimney	0	0
ball-furniture	2	0.166667	ball-furniture	0	0
ball-feathers	4	0.333333	ball-feathers	0	0
ball-balloon	6	0.5	ball-balloon	8	0.666667
ball-coin	1	0.083333	ball-coin	0	0
ball-bread	0	0	ball-bread	1	0.083333
ball-dough	1	0.083333	ball-dough	1	0.083333
ball-champagne	0	0	ball-champagne	1	0.083333
ball-egg	2	0.166667	ball-egg	1	0.083333
barrel-chimney	2	0.166667	barrel-chimney	2	0.166667
barrel-furniture	1	0.083333	barrel-furniture	3	0.25
barrel-feathers	1	0.083333	barrel-feathers	1	0.083333
barrel-balloon	1	0.083333	barrel-balloon	1	0.083333
barrel-coin	1	0.083333	barrel-coin	1	0.083333
barrel-bread	0	0	barrel-bread	0	0
barrel-dough	2	0.166667	barrel-dough	0	0
barrel-champagne	3	0.25	barrel-champagne	4	0.333333
barrel-egg	1	0.083333	barrel-egg	1	0.083333
chimney-feathers	1	0.083333	chimney-feathers	2	0.166667
chimney-balloon	1	0.083333	chimney-balloon	1	0.083333
chimney-coin	1	0.083333	chimney-coin	1	0.083333
chimney-bread	0	0	chimney-bread	1	0.083333
chimney-dough	1	0.083333	chimney-dough	0	0
chimney-champagne	0	0	chimney-champagne	1	0.083333
chimney-egg	0	0	chimney-egg	2	0.166667
furniture-feathers	3	0.25	furniture-feathers	1	0.083333
furniture-balloon	0	0	furniture-balloon	0	0
furniture-coin	1	0.083333	furniture-coin	0	0
furniture-bread	0	0	furniture-bread	0	0
furniture-dough	0	0	furniture-dough	0	0
furniture-champagne	0	0	furniture-champagne	0	0
furniture-egg	1	0.083333	furniture-egg	0	0
feathers-coin	0	0	feathers-coin	0	0
feathers-bread	0	0	feathers-bread	0	0
feathers-dough	0	0	feathers-dough	2	0.166667

feathers-champagne	1	0.083333	feathers-champagne	0	0
feathers-egg	1	0.083333	feathers-egg	3	0.25
balloon-coin	1	0.083333	balloon-coin	1	0.083333
balloon-bread	2	0.166667	balloon-bread	0	0
balloon-dough	1	0.083333	balloon-dough	0	0
balloon-champagne	1	0.083333	balloon-champagne	2	0.166667
balloon-egg	0	0	balloon-egg	2	0.166667
rice-sneakers	0	0	rice-sneakers	0	0
rice-shoes	0	0	rice-shoes	0	0
rice-trousers	0	0	rice-trousers	0	0
rice-jeans	0	0	rice-jeans	0	0
rice-jewelry	0	0	rice-jewelry	0	0
rice-spoon	3	0.25	rice-spoon	2	0.166667
rice-slide	0	0	rice-slide	0	0
rice-waist	0	0	rice-waist	0	0
sausage-sneakers	0	0	sausage-sneakers	0	0
sausage-shoes	1	0.083333	sausage-shoes	0	0
sausage-trousers	0	0	sausage-trousers	0	0
sausage-jeans	0	0	sausage-jeans	0	0
sneakers-jewelry	4	0.333333	sneakers-jewelry	4	0.333333
sneakers-spoon	1	0.083333	sneakers-spoon	2	0.166667
sneakers-slide	0	0	sneakers-slide	3	0.25
sneakers-waist	3	0.25	sneakers-waist	3	0.25
shoes-jewelry	5	0.416667	shoes-jewelry	4	0.333333
shoes-spoon	0	0	shoes-spoon	1	0.083333
shoes-slide	0	0	shoes-slide	2	0.166667
shoes-waist	3	0.25	shoes-waist	2	0.166667
trousers-jewelry	4	0.333333	trousers-jewelry	5	0.416667
trousers-spoon	0	0	trousers-spoon	1	0.083333
trousers-slide	1	0.083333	trousers-slide	2	0.166667
trousers-waist	4	0.333333	trousers-waist	2	0.166667
jeans-jewelry	4	0.333333	jeans-jewelry	5	0.416667
jeans-spoon	0	0	jeans-spoon	2	0.166667
jeans-slide	1	0.083333	jeans-slide	3	0.25
jeans-waist	4	0.333333	jeans-waist	2	0.166667
jewelry-slide	0	0	jewelry-slide	2	0.166667
jewelry-waist	1	0.083333	jewelry-waist	3	0.25
spoon-slide	3	0.25	spoon-slide	2	0.166667
spoon-waist	0	0	spoon-waist	2	0.166667

Within versus between voxels

Within_voxels	JS_In	Rel_JS_In	Between_voxels	JS_Between	Rel_JS_Between
cap-diameter	2	0.166667	ball-chimney	2	0.166667
cap-diameter	2	0.166667	ball-furniture	2	0.166667
cap-diameter	2	0.166667	ball-feathers	4	0.333333
cap-diameter	2	0.166667	ball-balloon	6	0.5
cylinder-diameter	5	0.416667	ball-coin	1	0.083333
cap-cylinder	4	0.333333	ball-bread	0	0
cap-diameter	2	0.166667	ball-dough	1	0.083333
cap-cylinder	4	0.333333	ball-champagne	0	0
cap-diameter	2	0.166667	ball-egg	2	0.166667
cap-cylinder	4	0.333333	barrel-chimney	2	0.166667
cap-diameter	2	0.166667	barrel-furniture	1	0.083333
cylinder-diameter	5	0.416667	barrel-feathers	1	0.083333
barrel-cap	1	0.083333	barrel-balloon	1	0.083333
barrel-ball	2	0.166667	barrel-coin	1	0.083333
barrel-diameter	3	0.25	barrel-bread	0	0
cap-ball	1	0.083333	barrel-dough	2	0.166667
cap-diameter	2	0.166667	barrel-champagne	3	0.25
ball-diameter	2	0.166667	barrel-egg	1	0.083333
cents-cap	1	0.083333	chimney-feathers	1	0.083333
cents-dollar	6	0.5	chimney-balloon	1	0.083333
chimney-furniture	6	0.5	chimney-coin	1	0.083333
container-cylinder	4	0.333333	chimney-bread	0	0
boots-cap	6	0.5	chimney-dough	1	0.083333
boots-gloves	11	0.916667	chimney-champagne	0	0
cap-gloves	9	0.75	chimney-egg	0	0
feathers-diameter	1	0.083333	furniture-feathers	3	0.25
feathers-cap	0	0	furniture-balloon	0	0
feathers-balloon	3	0.25	furniture-coin	1	0.083333

diameter-cap	2	0.166667	furniture-bread	0	0
diameter-balloon	1	0.083333	furniture-dough	0	0
cap-balloon	2	0.166667	furniture-champagne	0	0
bottle-cap	1	0.083333	furniture-egg	1	0.083333
bottle-boots	1	0.083333	feathers-coin	0	0
cap-boots	6	0.5	feathers-bread	0	0
coin-dollar	9	0.75	feathers-dough	0	0
coin-bread	1	0.083333	feathers-champagne	1	0.083333
coin-champagne	0	0	feathers-egg	1	0.083333
coin-egg	0	0	balloon-coin	1	0.083333
dollar-bread	0	0	balloon-bread	2	0.166667
dollar-dough	1	0.083333	balloon-dough	1	0.083333
dollar-champagne	1	0.083333	balloon-champagne	1	0.083333
dollar-egg	1	0.083333	balloon-egg	0	0
bread-dough	8	0.666667	rice-sneakers	0	0
bread-champagne	4	0.333333	rice-shoes	0	0
bread-egg	7	0.583333	rice-trousers	0	0
dough-champagne	2	0.166667	rice-jeans	0	0
dough-egg	5	0.416667	rice-jewelry	0	0
champagne-egg	4	0.333333	rice-spoon	3	0.25
container-cents	2	0.166667	rice-slide	0	0
container-bottle	6	0.5	rice-waist	0	0
cents-bottle	2	0.166667	sausage-sneakers	0	0
gloves-bottle	2	0.166667	sausage-shoes	1	0.083333
gloves-cap	6	0.5	sausage-trousers	0	0
bottle-cap	1	0.083333	sausage-jeans	0	0
cap-gloves	6	0.5	sneakers-jewelry	4	0.333333

cap-gloves	6	0.5	sneakers-spoon	1	0.083333
cap-diameter	2	0.166667	sneakers-slide	0	0
diameter-container	2	0.166667	sneakers-waist	3	0.25
leaf-millemetre	2	0.166667	shoes-jewelry	5	0.416667
top-millimetre	0	0	shoes-spoon	0	0
leaf-millimetre	2	0.166667	shoes-slide	0	0
millimetre-top	0	0	shoes-waist	3	0.25
leaf-orange	2	0.166667	trousers-jewelry	4	0.333333
uniform-tunic	9	0.75	trousers-spoon	0	0
uniform-leaf	0	0	trousers-slide	1	0.083333
uniform-wool	4	0.333333	trousers-waist	4	0.333333
tunic-leaf	0	0	jeans-jewelry	4	0.333333
tunic-wool	2	0.166667	jeans-spoon	0	0
leaf-wool	2	0.166667	jeans-slide	1	0.083333
hood-tunic	7	0.583333	jeans-waist	4	0.333333
sticks-top	0	0	jewelry-slide	0	0
rice-sausage	9	0.75	jewelry-waist	1	0.083333
stockings-shirts	8	0.666667	spoon-slide	3	0.25
stockings-tunic	7	0.583333	spoon-waist	0	0
stockings-uniform	8	0.666667	ball-chimney	0	0
shirts-tunic	8	0.666667	ball-furniture	0	0
shirts-uniform	8	0.666667	ball-feathers	0	0
tunic-uniform	9	0.75	ball-balloon	8	0.666667
sneakers-stockings	7	0.583333	ball-coin	0	0
sneakers-shoes	11	0.916667	ball-bread	1	0.083333
sneakers-trousers	9	0.75	ball-dough	1	0.083333
sneakers-jeans	9	0.75	ball-champagne	1	0.083333
stockings-shoes	7	0.583333	ball-egg	1	0.083333
stockings-trousers	9	0.75	barrel-chimney	2	0.166667

stockings-jeans	9	0.75	barrel-furniture	3	0.25
shoes-trousers	9	0.75	barrel-feathers	1	0.083333
shoes-jeans	9	0.75	barrel-balloon	1	0.083333
trousers-jeans	12	1	barrel-coin	1	0.083333
orange-hat	0	0	barrel-bread	0	0
orange-shirts	0	0	barrel-dough	0	0
hat-shirts	9	0.75	barrel-champagne	4	0.333333
jewelry-spoon	1	0.083333	barrel-egg	1	0.083333
stockings-top	8	0.666667	chimney-feathers	2	0.166667
top-ice	0	0	chimney-balloon	1	0.083333
top-wool	4	0.333333	chimney-coin	1	0.083333
ice-wool	0	0	chimney-bread	1	0.083333
slide-top	0	0	chimney-dough	0	0
slide-waist	2	0.166667	chimney-champagne	1	0.083333
top-waist	3	0.25	chimney-egg	2	0.166667
cap-diameter	0	0	furniture-feathers	1	0.083333
cap-diameter	0	0	furniture-balloon	0	0
cap-diameter	0	0	furniture-coin	0	0
cap-diameter	0	0	furniture-bread	0	0
cylinder-diameter	5	0.416667	furniture-dough	0	0
cap-cylinder	0	0	furniture-champagne	0	0
cap-diameter	0	0	furniture-egg	0	0
cap-cylinder	0	0	feathers-coin	0	0
cap-diameter	0	0	feathers-bread	0	0
cap-cylinder	0	0	feathers-dough	2	0.166667
cap-diameter	0	0	feathers-champagne	0	0
cylinder-diameter	5	0.416667	feathers-egg	3	0.25
barrel-cap	0	0	balloon-coin	1	0.083333
barrel-ball	0	0	balloon-bread	0	0

barrel-diameter	2	0.166667	balloon-dough	0	0
cap-ball	0	0	balloon-champagne	2	0.166667
cap-diameter	0	0	balloon-egg	2	0.166667
ball-diameter	3	0.25	rice-sneakers	0	0
cents-cap	0	0	rice-shoes	0	0
cents-dollar	11	0.916667	rice-trousers	0	0
chimney-furniture	6	0.5	rice-jeans	0	0
container-cylinder	2	0.166667	rice-jewelry	0	0
boots-cap	9	0.75	rice-spoon	2	0.166667
boots-gloves	10	0.833333	rice-slide	0	0
cap-gloves	10	0.833333	rice-waist	0	0
feathers-diameter	0	0	sausage-sneakers	0	0
feathers-cap	2	0.166667	sausage-shoes	0	0
feathers-balloon	0	0	sausage-trousers	0	0
diameter-cap	0	0	sausage-jeans	0	0
diameter-balloon	4	0.333333	sneakers-jewelry	4	0.333333
cap-balloon	0	0	sneakers-spoon	2	0.166667
bottle-cap	0	0	sneakers-slide	3	0.25
bottle-boots	1	0.083333	sneakers-waist	3	0.25
cap-boots	9	0.75	shoes-jewelry	4	0.333333
coin-dollar	9	0.75	shoes-spoon	1	0.083333
coin-bread	0	0	shoes-slide	2	0.166667
coin-champagne	0	0	shoes-waist	2	0.166667
coin-egg	1	0.083333	trousers-jewelry	5	0.416667
dollar-bread	1	0.083333	trousers-spoon	1	0.083333
dollar-dough	0	0	trousers-slide	2	0.166667
dollar-champagne	1	0.083333	trousers-waist	2	0.166667
dollar-egg	0	0	jeans-jewelry	5	0.416667
bread-dough	9	0.75	jeans-spoon	2	0.166667
bread-champagne	5	0.416667	jeans-slide	3	0.25

bread-egg	6	0.5	jeans-waist	2	0.166667
dough-champagne	3	0.25	jewelry-slide	2	0.166667
dough-egg	5	0.416667	jewelry-waist	3	0.25
champagne-egg	4	0.333333	spoon-slide	2	0.166667
container-cents	0	0	spoon-waist	2	0.166667
container-bottle	2	0.166667			
cents-bottle	1	0.083333			
gloves-bottle	0	0			
gloves-cap	10	0.833333			
bottle-cap	0	0			
cap-gloves	10	0.833333			
cap-gloves	10	0.833333			
cap-diameter	0	0			
diameter-container	2	0.166667			
leaf-millemetre	1	0.083333			
top-millimetre	1	0.083333			
leaf-millimetre	1	0.083333			
millimetre-top	1	0.083333			
leaf-orange	4	0.333333			
uniform-tunic	7	0.583333			
uniform-leaf	1	0.083333			
uniform-wool	2	0.166667			
tunic-leaf	1	0.083333			
tunic-wool	3	0.25			
leaf-wool	1	0.083333			
hood-tunic	8	0.666667			
sticks-top	3	0.25			
rice-sausage	8	0.666667			
stockings-shirts	8	0.666667			
stockings-tunic	8	0.666667			
stockings-uniform	8	0.666667			

shirts-tunic	9	0.75
shirts-uniform	9	0.75
tunic-uniform	7	0.583333
sneakers-stockings	6	0.5
sneakers-shoes	10	0.833333
sneakers-trousers	6	0.5
sneakers-jeans	8	0.666667
stockings-shoes	6	0.5
stockings-trousers	9	0.75
stockings-jeans	10	0.833333
shoes-trousers	7	0.583333
shoes-jeans	6	0.5
trousers-jeans	9	0.75
orange-hat	1	0.083333
orange-shirts	0	0
hat-shirts	9	0.75
jewelry-spoon	2	0.166667
stockings-top	9	0.75
top-ice	1	0.083333
top-wool	3	0.25
ice-wool	0	0
slide-top	3	0.25
slide-waist	2	0.166667
top-waist	2	0.166667