Gestures Enhance Foreign Language Learning

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Language and gesture are highly interdependent systems that reciprocally influence each other. For example, performing a gesture when learning a word or a phrase enhances its retrieval compared to pure verbal learning. Although the enhancing effects of co-speech gestures on memory are known to be robust, the underlying neural mechanisms are still unclear. Here, we summarize the results of behavioral and neuroscientific studies. They indicate that the neural representation of words consists of complex multimodal networks connecting perception and motor acts that occur during learning. In this context, gestures can reinforce the sensorimotor representation of a word or a phrase, making it resistant to decay. Also, gestures can favor embodiment of abstract words by creating it from scratch. Thus, we propose the use of gesture as a facilitating educational tool that integrates body and mind.

Keywords: education; embodiment; foreign language learning; gesture; memory

1. Introduction

When people speak, they spontaneously gesture. They do this to illustrate or to emphasize what they say (Hostetter 2011). When children acquire language, they also gesture. In particular, pointing has been described as a precursor of spoken language (Goldin-Meadow 2007; Tomasello *et al*. 2007). People trying to express themselves in a foreign language make use of gestures. The gestures help to convey meaning and to compensate for speech difficulties (Goldin-Meadow 2003; Gullberg 2008). Learners of a foreign language also express their provenience in intercultural settings through the gestures they use (Gullberg & McCafferty 2008; McCafferty 2008; McCafferty & Stam 2008). Foreign language teachers use gestures as a tool which favors and enhances the language acquisition process (for reviews, see Kusanagi 2005; Taleghani-Nikazm 2008).

However, gestures can do even more: If they are performed during learning of words and phrases, they enhance memory compared to pure verbal encoding (Zimmer 2001a). Also, gestures accompanying foreign language items enhance their memorability (Quinn-Allen 1995; Macedonia 2003; Tellier 2008) and delay their forgetting. Why this happens is the question we will discuss in this paper.

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2. The Effect of Gestures and Verbal Memory: A Brief Historical Overview

Over the past three decades, laboratory research has shown that action words or phrases such as *cut the bread* are memorized better if learners perform or pantomime the action during learning than if they only hear and/or read the words (Engelkamp & Krumnacker 1980; Saltz & Donnenwerthnolan 1981). Different research groups working on this topic gave the effect of gestures on verbal information different names: 'enactment effect' (Engelkamp & Krumnacker 1980) and 'self-performed task-effect' (Cohen 1981). Many experiments using various materials (verbs, phrases, actions with real objects, common, and bizarre actions), tests (recognition, free, and cued recall) and populations (children, students, elderly subjects, people with memory impairments have independently replicated this effect, for reviews, see Engelkamp 1998; Nilsson 2000; Zimmer 2001b). Interestingly, not only healthy subjects showed a benefit in retrieval of enacted information (Rusted 2003); likewise, mentally impaired subjects (Cohen & Bean 1983) and patients suffering from memory impairments such as mild to moderate dementia (Hutton *et al*. 1996) profited. Also, it was demonstrated that during stroke rehabilitation, patients can enhance their memory performance through enactment (Nadar & McDowd 2008). More recent studies with children have also reported positive effects on learning for action/object phrases (Mecklenbräuker *et al*. 2011).

Besides enhancing the quantity of memorized items and prolonging their longevity, enactment also improves the accessibility of the learned words. In free recall tests, Zimmer *et al*. (2000) observed that enacted items pop out of the mind effortlessly. In recognition tasks, reaction time is better for enacted encoding (Masumoto *et al*. 2006) and this occurs independently of the subjects' age (Freeman & Ellis 2003). Also, recent experiments have demonstrated better accessibility of enacted action phrases through immediate and delayed free recall tests on younger and older adults (Spranger *et al*. 2008; Schatz *et al*. 2011). Overall, compared to pure verbal learning, enactment has proven to be more effective in enhancing verbal memory.

3. The Body as a Learning Tool in Foreign Language Instruction

There have been attempts to integrate the body as a learning device in foreign language learning. The first was by Asher in the late 60s. His teaching method, the Total Physical Response (TPR), required students to respond with actions to commands that were given as imperative sentences by the teacher (Asher & Price 1967). TPR was intended to support not only the understanding, but also the memorizing, of vocabulary items that can be learned through imperatives. Also, Asher pointed out that focusing on listening and action performance and not on language production corresponds to the natural sequence of native language acquisition (Asher 1977). Krashen & Terrell, well known among language teachers for their influential Natural Approach (Krashen & Terrell 1983), supported TPR as a learning technique for beginners because it is capable of involving learners in realistic language activities. However, despite its potential, TPR did not succeed in developing into an everyday learning tool for second language instruction. There are at least two reasons for this. First, Asher did not conduct empirical studies: He could not demonstrate that action has a greater impact on the acquisition of verbal information compared to audiovisual strategies. Second, when Asher developed his TPR, theories based on a universal grammar (Chomsky 1959) considered language learning to be an innate process (Fodor *et al*. 1974; Chomsky 1975). Accordingly, like mother tongue acquisition, foreign language was thought to emerge by mere listening and without tools of instruction because it results from innate processes (Feyten 1991; Krashen 2000). Explicit explanation and vocabulary teaching by any means, and therefore, also by action, were considered superfluous. Although there were other opinions in the field sustaining that child language acquisition and adult foreign language learning are fundamentally different (Bley-Vroman 1990), the mainstream followed the mentalistic view of a core grammar present in the learners' minds. This view implicitly ruled out the body as a possible learning device, as suggested by Asher.

The TPR used action as a teaching instrument. Note that action and gestures are not equal (Kendon 1981; McNeill 1992). In order to enact the word *to drink*, one can perform the action of drinking and drink some liquid. However, the gesture related to this word can also be simulation of drinking without glass and without liquid. Also, the word *to drink* can be illustrated by shaping a 'c' with a hand and raising it toward the mouth. In foreign language lessons, both can occur: action and gestures are used.

In the eighties and nineties, gestures came into play in foreign language instruction embedded in a broader framework of lessons involving drama (Mariani 1981; Schewe & Shaw 1993). Carels (1981) proposed the systematic use of pantomimic gestures in foreign language learning. Importantly, he suggested that these gestures should not only be performed by the teacher, but also by the learner, as a memory supporting strategy. He illustrates a two-step procedure. First, the teacher narrates the text and pantomimes vocabulary items that are unknown or difficult to understand. Thereafter, learners repeat the text and the pantomimes, in order to consolidate the acquisition of the novel words. Macedonia (1996) adopted a similar approach and described the use of iconic, metaphoric and deictic gestures in Italian lessons for German speaking university students. Particularly, she observed the beneficial effects of gestures on memory. However, these papers were merely descriptive and lacked empirical evidence for the use of gestures.

4. The Effects of Gestures on Memory for Foreign Language Words and Expressions

The first systematic study on the impact of gestures on memory for verbal information in a foreign language was conducted by Quinn-Allen (1995). She taught English-speaking students 10 French expressions (e.g., *Veux-tu quelque chose à boire?* 'Do you want something to drink?') by accompanying the expressions with illustrative, semantically related gestures typical of French culture.

For example, the gesture paired with the above sentence was performed by pointing the thumb toward the open mouth. The study showed that better results in retrieval were achieved over the short- and long-term, i.e. immediately after learning and after 11 weeks, if learners had performed the gestures when encoding the expressions.

In a 14-month longitudinal study, Macedonia (2003) worked on single word retention. She demonstrated that verbal items belonging to different word categories benefited from gesture use during learning. She trained university students to learn 36 words (9 nouns, 9 adjectives, 9 verbs and 9 prepositions) in an artificial language corpus. For 18 items, participants only listened to the word and read it. For another 18 items, participants were additionally instructed to perform the gestures proposed by the experimenter. Retrieval was assessed through cued recall tests at five different time points. The results showed significantly better retrieval in the short- and long-term for the enacted items.

In a study with 20 French children (average age 5.5) learning English, Tellier (2008) presented 8 common words (*house*, *swim*, *cry*, *snake*, *book*, *rabbit*, *scissors*, and *finger*). Four items were associated with a picture and four items were illustrated by a gesture that the children saw in a video and they thereafter performed. Enacted items were better memorized than items enriched visually by the pictures.

Kelly *et al*. (2009) trained 28 young adults on 12 Japanese verbs conveying common everyday meanings. The words were presented according to four modes: (i) speech, (ii) speech + congruent gesture, (iii) speech + incongruent gesture, and (iv) repeated speech. The results showed that participants memorized the largest number of words in the speech + congruent gesture mode, followed by the repeated speech mode, and the least number of words was memorized when they were accompanied by an incongruent gesture.

Another study by Macedonia & Knösche (2011) investigated the impact of enactment on abstract word learning. The words were learned while embedded in 32 sentences, each comprising 4 grammatical elements: subject, verb, adverb, and object. Only the nouns for the subjects were assigned concrete meanings. They indicated the actors. The remaining words were abstract. Twenty subjects participated in the study and learned according to two conditions. Words were either memorized audio-visually or enriched through a gesture. Gestures illustrating abstract words were arbitrary and had a symbolic value. Free recall and cued recall tests assessed the participants' memory performance at six time points. The overall results indicate that enactment, as a complement to audiovisual encoding, enhances memory performance not only for concrete but for also for abstract words (nouns, verbs, and adverbs). Moreover, in a transfer test, participants were asked to produce new (non-canonical) sentences with the words they had learned during training. Enacted items were recruited significantly more often than words learned audio-visually.

A study controlling for the type of gestures was conducted by Macedonia *et al*. (2011). They used a set of iconic gestures (i.e. creating a motor image and a set of meaningless gestures) providing mere sensorimotor input. Thirty-three German-speaking subjects were trained on 92 concrete nouns in a novel artificial corpus created for experimental purposes and based on Italian phonotactics.

Half of the items were encoded with iconic gestures (McNeill 1992). They depicted some aspect of each word's semantics and enriched the word with a plausible sensorimotor connotation. The other half of the items was learned with meaningless gestures. They could be small (shrugging one's shoulders) or large (stretching one's arms in front of oneself). They were randomly presented when the subjects read and heard the word and they changed at every trial. The results showed significantly better memory performance for iconic gestures than for meaningless gestures in the short- and long-term (after 60 days), indicating that enhancement does not come from pure physical activity complementing the verbal information.

The results of these studies suggest that performing a gesture when learning a novel word in a foreign language or in an artificial corpus significantly enhances the word's retrieval and delays forgetting compared to pure verbal learning. Moreover, there is evidence that gestures representing the word's semantics, or some feature of it, help to memorize better the word than meaningless gestures do.

5. Possible Mechanisms Underlying the Effects of Gestures on Verbal Memory

In the debate on the mechanisms underlying enactment, four main positions have emerged. The first position emphasizes the crucial role of the overt action performed by the learner (Engelkamp & Krumnacker 1980; Engelkamp & Zimmer 1985). According to this view, the physical enactment creates a motor trace in the memory representation of the verbal item. The second position assumes that doing things in a wider perspective (i.e. cognitive activities like spelling the word) can lead to better verbal memory (Cohen 1981, 1985). In the third position, imagery (i.e. a kinetic representation of the word's semantics created through action) is the factor leading to improved performance (Saltz & Donnenwerth-nolan 1981). According to the fourth position, the impact on memory is caused primarily by increased perceptual and attentional processes occurring during proprioception and/or when using objects to perform the action (Bäckman *et al*. 1986). Thus memory enhancement does not come from enactment itself, as the motor component is not crucial (Kormi-Nouri 1995, 2001). Rather, it is the multi-sensory information conveyed into a word that leads to deeper semantic processing and higher attention level (Knopf 1992; Knopf *et al*. 2005; Knudsen 2007).

Studies dealing with the beneficial use of gestures in foreign language learning explain memory enhancement in terms of depth of encoding. Quinn-Allen (1995) observed that gestures provide an elaborated context for language; this enables deep processing of the verbal items and thus durability of the information (Craik & Tulving 1975). In her study, Macedonia (2003) proposes the Connectivity Model of Semantic Processing (Klimesch 1994) to account for the high memorability of novel words learned with gestures. Accordingly, a complex code involving sensory and motor information is deep and so improves retrievability and resistance to decay. Tellier (2008) also addresses the question in terms of the depth of encoding due to multimodality; she refers to Paivio's

Dual Coding Theory (Paivio 1969, 1971; Paivio & Csapo 1969) and to a possible motor trace left by the gesture.

Kelly *et al*. (2009) argued that gesture helps to deepen the motor image and thus the memory trace of a novel word. Moreover, they theorize that gestures can convey non-arbitrary meaning that is grounded in our bodies, since speech and gesture are strongly interconnected systems. In the study by Kelly and colleagues, within the discussion of why gesture helps to better memorize foreign language words, the scientists overtly address the body as a tool capable of supporting memory processes.

In their study of learning words paired with meaningful iconic and meaningless gestures, Macedonia *et al*. (2011) find empirical evidence for the existence of both a motor trace and a sensory motor image connected with a novel word in a foreign language. More recently, Macedonia & Knösche (2011), investigated the impact of gestures on memory performance for abstract words learned in the context of sentences and proposed that performing a gesture when learning a word can fulfill two functions. First, it strengthens the connections to embodied features of the word that are contained in its semantic core representation. Second, in the case of abstract words such as adverbs, gesture constructs an arbitrary motor image from scratch that grounds abstract meaning in the learner's body.

With their variations in experimental design, the different studies have shed light on the manifold aspects of enactment. The positions above are not mutually exclusive. Gestures paired with novel words in a foreign language enhance attention compared to learning the words in less complex contexts such as bilingual lists. Also, words enriched with gestures are complex deep codes and therefore better retained than shallow codes (Wig *et al*. 2004). However, the question of whether enactment favors the retention of verbal information because of a motor representation or due to imagery processes could only be elucidated by neuroscientific experiments. In the next section, we will review research on the topic published in the last 30 years.

6. Sensorimotor Representation of Gesture in the Brain

The question of whether a motor trace is left as the representation of an enacted word (Engelkamp & Krumnacker 1980) has been investigated by using different neuroscientific methods. In an event-related potentials (ERP) study, Heil *et al*. (1999) trained participants to passively listen to or to perform accompanying actions to phrases with imaginary objects. On testing, participants' recognition of the enacted phrases scored better, and during recognition a larger fronto-central negativity was detected. The authors interpreted these results as indicating information processing in the motor cortices.

In a Positron Emission Tomography (PET) study, Nilsson *et al*. (2000) also tested the hypothesis that enacted items show more activity in motor cortices during retrieval compared to verbal encoding. They trained participants in three learning conditions. During verbal training, participants simply rehearsed the command. During enactment training, participants overtly performed the actions described by the commands. During imagery training, subjects were cued to imagine performing the described actions. The results showed that enactment significantly increased activity in the right primary motor cortex compared to verbal training. Interestingly, activity of the right motor cortex was also observed during verbal and imagery training.

Another PET study by Nyberg *et al*. (2001) examined brain activity in the motor cortices for verbally encoded, overtly enacted and covertly encoded items. Activity registered in motor and somatosensory areas during retrieval was common to enactment and covert encoding. These results provide evidence that both performing an action and imagining performing it recruit the same neural substrate.

In an experiment by Masumoto *et al*. (2006), participants learned action sentences according to three conditions: by enactment, by observation of an agent enacting them, and by observation of an object mentioned in the action sentences. After encoding, participants performed a recognition test, during which magnetoencephalography data were acquired. The experiment tested the hypothesis that enacted action elicited activity in the motor cortex. Interestingly, only the left primary motor cortex was statistically relevant (participants were all right-handed).

In order to clarify whether action itself (i.e. independently of its shape) works as a learning enhancer, Macedonia *et al*. (2011) conducted a study in which participants were cued to learn concrete substantives by accompanying them with either iconic or meaningless gestures. In the fMRI-scanner, participants performed an audiovisual recognition task of the words they had trained. In the contrast meaningless gestures versus iconic gestures, the latter produced activity in the dorsal part of the premotor cortex. This localization within the motor cortices was interpreted as being due to the fact that action performed during the training mainly involved distal movement. The dimension of activation in the left precentral gyrus was larger than in the right hemisphere (the iconic gestures were performed by right-handed subjects with their dominant limbs). However, the region of interest analysis of the premotor cortex demonstrated that recognizing words encoded through meaningless gestures also activated premotor cortices. Thus, verbal material paired with action during learning leaves a motor trace independently of the kind of gestures used and independently of the impact that the gestures have on memory.

7. Words are Connected to Images

More than three decades ago, Engelkamp & Krumnacker (1980) reasoned that the gesture accompanying a word is connected with an existing image of its semantics. Saltz & Donnenwerthnolan (1981) proposed that enactment is effective because it leads to the storage of a 'motoric image'. Recent neuroscientific research has helped to clarify the link between motor imagery and language. Experiments investigating spontaneous co-speech gestures and their representation in the brain have shown different time courses and brain activity patterns if speech is accompanied by matching or non matching gestures.

In an ERP study examining the impact of representative gestures accompanying speech, Kelly *et al*. (2004) showed participants videos of an actor speaking and gesturing. When talking, the actor produced gestures for the words tall, thin, short and wide in reference to objects present in the videos. Participants had to decide whether speech and gesture were congruent. Mismatching stimuli produced a larger right-lateralized N400, an indicator for semantic integration (Kutas & Hillyard 1980).

The sensitivity to semantic relations between gestures and words was similarly demonstrated in a priming experiment by Wu and Coulson (2007a, b). Participants had to judge whether the presented gesture-speech utterance followed by a related picture was either related to speech alone or to both speech and gesture. Here, again, the N400 component was smaller when the pictures were related to speech and gesture.

Over the years, the tight integration of speech and gesture has been documented in a number of ERP studies (Holle & Gunter 2007; Ozyurek *et al*. 2007; Bernardis *et al*. 2008). The results of these studies suggest that the link between speech and gesture is immediate and not modulated by attentional processes. Modulation by attention was recently investigated in a stroop task experiment (Kelly *et al*. 2010). Participants had to decide whether the gender of the speaker corresponded to the gender of the speaking person gesturing in a video. Even if the task to be performed was not to detect the (mis)match between gesture and language, when speech and gesture were incongruent, a larger N400 was produced and reaction times for the task to be accomplished were slower. Also, another ERP component, the P600, also called Late Positive Complex (LPC), peaking at about 600ms after stimulus onset, was observed as a component indexing the recognition of imageable words.

In their study, Klaver *et al*. (2005) presented subjects words of high and low imageability that had been previously controlled for word frequency. Behaviorally, subjects recognized concrete words better. In the ERP experiment, the main effect of imageability was indexed by a hippocampal P600. This correlate was interpreted as involvement of the hippocampus during processing of verbal information with high imageability. Other studies describe the P600 as a correlate associated with recollection of verbal information that is concrete (Scott 2004) and has high imageability (Rugg & Nagy 1989).

More recently, a study comparing timing and topographical distribution of ERP components when subject processed concrete vs. abstract words detected activity in visual association areas (BA 18 and 19) for abstract words (Adorni & Proverbio 2012).

Also, functional magnetic resonance imaging (fMRI) experiments have evidenced the existence of motor images related to verbal information. In a study by Willems *et al*. (2007) investigating the neural integration of speech and action, the authors used a mismatch paradigm. Participants were presented with sentences followed by iconic gestures that either matched or mismatched the preceding context. The conflict between language and gesture produced enhanced activity in the left inferior frontal cortex, the premotor cortex, and the left superior temporal sulcus. This activity was interpreted as an increase in the semantic load resulting from conflicting speech and action.

In a disambiguation paradigm, Holle *et al.* (2008) showed participants videos of a speaker uttering sentences (she touched the mouse) with an ambiguous word (mouse). The ambiguous part of the sentence was accompanied by either an iconic or a meaningless gesture. During sentence presentation, fMRI data were collected. Compared to meaningless gestures, the processing of iconic gestures revealed hemodynamic activity in the left posterior superior temporal sulcus (STS), in the inferior parietal lobules and in both ventral precentral sulci. Of particular interest is the response of the posterior STS. This cortical area is known to become active during multisensorial integration or when integration does not match expectations (Beauchamp 2005). The authors of the study attribute activation of the STS to the lack of meaning in the meaningless gestures.

In an experiment by Green *et al.* (2009), German speaking subjects were presented with short videos of an actor performing gestures and sentences while their brain activity was measured by means of fMRI. The accompanying gestures were either related or unrelated to the sentences, which were in German (familiar to the participants) or in Russian (unfamiliar). While speech accompanied by iconic gestures activated left occipital areas, speech with mismatching gestures engaged bilateral parietal and posterior temporal regions.

In another fMRI study, Straube *et al.* (2009) investigated memory for speech and gesture representations. Participants were presented with abstract sentences accompanied by video clips where an actor produced either meaningful metaphoric gestures, unrelated free gestures, or no gestures. After the training, participants were administered a recognition test. They performed better for sentences accompanied by meaningful metaphoric gesture. The results of the fMRI data analysis for the metaphoric gesture mode showed left-hemispheric activations in the inferior frontal gyrus, the premotor cortex, and the middle temporal gyrus. This left-lateralized activation pattern was interpreted by the authors as an indicator of semantic integration between speech and gestures. Interestingly, the metaphoric gesture mode showed significant correlations between memory performance and activity in the hippocampus. Several other studies have concentrated on the loci for integration between gesture and language (for reviews, see Willems & Hagoort 2007 and Willems *et al.* 2009). They indicated the posterior superior temporal sulcus, the middle temporal gyrus and the left inferior frontal gyrus as areas integrating information from different modalities.

Similarly to neurophysiological studies documenting larger N400 components, brain imaging experiments have revealed brain networks denoting disturbance and integration effort if words and gestures are incongruent. Although neuroscientific research up to now has mainly focused on language comprehension and not on memory effects of motor imagery, it has provided converging evidence that words do have a corresponding (motor) image in their semantic representation.

In foreign language learning, we found two experiments showing disturbance effects when words and gestures do not match. In an ERP experiment aiming to explore whether gestures create a deeper imagistic representation of words in memory, Kelly *et al.* (2009) trained participants on a Japanese word list comprising twelve common verbs, such as *to drink*. The verbs were learned with or without iconic hand gestures. The results demonstrated that words encoded with gestures were better memorized. Event-related potentials of words learned with gestures compared with words learned without gestures showed a larger LPC bilaterally, denoting recollection with high imageability.

In their study on foreign language learning, Macedonia *et al*. (2011) employed a set of iconic and a set of meaningless gestures. They were paired with the words to be learned. During the recognition phase in the fMRI experiment, words learned with iconic gestures activated premotor cortices, as described above, while meaningless gestures elicited activity in a vast brain network in both hemispheres comprising the cunei, the left posterior cingulate gyrus, the right anterior cingulate gyrus, the left inferior frontal junction area and the right rostrolateral prefrontal cortex. These regions orchestrate a network for cognitive control that possibly denotes conflict detection and effort to integrate information (Cole & Schneider 2007).

Although speculative, we reason that a single concept might comprise multiple images. They vary depending on the factors experienced by the subject. Motor images of a word like *car* represent the possible motions of cars but also pantomimes performed by a person producing some characteristics of a car (e.g., the shape). Thus, in the stroop-like experiments reviewed above, the mismatch possibly occurs between the internal image (i.e. the neural pattern created through learning), and the pattern of activity elicited through the perception of the presented stimulus.

8. Neural Representation of Words

Early theories of cognition considered concepts as amodal, symbolic entities (Fodor 1976, 1983; J.D. Fodor 1977), their meaning being referential and *somehow* connected to objects. As Meteyard *et al*. (2010) point out in their review, amodular theories of cognition had an Achilles' heel: The representation of how symbols refer to real things. The problem, although overtly recognized (Pylyshyn 1984; Fodor 1987), was never solved. The focus of these theories mainly resided in the structure of processes rather than in the content of symbols. However, without grounding (i.e. linking a symbol causally to its reference), it is hard to conceive how meaning could be established.

In the past decade, symbolic theories have been challenged by the advent of brain imaging techniques. The fact that merely listening to words like *kick, lick, or pick* (Pulvermüller 2005) or phrases like *press the piano pedal, bite the banana,* or *grasp the pen* (Aziz-Zadeh *et al*. 2006) activates brain motor areas controlling movements, respectively performed by leg, mouth, and hand, could not be accounted for in terms of symbolic theories on cognition (Simon 1981; Fodor 1983; Pylyshyn 1984). Similarly, if listening to words like *cinnamon* or *garlic* elicits activity in olfactory brain regions (González *et al*. 2006), even in the absence of real objects, it becomes clear that concepts, here expressed as words, are not amodal. Consequently, the word *garlic* must be tightly linked with sensory perception (i.e. with smell, taste, texture, color, etc). Also, action (e.g., peeling or mincing garlic, rubbing it on bread, and chewing it) can be part of the representation of the word. Thus, sensory and motor information related to *garlic* that has a representational role, constitutes the word's semantics (Gallese & Lakoff 2005). A word is not an abstract entity with a reference in the world; rather, a word is grounded in the perception and action a subject experiences (Kiefer & Spitzer 2001; Vigliocco *et al*. 2004; Barsalou 2008; Pulvermüller & Fadiga 2010).

From a neurobiological perspective, a word can be described as a network linking cell assemblies that code and process linguistic, sensory, motor (Pulvermüller 1996, 2001, 2002) and emotional (Vigliocco *et al*. 2009) features. In this view, words are represented in distributed networks with different topographies, including perisylvian areas and areas critically involved in processing perception and action. The extension and shape of networks change over time depending on the interaction the subject has with the world. During brain imaging experiments, stimulation activates cell assemblies processing stimuli in crucial cortical areas that are specialized for the task. However, as activity spreads within the network (McClelland & Rogers 2003), activity reaches assemblies that code features bound to the concept. This explains why simply hearing *garlic* activates not only auditory cortices but also olfactory areas. Similarly, hearing a sound related to finger actions elicits activity in motor areas associated with the hand (Hauk *et al*. 2006). Thus, there is clear evidence for a complex neural representation of a word that comprises sensorimotor components linked during learning.

9. Learning Words in a Foreign Language through Gestures

To our knowledge, there are no studies documenting the processes of acquisition of a novel word in a foreign language in terms of a functional network. However, on the basis of the literature reviewed, we reason that when people learn a novel word by merely listening to it or reading it, the neural representation of the novel word will be poor compared to a word in the native language. For the novel phoneme chain, most of the sensorimotor and emotional experience embodied in the corresponding word in the native language is lacking or, at best, only partially present. Pulvermüller (2002) proposes that there is activity in response to a novel word co-occurring with a known word in perisylvian regions, with extensions to extra-perisylvian cortex areas that code semantic features of the known word. We speculate that this could happen when learners acquire the word in the foreign language by listening to it and knowing its translation in the native language. Through frequent repetition, cell assemblies coding the novel phoneme chain would be active together with the sensorimotor network of the word in the native language. Finally, this correlated activity would strengthen the synaptic connections (Hebb 1949) between both words, and lead to the creation a larger network integrating the novel word within the semantic representation of the word in the mother tongue. However, this integration would be indirect as long as learners have not gain experience using the word and thus have grounded it in their body. From a neurobiological perspective, these networks represent the substrate of memory (Garagnani *et al*. 2007, Wennekers & Ay 2003). Thus, it is conceivable that if the integration is not driven by action and strong sensorimotor experience, the connections to the network in the native language are poor; hence memory is unstable.

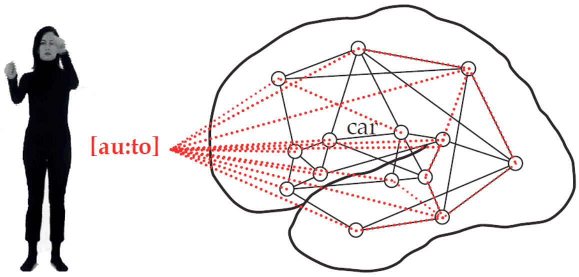

Figure 1: Schematic illustration of a possible word network representing the word car in the learners´ native language and the corresponding word in German Auto after acoustic learning. Note that the dotted lines represent indirect connections with the sensorimotor network of the native language (adapted from Pulvermüller 2002)

When learning a novel word by enacting it, the learner has a complex multimodal sensorimotor experience. It is conceivable that, depending on the kind of words and relative gestures, the process of embodiment is different. Gestures for action words like *to go* or *to give* reproduce the action itself. In this case, the novel phoneme chain possibly docks on networks representing the action itself. Thus, enactment reproduces and reinforces sensorimotor patterns created during native language acquisition. This might explain the strong effect of enactment on memory, especially for action words and phrases (Zimmer 2001b).

Gestures accompanying concrete words tend to be mostly iconic (Macedonia 2003). An iconic gesture might match internal (motor) images of the concept and create a strong connection to the novel word with a preexisting circuit that represents the concept.

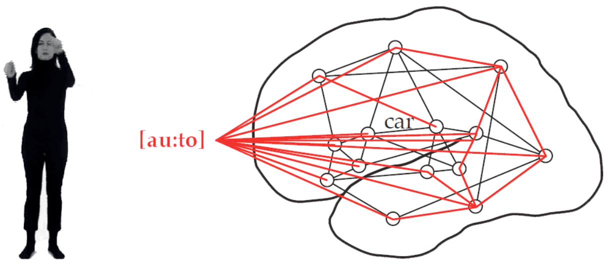

Figure 2: Schematic illustration of a possible word network representing the word car in the learners´ native language and the corresponding word in German Auto after enactment. The lines represent strong connections with the sensorimotor network of the native language (adapted from Pulvermüller 2002)

Also, the iconic gesture might support the so called 'concreteness effect'. This effect, fully demonstrated in the literature, mirrors the easier processability (Binder *et al*. 2005) and better memorability of concrete words (Allen and Hulme 2006; Fliessbach *et al*. 2006; Romani *et al*. 2008). The concreteness effect has been accounted for in terms of the Dual Coding Theory (Paivio 2006, 1971, 1986, 1991) and the Context Availability Model (Schwanenflugel *et al*. 1988). According to Paivio, words can have two modalities of representations: one is purely verbal and the other imagistic. Whereas abstract concepts lack the imagistic component and are primarily verbally represented, concrete words are represented in both modalities. This explains their advantage in processing and retrieval. The Context Availability Model postulates only one modality of representation for concepts. However, concrete words are better processed and retrieved because of the dense associative context in which they are embedded. Both proposals (i.e. the Dual Coding Theory and the Context Availability Model) put forward the idea that the cognitive advantage is grounded in richer representation of the word´s semantics. This view is also accounted for in neurophysiological research. ERP experiments have, in fact, demonstrated that concrete words elicit a larger N400 than abstract words (West & Holcomb 2000; Levy-Drori & Henik 2006). This ERP component has been reconducted to the activation of more extended, and hence, richer semantic networks.

However, abstract words also benefit from enactment learning. In their experiment, Macedonia & Knösche (2011) cued participants to perform arbitrary gestures accompanying abstract words. For abstract nouns they represented and embodied a motor image of the word, connected somehow with the word's semantics (i.e. in a more remote way than for concrete words). For instance, for the Vimmi word *sigule* 'theory', the actress in the video simulated the opening of a book in front of her in an interested way. Here the gesture might have made the concept more concrete, and hence, have taken advantage of the concreteness effect.

For other abstract nouns, gestures addressed some emotional component present in the neural representation of the word. For instance, for the word *boruda* 'sensation' the actress performed a gesture of astonishment. Her arms and mouth were wide open. According to Kousta *et al*. (2011) abstract words differ from concrete words in terms of embodied experiential information. Whereas for concrete words sensory-motor information is preponderant in their representation, abstract words statistically contain more emotional information. Enacting a word through a gesture expressing emotion possibly reinforces the emotional content and enhances memory for the item. However, how is emotional content to be understood in terms of brain circuits? 'Canonically', emotion is processed in limbic areas. Is this always the case? In an fMRI study by Moseley *et al*. (2012) when participants passively read highly abstract emotion words, not only language areas (Broca's region, Wernicke's region, and fusiform gyrus) and limbic structures became active, but also their premotor cortices. Particularly, inferior and dorsolateral motor areas processing face and arm related movements, respectively, were involved. The authors explain the data in terms of semantic networks representing not only the intrinsic emotional content of the words, but also motor programs used to express the emotions. It seems plausible that at least facial actions are a part of a circuit for an emotional word. Thus, if a 'meaningful' facial gesture accompanying an abstract concept represents some emotional component of its semantics, it could reinforce its embodied representation and therefore support memory.

Adverbs, another category of abstract words, also are better memorized if encoded with a gesture. In this case, the gestures used are arbitrary with no representative value. Adverbs like *already* or *still* serving primarily a grammatical purpose are difficult to relate to an image and their emotional content is poor. Thus, their representation in term of functional networks is hardly connected with sensorimotor information per se. This might also represent a reason for their low memorability. For function words, Pulvermüller (1999) proposed a more localized topography restricted to perisylvian areas. Gestures accompanying adverbs are thus arbitrary and have no semantic relationship with the words' semantics. These gestures thus create a motor image from scratch. They thus enrich the original representation of the word with a sensorimotor component not present before. This might explain the better retention achieved when adverbs are paired to arbitrary gestures during learning.

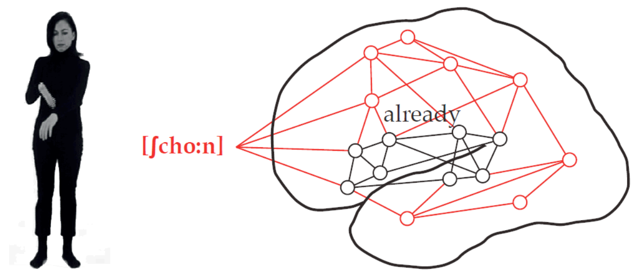

Figure 3: Schematic illustration of a possible word network representing the word already in the learners´ native language and the corresponding word in German schon after learning through enactment. Note that the original network in perisylvian areas is enriched with sensorimotor components provided by the arbitrary gesture (adapted from Pulvermüller 2002)

10. Why Gestures Enhance Memory

We have described how gestures may enrich the representation of novel phoneme chains of a foreign language and ground them in the body. We believe that learning words in a foreign language together with motor and multimodal information helps to create similar networks for the foreign language word.

Studies of foreign language word learning address the depth of processing as a factor that enhances learning (Macedonia 2003; Tellier 2008; Kelly *et al*. 2009). Pairing a gesture to a novel word makes the network more complex (i.e. deeper) by binding sensorimotor information to verbal information. According to Klimesch's Connectivist Theory on the structure of long-term memory (Klimesch 1994), it is the complexity of a code that leads to its better retrieval in memory. Thus, the factor enhancing memory when words are accompanied by gestures could be complexity. However, it should be investigated if, within the network, there are components driving the memory performance more than others. In fact, it is possible that motor information functions like a supramodal device with hub characteristics (Tomasi & Volkow 2011). As such, motor information could have hierarchical properties and affect memory more than other sensory components within the network.

Besides the neurobiological view of memory and on how words are grounded in the body, there are at least two issues that might play a role for enhanced verbal learning through gestures. The first is the synchronicity between word and gesture production. An fMRI study by Xua *et al*. (2009) has demonstrated that symbolic gestures and spoken language are processed by a common neural system mainly localized in the left hemisphere, in anterior and posterior perisylvian regions. It is possible that performing both language and gestures together when learning novel words, boosts the language system and stimulate memory structures.

Moreover, from an evolutionary perspective, language and action are tightly connected. According to a number of authors (Rizzolatti & Arbib 1998; Gentilucci & Corballis 2006; Tomasello 2008; Arbib 2009), language evolved from signs that our ancestors used in combination with vocalizations. Thus, gestures have scaffolded the emergence of a protolanguage. Because of the vast range of phenomena that have been demonstrated in neuroscientific research, particularly the mismatch effects appearing if language and gesture are incongruent, the evolutionary view has gained strong plausibility over the years. Hence, by accompanying novel words with gestures, learners assemble the two parts of an ancient communicative system. This might be beneficial for memory processes.

Second, imitation is another important issue connected to the use of gestures during encoding of foreign languages. In fact, if learners are instructed to perform a gesture they are presented with mechanisms of imitation and thus mirror neuron circuits might become active and enhance learning (Vogt *et al*. 2007; Vogt & Thomaschke 2007; Mukamel *et al*. 2010).

11. Implications for Second Language Instruction

When learning a foreign language, students usually read or listen to the verbal information they want to acquire. Traditional instruction makes wide use of listening and comprehension activities (Winitz 1981; Swain & Lapkin 1995). As homework, learners go through bilingual vocabulary lists and learn the words by reading them. Foreign language instruction is far from reconstructing the experiences we have when acquiring our native language. In fact, children make sensorimotor experiences by interacting intensively with their caregivers and their environment (Tomasello 2005; Kuhl 2010). Thus, it is no surprise that the outcome of the two learning processes is different with respect to memory. While under normal conditions it is unlikely that people forget words of their native language, adults learning a foreign idiom are plagued by forgetting what they have previously learned.

It has been demonstrated that multimodal learning helps to better memorize information (Shimojo & Shams 2001; von Kriegstein & Giraud 2006; Shams & Seitz 2008; von Kriegstein *et al*. 2008; Shams *et al*. 2011) and efforts have been made in foreign language teaching practice to enrich vocabulary with multisensory input by using flash cards (Barcroft 2009; Boers *et al*. 2009; Tonzar *et al*. 2009), videos (Sydorenko 2010), songs (Keskin 2011), and implementing them on novel technical devices such as mobile phones (Başoğlu & Akdemir 2010). However, a view linking the body and mind, considering the body in action as a learning tool, is still missing in foreign language instruction. Hence, we propose the use of gestures as a learning device that grounds foreign language in the body and thereby enhances memory.

This paper focuses on the impact of gestures memory for lexical items. In fact, the acquisition of lexical items is basic to language learning at any level. However, it is conceivable that gestures can also help to acquire morphological (Goldin-Meadow *et al*. 1995) and syntactic structures. In a German publication, Macedonia (1999) addressed both aspects when describing teaching practice in foreign language with gestures. Observations from classroom activities encourage the use of gestures for complex verbal morphology in Romance languages and for different kinds of combined clauses in syntactic contexts in Italian. Nevertheless, controlled laboratory research is lacking and is needed in order to collect empirical evidence for the use of gestures in these language domains.

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