Semantic memory and bilingualism:

A review of the literature and a new hypothesis

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Abstract

For a long time there were two exclusive views of semantic memory. One approach held that word meanings are based on semantic features, which can be experienced in the physical world. According to the other approach, word meanings are derived from the words co-occurring with the target word. Recent simulations suggest that both views are complementary and that a combined semantic network better predicts human performance. We notice that the experience-based view is well represented in the literature on bilingualism (e.g., the distributed feature model of de Groot), but that the view based on word co-occurrences has been overlooked. We hypothesize that this may be due to the fact that the association links between words of different languages are weak because words of various languages are rarely used together. Implications for memory encoding, storage, and retrieval are discussed.

Semantic memory vs. episodic memory

In long-term memory research, Tulving (1972) introduced a distinction between episodic memory and semantic memory that was very productive. In Tulving's conception, episodic memory refers to memories for events we experienced ourselves. These memories have strong "then and there" connotations, meaning that reminders about "when and where" are powerful retrieval cues (e.g., Wagenaar, 1986). In contrast, semantic memory refers to memories for facts and other kinds of person-independent knowledge. Semantic knowledge (e.g., knowing that dogs have legs) is not tied to a specific episode, so that when and where information is of little use for retrieval. This distinction between episodic and semantic memory was further validated with neuropsychological evidence from patients who, due to brain damage at an early age, developed an extremely poor episodic memory, while preserving reasonably good semantic memory (Vargha-Khadem, Gadian, Watkins, Connelly, Van Paesschen & Mishkin, 1997).

In the broad distinction between semantic and episodic memory made by Tulving, semantic memory contains information about the meaning of words, like *cats*, *bats*, *furniture* and so on, but also more general knowledge of the world, like how to multiply numbers, what the chemical formula of water is, and what the typical sequence of events is to have a meal in a restaurant (Baddeley, Eysenck, & Anderson, 2009). In this chapter, we will focus on the part of semantic memory related to the meaning of words. Many authors have, implicitly or explicitly, made a distinction between two levels of word-related information: a level of semantic representations and a level of lexical representations (e. g., Humphreys, Price, & Riddoch, 1999; Kroll & de Groot, 1997; Malt, Sloman, Gennari, Shi, & Wang, 1999; for an overview of the relevant literature, see Vigliocco, Vinson, Lewis &

Garrett, 2004). Semantic representations represent the meaning of the words; lexical representations refer to the forms of the words. Two reasons for this distinction were the facts that words can be represented in different modalities (spoken, written) and in different languages (mother tongue –L1 – and second language – L2). In all cases, different forms refer to (roughly) the same meaning.

Two types of models have been proposed about how word meanings are stored in semantic memory: experience-based and distribution-based. We first review the models and then discuss recent attempts to unite them.

Experience-based models of semantic memory

Experience-based models of word meanings start from the principle that words refer to entities in the universe, which have features that can be perceived by humans and which can take part in certain actions. Andrews, Vigliocco, and Vinson (2009) called these models *experiential* or *experience-based*. The models go back to the empiricist conviction that all knowledge starts from sensory data.

Hampton (1979) published one of the first studies to provide a quantitative investigation of feature-based models. Participants were asked to give features (descriptions) of the following eight categories: kitchen utensils, furniture, vehicles, sports, fruits, vegetables, fish, and birds. On the basis of the answers, both defining and characteristic features of the categories were compiled. Figure 1 gives the outcome for furniture.

Figure 1: Defining and characteristic features of furniture according to Hampton (1979)

Defining features of furniture:

- Has a specific function, is used by humans.
- Is for comfort, convenience or satisfaction.
- Is manufactured, man-made.
- Is not just decorative.

Characteristic features:

- Is made of wood.
- Has legs.

Hampton (1979) observed that items with many of the category features (both defining and characteristic) were seen as more typical members of the category than items with fewer features.

Other well-known studies resulting in lists of features on the basis of responses from groups of participants were published by Rosch and Mervis (1975), McRae, de Sa, and Seidenberg (1997), Storms, De Boeck, and Ruts (2000), and Vigliocco, Vinson, Lewis, and Garrett (2004). The difference between these studies and Hampton's was that they also collected lists for individual concepts rather than categories alone. Figure 2, for instance, gives the 20 most commonly produced features for the words "duck" and "pilot" (based on Ruts et al., 2004).

Figure 2: Most commonly given features for the words "duck" and "pilot" (Ruts et al., 2004)

Duck

1. quacks
2. has fins
3. lives in water
4. has a beak
5. can swim
6. has wings
7. is food
8. bird
9. has two legs
10. is often seen in parks
11. eats bread
12. is an animal
13. is delicious
14. female is brown
15. is hunted upon
16. can fly
17. male has different colors
18. migrates
19. small
20. has a big beak

Pilot

1. flies a plane
2. good sight
3. wears a uniform
4. demanding education
5. has big responsibility
6. flies
7. is in the cockpit
8. works on a plane
9. must be physically fit
10. can work for the army
11. is rarely with the family
12. must not have vertigo
13. is helped by a co-pilot
14. is a man
15. has a kepi
16. education is expensive
17. is intelligent
18. carries passengers
19. wears a nice suit
20. has studied for a long time

Experience-based models of semantic memory received extra impetus from brain imaging studies, when it was found that words with a strong visual component (e.g., names of objects with a typical color) activate brain parts involved in visual perception, whereas words with a strong motor component (e.g., action verbs such as "kick") activate the motor cortex (Martin et al., 1995). The involvement of perceptual and motor areas in word meanings explains the vividness of the representations (in philosophy called *qualia*): Perceptual aspects of stimuli activate brain regions involved in perceiving these attributes, and action components of words fire up the brain regions involved in performing the actions. For a general overview of the literature on this kind of modal cognition, we refer to

Barsalou (2008). Connectionist versions of feature-based semantic models could also account for developmental data (i.e., how semantic concepts differentiate as children develop) and for the deterioration of semantic knowledge in dementia (Rogers & McClelland, 2004).

Distributional models of semantic memory

A second class of models starts from the idea that the meaning of a target concept to which a word refers can be derived from the words often co-occurring with it. Andrews et al. (2009) trace this tradition, which they called the *distributional tradition*, back to Wittgenstein and Firth in the 1950s. It took off when researchers were able to analyze big collections of texts (corpora) and observed that similarities in word meanings were well captured by tabulating the distributions of words found in close contiguity to the target words or to the texts in which the words occurred. Well-known examples of the former are the hyperspace analog of language (HAL; Burgess and Lund, 1997) and the latent semantic analysis (Landauer & Dumais, 1997). An example of the latter, text-based approach is Griffiths et al. (2007). Figure 3 gives the 20 English words with the highest LSA similarity to "duck" and "pilot" (based on http://lsa.colorado.edu/; Retrieved on 05/23/2012).

Figure 3: Words most similar to duck and pilot according to LSA (http://lsa.colorado.edu/)

Duck	Pilot
1. hen	1. runway
2. bear	2. plane
3. duckling	3. pilots
4. ducks	4. aircraft
5. mitten	5. cockpit
6. bluebird	6. airport
7. rabbit	7. airplane
8. bird	8. stewardess
9. fox	9. flying
10. paw	10. runways
11. ducklings	11. beiruit
12. beefsteak	12. hijackers
13. turtle	13. derickson
14. bears	14. flown
15. nest	15. flight
16. yookoohoo	16. fuselage
17. unmannerly	17. planes
18. teresa	18. gliders
19. grizzly	19. glider
20. pecked	20. altimeter

The co-occurrence of words is thought to form the basis of word associations. When given a target word and asked to report the first word that comes to mind, for many words participants produce a consistent, small set of answers. For instance, when given the word "hot", many people spontaneously reply "cold". Word associations have been collected by Kiss, Armstrong, Milroy, and Piper (1973; available at http://www.eat.rl.ac.uk/), Nelson et al. (2004; available at http://w3.usf.edu/FreeAssociation/), and more recently by De Deyne and Storms (in progress; available at http://www.smallworldofwords.com). Figure 4 shows the 20 most frequent associates produced to the words "duck" and "pilot" in De Deyne and Storms.

Figure 4: Associates most frequently produced to duck and pilot according to De Deyne and Storms (http://www.smallworldofwords.com)

Duck
1. quack
2. goose
3. bird
4. water
5. yellow
6. bill
7. pond
8. down
9. feathers
10. fowl
11. hunting
12. mallard
13. animal
14. beak
15. cover
16. lake
17. bob
18. feather
19. bath
20. bend

Pilot
1. plane
2. airplane
3. fly
4. light
5. captain
6. ship
7. study
8. aeroplane
9. cockpit
10. first
11. flight
12. hat
13. man
14. steer
15. travel
16. uniform
17. wings
18. airline
19. co-pilot
20. sky

Word associations can be translated into networks of nodes linked to each other. In an unorganized network the links only differ in weight. In an organized network they can have separate meanings (e.g., “is a”, “has”, “can”) and nodes can be organized hierarchically (i.e., ordered in different levels; see, e.g., Collins & Quillian, 1969). A particularly interesting idea of networks for the organization of the memory system is that nodes (memories) connecting to a particular piece of information can be used as cues to this information through the principle of activation spreading (Collins & Loftus, 1975). Knowledge of “ducks” can be used to retrieve knowledge of other birds and animals.

Proposals for integration

Although experience-based models en distributional models were developed independently and are often presented as incompatible, Andrews et al. (2009) noted that they are not mutually exclusive. As a matter of fact, they are quite complementary. Whereas experience-based models work well for concrete, tangible concepts, distributional models are particularly well-suited for information that is disconnected or disembodied from the physical world. As Andrews et al. (2009, p. 467) wrote: “It is not … necessary to choose between experiential and distributional data as if they were mutually exclusive. Both types of data are available to humans when learning the meaning of words. Words are encountered simultaneously within two rich contexts: the physical world itself and the discourse of human language. As such, it is reasonable to assume that both data types are used concurrently to learn word meanings.” Andrews et al. (2009) used simulation data to show that the combined use of experiential and distributional information resulted in more complete semantic networks, which were able to better predict human performance. Figure 5 shows the outcome of the various models for the word “drink”.

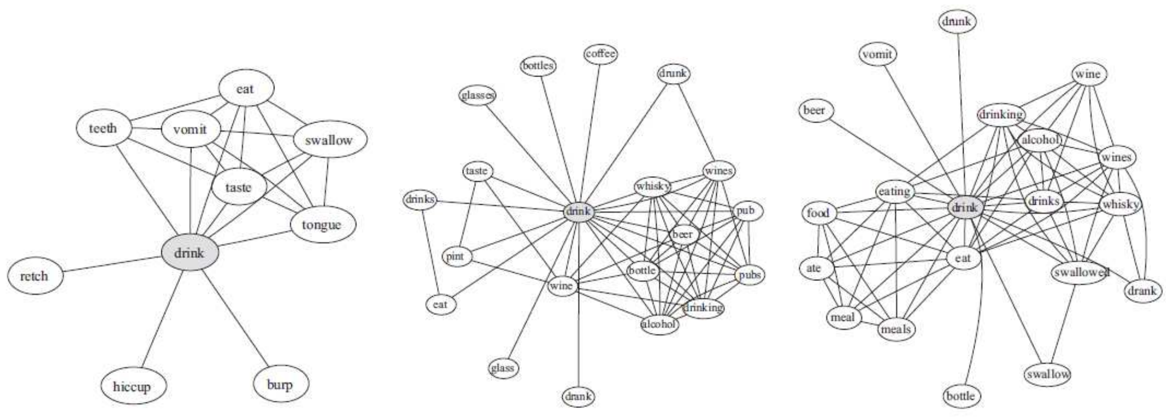

Figure 5: Semantic networks on the basis of an experiential model (left), a distributional model (middle), and a combined model (right).
Source: Andrews et al. (2009).

The contribution of semantic and associative information is also well known within the literature of semantic priming. An intense discussion within this area has been to what extent semantic priming is due to meaning overlap or to association strength. Does “bread” prime “butter” because they are experientially linked or because they often co-occur in texts and discourse? A meta-analysis by Lucas (2000) showed that both factors contribute. There is a small but reliable priming effect between words that share meaning but that are not strongly associated (such as “lion” and “ant”). In addition, there is an associative priming “boost” for words that are associated with each other (lion-tiger).

Experience-based and distributional elements within current views of bilingual semantic memory

Going through the literature of the organization of semantic memory in bilinguals, we noticed that authors have not yet made a distinction between experiential and distributional components of word meaning (e.g., Francis, 2005). Most theorizing has been done within the experiential tradition, although the distributional idea can be found in the word-word associations of the Revised Hierarchical Model.

The experiential view of semantic memory is the basis of de Groot’s *distributed feature model* (de Groot, 1992; Kroll & de Groot, 1997). According to this model, a distinction must be drawn between word forms (the lexical level) and word meanings (the conceptual level). The word forms refer to the spoken and written representations of words in the first and second language (L1 and L2). The conceptual level is thought to be language independent and based on collections of features, which are activated by words referring to them. Words in L1 and L2 with a large meaning overlap (typically concrete words) share many features. In contrast, words with language-specific meanings (often abstract words) have a small feature overlap of the translations. The larger the meaning overlap between L1 and L2 words, the easier they are to translate. Schoonbaert, Duyck, Brysbaert, and Hartsuiker (2009) argued that the degree of cross-language priming (both translation priming and semantic priming) can also be understood by looking at the number of overlapping features between the prime and the target (figure 6).

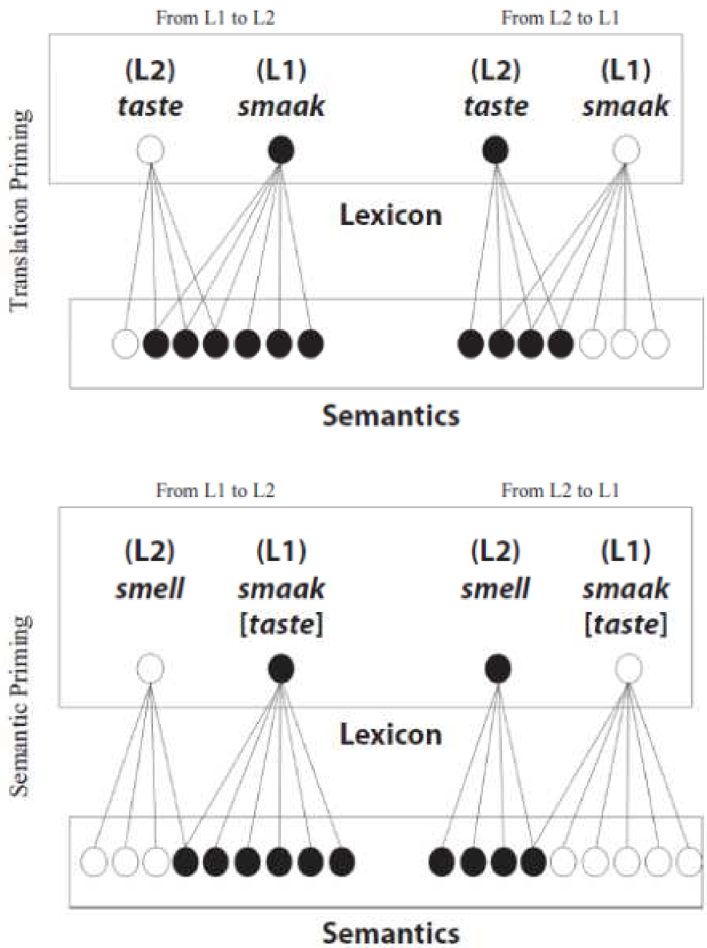

Figure 6: Model of Schoonbaert et al. (2009) to explain differences in cross-language priming.

According to Schoonbaert et al. (2009), the distributed feature model of de Groot can explain why cross-language priming (both translation priming and semantic priming) is larger from L1 primes to L2 target words than vice versa. If one assumes that the meaning of L1 words is richer (contains more features) than the meaning of L2 words, then L1 primes will always activate a larger proportion of the L2 features than vice versa and, hence, will prime the target word more than the other way around. Top row: situation for translation priming (i.e., target is the translation of the prime); bottom row: situation for semantic priming (i.e., target differs in language from the prime but is related to its meaning). Each panel shows the number of semantic features that become active upon presentation of a word in L1 or L2, and the number of features overlapping with the word in the other language.
Source: Schoonbaert et al. (2009).

Also within the tradition of de Groot's distributed feature model, Ameel, Storms, Malt, and Sloman (2005) and Ameel, Malt, Storms, & Van Assche (2009) showed that the word-to-meaning mappings in bilinguals change if the mappings disagree between L1 and L2. In such cases, the two languages shift towards each other and the mappings in each language start to differ from those used by native speakers.

It is easy to see how the above publications followed the experience-based tradition of word meanings, even though this was nowhere mentioned explicitly: Words are assumed to make reference to language-independent (experiential) features that are shared to various degrees between translation equivalents.

It was harder to find a model of bilingual word recognition inspired by the distributional approach. The only model we found was the Revised Hierarchical Model of Kroll and Stewart (1994; see also Brysbaert & Duyck, 2010; Kroll, van Hell, Tokowicz, & Green, 2010). According to this model, the lexical representations of L1 and L2 not only make contact to a language-independent semantic system (similar to what happens in the model of de Groot), but also to the lexical translation equivalents of the other language. That is, L1 words directly activate their L2 translations, and vice versa. The connections between the lexicons are based on co-occurrences of words (because L2 words are learned by combining them with their L1 translations) and the weights of the connections depend on the association strengths between the words.

A new hypothesis of bilingual semantic memory based on the integrated view

If we follow Andrews et al.'s (2009) argument that a combined model of experiential and distributional data of semantic memory is better than each model alone, then we can think of the implications for bilingual semantic memory.

As indicated above, the experiential view is already well incorporated in research on bilingualism. Indeed, there is a large degree of consensus that translation equivalents are connected to a set of semantic, language-independent (experiential) features (Francis, 2005; Kroll & de Groot, 1997; Schoonbaert et al., 2009). In contrast, the importance of word co-occurrences for word meanings has not yet received much consideration, maybe because word co-occurrences between languages are very limited (which suggests that researchers, like all humans, are more sensitive to the presence of co-variation than to the lack of it). Indeed, words of a language tend to be used almost exclusively within the context of that language (be it in written or spoken form). This means that the association strengths between L1 and L2 words will be very weak if these are based on word contiguity, as argued by the distributional model of semantic memory. To our knowledge, there are only three cases in which words from L1 and L2 are not separated: (1) in direct translations, (2) when L1 and L2 words have the same form and meaning (i.e., are so-called cognates), and (3) when a word of one language is used extensively in the context of the other language (cf., so-called loan words, because the word only exists in one language). For the rest, the words of different languages are largely used in separate contexts and, therefore, are expected to have weak associative links.

The hypothesis that words of different languages have weak associative links makes two interesting predictions for word recognition research. First, it predicts that bilingual participants will find it nearly impossible to produce a word associate in a language other than the probe word (which agrees with the authors' intuitions). Most of the time, bilinguals will have to work via covert translations if they are asked to produce a cross-language associate. This can be either a translation of the probe word or a translation of the associated word. A second prediction is that the associative boost (see above) will be largely absent in cross-language semantic priming. Words only prime targets from the other language to the extent that their meanings are based on language-independent, experiential feature overlap.

Implications for memory encoding, storage, and retrieval

The hypothesis that words of different languages have weak associative links also has implications for memory encoding, storage, and retrieval (the central theme of the present book). It predicts that memory encoding and storage are much more language dependent than assumed so far. Indeed, a review of the literature points to various indications of language specificity in memory representations.

Arguably the best known study is that of Marian and Neisser (2000). The authors interviewed students in the US who had immigrated from Russia at the age of 14. Participants were given memory probe words (such as "summer, neighbors, birthday, cat") and asked to report the first autobiographical memory that came to mind. Half of the study was run in English, half in Russian. Participants reported more memories from their Russian part of life when the interview was done in Russian, and more memories from the American part when the interview was done in English.

Because Marian and Neisser's (2000) study involved autobiographical memories, it can be objected that their result is limited to episodic memory. However, there are similar findings with respect to semantic memory. Saalbach, Eckstein, Andri, Hobi, and Grabner (2013), for instance, examined the impact of language specificity on mathematics education. On three consecutive days, proficient German-French bilingual students of a bilingual secondary school in Switzerland were trained on multiplication and subtraction problems (e.g., 17 x 5 = ?, 41 – 14 = ?). Training occurred in German or French. Afterwards, the participants were tested in the same language or in the other language. Some problems had been trained before; others were new. Performance was better when testing happened in the same language as in training. This was true both for trained and (to a lesser extent) untrained problems, making the authors conclude that educational authorities must not underestimate the cost of learning information in one language and having to use it in another language.

A similar finding was reported by Marian and Fausey (2006), who taught Spanish-English bilinguals academic-type information about history, biology, chemistry and mythology in their two languages. Upon testing, the authors observed that memory was more accurate and retrieval faster when the language of retrieval and the language of encoding matched than when they did not.

A study of Sahlin, Harding, and Seamon (2005) suggests that language already plays a role at encoding. These authors presented highly proficient English-Spanish bilinguals with 12 lists of 10 words spoken at a rate of about one word every 3 seconds (each list of words was related to a single topic). Half of the lists were given in English, half in Spanish. Afterwards, participants were given a new list of words, either in English or in Spanish, and had to indicate which words had been presented before, independent of language, and which were entirely new. Sahlin et al. (2005) were interested in whether the participants would show cross-language false memories (i.e., memories of words not presented in the list but related to the list topic), which the participants indeed did. However, the most striking aspect of the results was that participants correctly recognized more than 85% of the words presented in the same language at encoding and retrieval versus less than 20% of the words presented in different languages, suggesting that the encoding had been largely language dependent.

All the findings above agree with our hypothesis that words in one language do not work equally well as memory cues for the other language, because memories are to a large extent language-specific and have weak associative links with memories of the other language. Words in one language require translation before they can make access to memories in the other language.

Conclusion

The degree to which the bilingual memory is language dependent or independent has been a vexing issue in research on bilingualism since the very first explorations. On the one hand, there is ample evidence of cross-language influences (Francis, 2005). On the other hand, there are also various indications of language-specific memories (Marian & Fausey, 2006; Marian & Neisser, 2000; Saalbach et al., 2013; Sahlin et al., 2005). Hopefully, the distinction between the experience-based and distributional components of word meanings we have discerned as part of our research for the present chapter, will help to get a better insight in the reasons why some aspects of semantics generalize seamlessly across languages, whereas other do not.

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