PART ONE: Basics and basic findings

1 Semantic memory

The term 'semantics' refers to the elementary meaning of concepts and objects. Therefore, within semantic memory, persons have represented facts and knowledge about the world in a symbolic manner without referring to a particular or personal spatiotemporal experience (e.g., Zimbardo, 1995). With the help of our semantic knowledge we can answer questions like: What is the capital of Germany? What does the binomial theorem says? What does a bulb look like? What is a stereoscope used for? What is the basic color of a Ferrari? What does the word 'Zeitgeist' mean? Metaphorically, semantic memory can be compared to a dictionary with information regarding a concept's identity, spelling, and pronunciation, to an encyclopedia with information about the meaning of a concept, and to a thesaurus with information about words or concepts with similar meanings (e.g., Hutchison, 2003).

No one would deny the importance of semantic memory for our everyday life. And since antiquity, philosophers such as Aristotle have been interested in the question of how we should think about concepts. In the following period of time, philosophy, linguistics, computer sciences, science of education, and psychology have been engaged in the study of semantic memory in one way or another (e.g., Baddeley, 1997; Rogers & McClelland, 2004). However, although it is an old topic to understand the organization and representation of semantic memory or categories, it is nevertheless a prevailing theme and probably one of the most debated topics of contemporary neuropsychology (e.g., Canessa et al., 2008; Laiacona, Barbarotto, & Capitani, 2006; Mahon & Caramazza, 2003; Matsuka, Sakamoto, & Chouchourelou, 2008; McMullen & Purdy, 2006; Mechelli, Sartori, Orlandi, & Price, 2006). To some scientists, the field of research seems somewhat fragmented why a generally accepted approach is still lacking (e.g., Baddeley, 1997).

However, one way to an understanding of semantic memory is to subdivide the domain of categories. Conceptually, there are a priori several distinctions within the domain of categories. One common distinction is the division between abstract and concrete categories (e.g., Noppeney & Price, 2002; Warrington & Shallice, 1984). Within the concrete domain, the most obvious and traditional distinction is the division between natural (also called biological, animate, or living) categories, for instance, fruits, animals, or vegetables, and artifactual (also called man-made, inanimate, or nonliving) categories, for instance tools, clothing, or furniture (e.g., Atran, 1989; Farah, Meyer, & McMullen, 1996; Warrington & McCarthy, 1987). There is abundant evidence from behavioral studies, studies with brain-

damaged patients, and studies using brain imaging or electrophysiology that this distinction is not only a conceptual one, but one that becomes manifest in cognition (see e.g., Kiefer, 1999; Marques, 2002a; Wurm, Whitman, Seaman, Hill, & Ulstad, 2007). In the following, I will give an overview of this evidence.

1.1 Behavioral evidence for a distinction between natural and artifactual categories

1.1.1 The basic distinction

There is some evidence from behavioral studies that natural and artifactual objects (or categories) were processed in different ways or at least with a different time course. Thus, one basic finding is that processing living (versus nonliving) objects seems to be faster and more accurate in the majority of studies, as indicated by several tasks, for example, by a living versus nonliving decision task (e.g., Allen, Goldstein, Madden, & Mitchell, 1997; D. Gold, Beauregard, Lecours, & Chertkow, 2003), by naming pictured objects (using matched stimuli regarding, for example, concept familiarity and visual complexity; e.g., Laws, Leeson, & Gale, 2002; but see Lloyd-Jones & Humphreys, 1997a, 1997b, for a reversed pattern of results using unmatched material), by semantic classification tasks (e.g., Marques, 2002a, Experiment 1) or by an auditory lexical decision task (e.g., Wurm et al., 2007).

Furthermore, naming natural objects (but not artifactual objects) was facilitated when surface details (i.e., color) were given (J. W. Tanaka & Presnell, 1999; Humphrey, Goodale, Jakobson, & Servos, 1994), or if a word or picture target was preceded in a first experimental phase by the same object as picture or word in a second phase, respectively (e.g., D. Gold et al., 2003). In addition, Price and Humphreys (1989) found that categories containing highly similar exemplars (that are the natural categories) profited especially from color or texture information if the exemplars had to be differentiated in a naming task. However in a categorization task, categories containing highly similar exemplars did not profit from color or texture information. The authors assumed that the difference between objects of one category is irrelevant for a categorization decision. These findings indicate that the processing and differentiation of natural objects benefit from contextual or additional information (see also Deutsch, Bentin, & Katz, 1999).

In summary, there are global processing differences between natural and artifactual categories. More specifically, natural objects were processed faster than artifactual objects and natural objects seem to profit from additional information.

1.1.2 Sex differences

A look at the literature reveals a lot of studies which reports sex differences using semantic tasks like reading or semantic fluency. This is especially interesting and noteworthy, because one would not assume sex differences within such a basic system as semantic memory. However, how do the sex differences look like?[4] Generally, women often outperform men in semantic tasks (e.g., de Frias, Nilsson, & Herlitz, 2006; Maitland, Herlitz, Nyberg, Bäckman, & Nilsson, 2004). Interestingly, processing differences for natural versus artifactual categories are also often moderated by the participants' sex. Apparently, females seem to have a processing advantage for natural objects, whereas males show an advantage for artifacts. More specifically, in picture naming (see above), male subjects are faster and/or more accurate at naming nonliving things, while female subjects show an advantage for living things (Laws, 1999, 2000, 2002; Laws & Hunter, 2006; McKenna & Parry, 1994). More evidence for sex differences with semantic tasks comes from object decision tasks and semantic fluency tasks. In object decision tasks, subjects are requested to decide whether an object is real or chimerical. Here, females are better than males at discriminating biological objects (especially fruits and vegetables) and males seem to be better than females with man-made things (especially tools, vehicles, and furniture; Barbarotto, Laiacona, Macchi, & Capitani, 2002). Accordingly, in semantic fluency tasks, females apparently have better fluency for fruits whereas males have better fluency for tools (Capitani, Laiacona, & Barbarotto, 1999; Coppens & Frisinger, 2005) or for tools and vehicles (Laws, 2004).

The sex differences are especially noteworthy because – from the perspective of a cognitive psychologist – it is rather astonishing that such a basic system as semantic memory and such basic processes within this system are to differ with the sexes. The fact that there are sex differences is evidence that semantic memory and the processes within semantic memory are probably not so cemented as commonly thought. However, so far it is less clear whether the sex differences reflect differences in the representation of categories or whether they simply reflect processing advantages for specific stimuli which are, for instance, more familiar to a specific subject. Given traditional roles, one might speculate whether women may have more experience and contact in daily life with fruits and vegetables than men, whereas men have more experience and contact with tools and

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[4] The following details refer to the results of young persons. There are some findings of age effects. Most often there were no significant sex differences in older subjects (see e.g., Cameron, Wambaugh, & Mauszycki, 2008; Coppens & Frisinger, 2005; Mack, Teng, Zheng, Paz, Chui, & Varma, 2005; Marra, Ferraccioli, & Gainotti, 2007). For the sake of conciseness, I will focus on young persons.

vehicles. The sex differences in fluency tasks may hence reflect mere advantages for frequently encountered stimuli.

1.2 Evidence from brain-damaged patients

The distinction between natural and artifactual categories seems to have an anatomical or neurophysiological basis as well. There is some evidence from studies with brain-damaged patients: These studies indicate that, at least partially, different brain areas are involved in processing natural versus artifactual categories. The reviews of Forde and Humphreys (1999) and Capitani, Laiacona, Mahon, and Caramazza (2003) point out that the most reliable form of category-specific deficits can be observed for biological objects. The reviews suggest that the representation of artifacts is the other global subtype that can be damaged independently from the biological categories. Furthermore, Gainotti (2000) derives from his review a network of different brain regions involved in the processing of living versus nonliving objects. For the processing of living things, he supposed the inferior temporal cortex, the mesial temporo-limbic structures and, possibly, the temporal lobe to be involved. For the processing of man-made objects he assumed that the frontoparietal areas of the left hemisphere (usually attributed to functional information) are involved.

Remarkably, and in line with behavioral studies, there is evidence from lesion studies for sex differences. That is, males with brain lesions seem to show more deficits for natural categories, whereas there is no obvious sex difference for artifactual categories: In their overview, Capitani et al. (2003) reported 43 brain-damaged males – but only 17 females – who were showing primary deficits for natural categories. In contrast, 8 males and 7 females were showing primary deficits for artifactual categories (but see Brickman et al., 2005; Gainotti, 2005; Laiacona et al., 2006 for more fine-grained patterns of result regarding a sex by category interaction).

1.3 Evidence from cognitive neuroscience

Brain imaging studies and electrophysiological data have shown a diverse pattern of results. Yet, often there were category specific or category type specific activations (e.g., Kreiman, Koch, & Fried, 2000), especially in temporal brain regions (for reviews and/or meta-analysis see Bookheimer, 2002; Humphreys & Forde, 2001; Joseph, 2001; Martin & Chao, 2001; but see Devlin et al., 2002; Tyler & Moss, 2001). For example, Bookheimer (2002) reported in her review the common finding of increased occipital activation for animals compared with tools investigated by positron emission tomography (PET) or functional

magnetic resonance tomography (fMRI). Martin and Chao (2001) summarized in their review that the overall data suggested an activation cluster in the more lateral region of the fusiform gyrus for living objects and a cluster in the more medial region of the fusiform gyrus for nonliving things. This means that a region – the fusiform gyrus (lying in the ventral occipitotemporal cortex) – that was thought to be responsible especially for the processing of shape responds differently in dependence on the category type. A further common finding is that manipulable things (especially tools) activate brain regions usually associated with motion perception or with grasping. For instance, in the picture naming task, artifacts (compared to natural objects) have been reported to evoke more activation in the left ventral premotor cortex, a brain area involved in action representation (e.g., Bookheimer, 2002; Damasio, Grabowski, Tranel, Hichwa, & Damasio, 1996; Martin & Chao, 2001; Martin, Wiggs, Ungerleider, & Haxby, 1996). Additionally, category specific activations (e.g., for animals, furniture, fruit, and tools) using fMRI were found with a diversity of tasks (e.g., Bookheimer, 2002; Spitzer, Kwong, Kennedy, Rosen, & Belliveau, 1995).

Using event-related potentials (ERPs) and repetition priming, a semantic decision task, or a classification task, different waves, and a different topography for the activation of artifactual versus natural categories have been found (Kiefer, 2001, 2005; Paz-Caballero, Cuetos, & Dobarro, 2006; but see Hinojosa, Martín-Loeches, Muñoz, Casado, Fernández-Frías, & Pozo, 2001). For example, Paz-Caballero et al. (2006) found bilaterally more positive ERPs from about 300 ms up to about 600 ms for natural compared to artifactual line drawings with a semantic categorization task.

Remarkably, there is also some evidence for sex differences when language processing is investigated using ERPs or neuroimaging. For example, Wirth et al. (2007) conducted an EEG study in which they presented two words one after the other. The words could be semantically related or semantically unrelated and the subjects' task was to read both words silently. Wirth et al. (2007) tested some ERP components which are typically associated with semantic tasks, especially the N400[5] which is the most important and the most investigated component when studying semantics. Women and men differed significantly in the latency and duration of the N400 (e.g., Kutas & Van Petten, 1994). In contrast, Hill, Ott, Herbert, and Weisbrod (2006) found no N400 sex differences with a visual semantic

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[5] The N400 is a negative deflection in the time-window of about 300–500 ms after stimulus onset. The negativity is more pronounced for words that do not fit with the previous context or that are semantically unrelated to a previous stimulus as compared to related stimuli. For details see Chapter 5 which deals especially with this ERP component.

priming task (see Chapter 5). However, they found a different activation pattern for females compared to males: females' ERP waveforms were more positive at posterior sites and more negative at frontal sites compared to the male subjects. Additionally, the authors found an attenuated positivity over the left posterior scalp region and an attenuated negativity at right frontal sites for males compared to females.

Using fMRI, Baxter and colleagues (2003) found evidence for sex differences in the pattern of brain regions activated in an auditory semantic decision task (but see Sommer, Aleman, Bouma, & Kahn, 2004). Here, participants had to decide whether a subordinate category exemplar (e.g., milk) and a superordinate category (e.g., beverage) matched. The authors found a greater right hemispherical activation for females than for males. However, in the left hemisphere males showed a more diffuse activation pattern compared to females. The authors concluded that females have greater bilateral language representation but that males and females also differ intrahemispherically (especially within the left hemisphere). Similarly, Shaywitz et al. (1995) conducted an fMRI experiment using different tasks (including a rhyme-judgment task and a semantic category decision task). They found bilateral activation for females and more left hemisphere activation than right hemisphere activation for males especially within the inferior frontal gyrus (for more details see Chapter 4).

In conclusion, there is much evidence from studies with brain-damaged patients as well as from studies using brain imaging and electrophysiology that corroborate the claim of at least partially different subsystems for the processing of natural and artifactual categories. Additionally, sex differences were also evident and were found with different methods and paradigms for investigating language processing.

1.4 Theories on category-specific effects

McMullen and Purdy (2006) stated that the mechanisms underlying category-specific effects were unresolved to date (see also Mahon & Caramazza, 2003). Furthermore, the locus of category-specific effects is still unclear: Are the differences due to different visual structural representations, due to different semantic representations, or due to different phonological representations for instance? Most theories assume that the locus lies in semantic representation, but there are also theories for a visual locus. Several accounts deal with possible explanations of the mechanisms leading to differences of categories or category types. In the following, I will summarize the most important accounts (see also Cree & McRae, 2003, who summarized several theories).

1.4.1 Familiarity

Some authors explained the natural/artifactual distinction (and sex effects) with different individual familiarities with the objects from one type of category (or with other confounding variables as complexity, e.g., Cree & McRae, 2003; Tranel, Logan, Frank, & Damasio, 1997). The assumption is that less experienced or less familiar objects are more affected by brain damage. Therefore, knowledge about these objects is more often impaired (e.g., Marra et al., 2007; Albanese, Capitani, Barbarotto, & Laiacona, 2000). The same explanation can be given for non-brain-damaged subjects and semantic fluency tasks; subjects produce more items of categories that are more familiar to them (e.g., Albanese et al., 2000). Given traditional roles, life experience, and evolutionary pressure, one might assume that females are more familiar with natural objects, for instance, objects related to preparing food. However, males should be more familiar with artifactual objects like weapons and other technical things. Although some findings are problematic for the familiarity-based explanation of the natural/artifactual distinction and associated sex differences (e.g., Humphreys, Francis, & Samson, in preparation, reported in Humphreys & Forde, 2001), most of the tasks used (especially fluency tasks) have not been able to differentiate familiarity effects from effects due to different underlying structures or processes. However, the control of several factors including familiarity shows that most data indicate "that the category effect represents a psychological reality even without the influence of the word properties" (Coppens & Frisinger, 2005, p. 62; see also Bunn, Tyler, & Moss, 1998; Humphreys & Forde, 2001; but see e.g., Mechelli et al., 2006 for the factor semantic relevance).

1.4.2 Domain-specific or category-specific theories

Domain-specific theories are based on the assumption that natural objects and artifactual objects are represented in different brain regions or separate neural substrates; category-specific theories assume even different regions for particular categories (e.g., Caramazza & Shelton, 1998). Therein, semantic knowledge is represented in an amodal and abstract format, that is, the knowledge about an object is separated from, for instance, action-related systems or systems involved in perceptual processing. The items within one neural substrate are highly inter-connected and clustered. The separation of at least the substrate for natural categories from the substrate in which all other categories are stored is constituted by evolutionary advantages and the evolutionary necessity for a fast selection of the natural

objects. After brain damage, those categories are impaired that are stored or represented within the damaged regions.

1.4.3 Sensory-functional or modality-specific theories

Sensory-functional theories assimilate the old idea that concepts are defined on the one hand by sensory properties and on the other hand by motor properties, both acquired during experience (e.g., Broadbent, 1878). Sensory-functional theories (see also Farah et al., 1996) assume that artifactual objects rely more on functional properties and that these functional properties therefore have a greater weighting for artifacts in semantic memory. In contrast, natural things are represented in semantic memory with greater weighting for perceptual/sensory properties. The theory further postulates different and distinct neural substrates where functional and perceptual properties are represented (e.g., Humphreys & Forde, 2001; Warrington & Shallice, 1984; Kiefer, Weisbrod, & Spitzer, 1998; Kiefer, 1999; but see Moss, Tyler, & Jennings, 1997, for a different interpretation). Thus, sensory-functional theories assume that semantic knowledge is represented either spatially or anatomically close to the sensory or motor cortex depending on whether the knowledge is deduced and what region is active during acquisition (e.g., Barsalou, Simmons, Barbey, & Wilson, 2003; Humphreys & Forde, 2001; Kiefer, 2008; Kiefer & Spitzer, 2001; Martin & Chao, 2001; Pulvermüller, 2005). The retrieval of a specific concept requires at least partially the (partial) reactivation of the neurons that were active during acquisition. Category-specific deficits after brain damage were explained by the damage of that neural substrate related to the key identifying (or heavily weighted) properties for the specific category/categories.

1.4.4 Correlated features theories

Due to some data which could not be explained by sensory-functional theories, some researchers suggested that the links or correlations between different features are more important for the differences between artifactual and natural categories instead of the perceptual or functional features per se. Feature correlation is defined for pairs of features that often co-occur in concepts (McRae, Cree, Westmacott, & de Sa, 1999). For instance, 'has feathers' and 'is bipedal' appear together in a wide range of exemplars, namely birds. Therefore, these two features are correlated. A basic finding of McRae, Cree, and colleagues is that natural (i.e., living) things cohere around clusters of intercorrelated features. Artifactual things do not show such a high extent of intercorrelation (e.g., McRae & Cree,

2002; McRae et al., 1999; McRae, de Sa, & Seidenberg, 1997). For artifactual categories, there is the suggestion that the connection between shape and action is relevant because a special shape is in close relation to the action that can be done with the specific object (e.g., Humphreys & Forde, 2001). For example De Renzi and Lucchelli (1994) argued that for artifactual categories there are two routes to access the representation of an object (namely the sensory and the functional) which will lead to a compensation when one route or one feature dimension is damaged. For natural things, the authors proposed that the functional route is unavailable due to the few links between perceptual and functional features. The authors premised that (naming) impairments are the result from a general failure to retrieve the (e.g., perceptual) features of things instead of an impairment of the category. Whereas De Renzi and Lucchelli (1994) assumed different semantic stores for sensory and functional features, which interact in the case of artifactual objects, Caramazza, Hillis, Rapp, and Romani (1990) assumed only one semantic store which does not differentiate between functional and perceptual properties.

Moss, Tyler and colleagues (Moss et al., 1997; Tyler & Moss, 1997) extended the general proposal with their form-function interrelation account by claiming that natural or living things share many perceptual features associated with the same functions (e.g., biological functions such as eating) and therefore there are links between form and function. However, there are only a few links of this kind and these few links are not distinctive for different natural things. When visual properties are disturbed for processing or retrieval ("whether due to noise in the system, altered connection weights, or raised thresholds", Moss et al., 1997, p. 943), functional properties are used to retrieve the objects. However, in the case of natural things, the functional properties would lead to the shared visual properties and therefore, are not predictive for a specific natural object. In the case of artifactual objects, the functional properties are linked to distinct visual properties and therefore the specific artifactual object can be retrieved via the function-form link.

1.4.5 Evaluative summary

There are several accounts for explaining category-specific effects. To date, all different accounts cited above are still under debate. Furthermore, all accounts cited above are supported by any brain-damaged patient who shows a specific deficit. In almost the same manner, there is always a brain-damaged patient who has a specific deficit which could not be explained by a particular theory. Therefore, case studies seem to be no good arguments for the one or the other theory. Furthermore, it was often argued that it is rather difficult to

explain language processing of healthy subjects with brain-damaged patients although this is a common method (e.g., Springer & Deutsch, 1981).

Additionally, the different theories are confronted with further problems. First, familiarity (as well as other confounding variables) could not really be ruled out as an explanation, although, when controlled for familiarity, most category effects still remained. Second, the account of category specificity can explain the pattern that arises for conceptual knowledge but it was criticized (e.g., Barsalou et al., 2003) due to the amodal thinking of memory storage because, in principle, amodal models can explain anything (a deficit for vehicles may be due to the damage of the amodal store of vehicles and so on).

In contrast, sensory-functional accounts reflect more the current point of view (e.g., Kiefer, 2008). However, it might be possible that the activation in sensory versus motor areas is just an epiphenomenon, that means that the activation does not have any functional significance for the conceptual representation. Instead, the conceptual meaning is represented somewhere else and the activation of visual and motor areas is just of associative manner because the meaning of the object is associated with the activation of the visual and motor areas during learning (e.g., Kiefer, Sim, Liebich, Hauk, & Tanaka, 2007). Unfortunately, by using neuroimaging methods or ERPs it cannot be tested whether the activation of visual and motor areas is only epiphenomenal or whether it is essential for the representation of meaning. However, Kiefer et al. (2007) argued that an only epiphenomenal activation seems rather unlikely because of the accumulating evidence for the significant role of sensory and motor representation in conceptual processing. For example, Kiefer et al. (2007) found very early activity in premotor areas in response to function-related categories. They concluded that this premotor activity could not occur subsequently to conceptual processing and therefore an (only) associative activation seems unlikely.

Distributed networks (on which correlated feature theories are based) are criticized, too. They are seen as being an oversimplification by assuming that conceptual information is distributed without any organization in terms of category or domain (e.g., Humphreys & Riddoch, 2003). Therefore, the models do not fit with the evidence from imaging studies in healthy subjects which found specialized regions for processing of different category types. Tyler and Moss (2001) assumed already that "even a completely distributed connectionist network will develop its own organization such that semantic space will be 'lumpy' " (p. 249). Thus, due to the many shared features, which are highly intercorrelated, similar concepts are represented 'close together' and build semantic regions (see also Kiefer & Spitzer, 2001, who assumed different conceptual maps).

Indeed, most researchers come around and assume that most likely different theories have to be merged. To explain the whole pattern of results, different aspects from the different accounts should be considered. However, it is necessary that the particular aspects will be differentiated and elaborated further (Caramazza & Shelton, 1998; Humphreys & Forde, 2001; McRae & Cree, 2001; Mummery, Patterson, Hodges, & Price, 1998; Tyler & Moss, 2001; see additionally all comments on the article by Humphreys & Forde, 2001).

Furthermore, there is one general problem with a large part of evidence used for investigating semantic memory. Often, it is difficult to be certain that performance really reflects the (different) storage of semantic memory or whether performance reflects processes which tap the voluntary access or retrieval to semantic information and specific executive abilities. Especially studies using semantic fluency tasks which are also often used in studies with brain-damaged patients cannot distinguish between explanations regarding semantic memory and explanations regarding voluntary processes or executive abilities (e.g., Moss & Tyler, 1995; Ruff, Light, Parker, & Levin, 1997). However, there is one experimental paradigm which is thought to tap – given some parameters – (more or less) exclusively automatic access to semantic representations rather than voluntary access, that is, the semantic priming paradigm (e.g., Moss & Tyler, 1995). Unfortunately, research using this paradigm is neglecting (research to) different category types. Likewise, research focusing on the natural/artifactual distinction is neglecting the semantic priming paradigm – with very few exceptions. Chapter two therefore deals with this common paradigm for investigating semantic memory and ends with the presentation of the few studies which combines semantic priming and the investigation of different category types.