The challenge of abstract concepts

Abstract

Abstract concepts (‘freedom’) differ from concrete ones (‘cat’), as they do not have a bounded, identifiable and clearly perceivable referent. The way in which abstract concepts are represented is becoming a topic of intense debate, especially due to the spread of the embodied and grounded approach to cognition. Within this framework, concepts derive their meaning from the same perception, motor and emotional systems that are involved in online interaction with the world. Most of the evidence favoring this view, however, has been gathered with concrete concepts. We argue that being able to explain abstract concepts is a crucial challenge that embodied and grounded theories need to address. The aim of this article is to offer a critical review of the most recent embodied and grounded theories on abstract concepts. Starting with theories that question the distinction between abstract and concrete concepts, we discuss theories claiming that abstract concepts are grounded in metaphors, in situations and introspection, and in emotion. Then we introduce multiple representation theories, according to which abstract concepts evoke both sensorimotor and linguistic information. We conclude discussing whether or not a single theoretical framework might be able to explain all different varieties of abstract concepts.

The challenge of abstract concepts

The challenge

What do we talk about when we talk about “love”? This question is difficult to answer for many reasons. An important one, though probably not one that makes for interesting literature, is that the word “love”, similarly to words referring to other commendable virtues like “honesty” and “justice”, cannot be easily pinned down to concrete and easily identifiable referents. Indeed concrete concepts, such as “table” and “cat”, typically have single, bounded, identifiable referents that can be perceived with our senses – for example, we can see and move a table, and we can see, caress and hear a cat meowing. In contrast, abstract concepts, such as “fantasy”, “freedom” and “justice”, do not have bounded, clearly identifiable and clearly perceivable referents, even if they might evoke situations, scenes, introspection and emotional experiences. This makes it harder to understand what we talk about when we talk about “fantasy”, “freedom” and “justice” than when we talk about “cats”, even if many different cats exist.

All concepts are highly dependent on context and are variable. However, there is less cross–cultural differences in the meaning of concrete concepts and they remain relatively stable throughout lifespan. In contrast, abstract concepts are not stable over time and are shaped by current life experiences and situation (Barsalou, 1987). Moreover, they are by far the most variable. For example, people agree more with others when required to define, produce associations or generate characteristics for “chair” than for “truth” or “love”. Furthermore, most concrete concepts can be inscribed into the two broad categories of man-made (e.g. “artefacts”) and natural objects (or living

and not living entities).(e.g., “furniture”, “animals”). Abstract concepts come instead in a great variety, as the difference between “number”, “opinion” and “philosophy” suggests.

The way in which abstract concepts and abstract word meanings are represented has been discussed within the literature for over 30 years. However, it is now becoming a topic of intense debate in psychological science, due to the emergence of the *embodied* and *grounded* approaches to cognition.Embodied and grounded (from now on embodied) approaches posit that cognitive processes are influenced by the kind of body that organisms possess.

According to these approaches, human concepts are “grounded” in perception, action and emotion systems (Barsalou, 1999, 2012; Borghi, 2005; Gallese & Lakoff, 2005). This means, for example, that according to the embodied viewthe concept of “cat” acquires its meaning by the internal simulation (re-enactment) of the physical and emotional experiences linked to seeing a cat, caressing it, hearing it meowing. Thinking of a cat or using the word “cat” both activate a simulation of the experience of a cat (Barsalou, 2009; Gallese, 2008). This simulation consists of the reactivation of the neural patterns active when we experience a cat; this helps us to interact with novel cats as we encounter them, forming predictions about what they will do next.

In the last 10-15 years researchers have collected a considerable amount of evidence in support of the embodied view. Many studies have clearly demonstrated that concrete concepts and words (e.g. "bottle", "cat") activate perceptual properties, actions and emotions. It is much more difficult to provide compelling demonstrationsthatabstract concepts as “freedom” and “justice”are embodied,as they do not have a clearly identifiable referent. Many proponents of embodied theories have acknowledged this difficulty but keep restricting their attention to a limited domain, mainly focusing on manipulable objects and action words. Unfortunately, this weakness has led others to suggest that embodied views cannot in the end explain the formation, use and representation of abstract concepts at all (e.g., Dove, 2009).

In this paper we intend to argue that abstract concepts and words pose a challenge that cannot be further postponed. The challenge consists in demonstrating that not only concrete but also abstract concepts are grounded in perception, action and emotional systems.

This challenge is crucial for a simple but pivotal reason: the capability of abstraction and the ability to use abstract concepts represents one of the most sophisticated abilities in possess of our species. For example, we use abstract language to characterize phenomena that we feel more distant from us (Snefjella & Kuperman, 2015). Any theory of higher order cognition would be incomplete if unable to explain how we make use of abstract concepts.

It could be argued that for some current theories abstract concepts and words do not constitute a problem. For example, distributional theories of meaning can easily explain how abstract concepts are represented (Andrews et al., 2014). Because according to them meaning is captured by associations between words, these theories do not need to posit any difference between concrete and abstract words. However, in our view the explanation offered by distributional theories of both concrete and abstract concepts representation is only partial, since distributional theories are unable to solve the "symbol grounding problem" (Harnad, 1990): to be understood and avoid circularity, symbols need to be grounded in their world referents: For example, a complete theory of concepts in our view needs to take into account that a word as "deer" refers to a specific animal, endowed with peculiar perceptual and behavioral characteristics.

In sum: the challenge to provide an explanation of abstract concepts representation is crucial for our understanding of "higher order" human cognition. Importantly, such a challenge does not concern only a subset of theories, i.e. the embodied ones, since non embodied theories fail to provide a thorough explanation of concepts overall. However, the increasing popularity of embodied theories has rendered the challenge to explain abstract concepts and words an urgent one. Being able to understand how abstract concepts can be grounded in perception, action and emotional systems will not only strongly underpin the theoretical explanatory power of embodied theories but also widely increase their acceptance among researchers. We will present the current debate on abstract

concepts and words representation (for recent reviews, see Borghi and Binkofski, 2014; Pecher et al., 2011). In addition, we will focus on the most recent embodied theories on abstract concepts, critically evaluate recent evidence supporting them, and discuss their strengths and their limitations. Since the literature on abstract concepts and words is heterogeneous, this review does not aim to be exhaustive. Specifically, we will not treat in detail neuropsychological and brain imaging evidence, unless the results of a study is crucial to test or support a specific embodied theory (for a recent review on insights from neuropsychology on abstract concepts, see Hoffman, 2015). Finally, even if numbers and emotions represent important domains of abstract concepts, investigation of specific issues related to numerical cognition or to conceptualization of emotions is beyond the scope of this work. We will not review the emotion literature, nor the literature on numerical cognition and number processing. We will refer to emotion and number concepts only when treating studies on wide samples of abstract concepts, which include, among others, emotional and numerical concepts. As to the theories we decided to select and to handle, while we will only briefly overview classical theories on abstract concepts, we have decided to describe all the embodied theories proposed from 2004 to 2014-5, illustrating if possible all evidence in their favor. For very influential theories, as the Conceptual Metaphor one, we did not review all evidence since this would require an entire paper. Instead, we chose to refer to some very influential studies as well as to reviews of studies. From the review we hope it will appear that the debate on abstract concepts is not internal to embodied theories, that it involves distributional theories of meaning as well and that new exciting direction of research will emerge by bridging these two approaches.

Classical theories of abstract concepts

Concreteness and abstractness effect: a tale of two theories

Concrete words have an advantage over abstract ones: they are processed faster and more accurately in a variety of tasks such as lexical decision (i.e deciding whether a word exists or not),

naming and recall. During the 80's and 90's, two classical theories on abstract concepts proposed different explanations of this "concreteness effect". These are Context Availiability Theory and Dual Coding Theory.

According to the Context Availability Theory **(CAT)** (e.g., Schwanenflugel et al., 1988; 1992), concrete concepts are strongly associated to a reduced number of contexts,while abstract concepts are weakly associated to a much wider range and number of contexts. Indeed, context availability ratings, where participants are given a word, which is then assessed on how easy is for them to think of associated contexts, have demonstrated that greater context availability of concepts is strongly and positively correlated with concreteness ratings (i.e. how concrete is a given word, on a 7 point scale: Schwanenflugel et al., 1988). Therefore, using the CAT theory, the weaker association between abstract concepts and context explains why, when presented with isolated words, participants have better recall of concrete than abstract concepts: processing abstract words is slower because activating their context requires more effort.

An alternative theory which has become far more influential on our understanding of abstract concepts is the Dual Coding Theory (DCT) (e.g., Paivio, 1986; Paivio et al., 1968).This theory explains the concreteness effect with the higher imageability of concrete compared to abstract concepts. According to DCT all concepts are represented through the verbal system, but only concrete concepts are also represented through images. Put simply, only concrete concepts have a direct connection with images. For instance, the abstract concept of "religion" evokes images only through the mediation of concrete concepts, such as "church".

This theory posits a negative relationship between abstractness and imageability: the more abstract a concept is, the less it is imageable. However, this intuitive relation is problematic since, as recently highlighted (Kousta et al., 2011), the two dimensions are correlated but not equivalent. An additional area of contention, shared by both CAT and DCT, is the weak evidence base for'concreteness effect', which is the advantage of concrete over abstract words,. While some research did not find this effect (Barca et al., 2012), others found a reversed effect (Kousta et al.,

2011).. Kousta et al. (2011) controlled word valence and found an opposite “abstractness effect”, i.e. a processing advantage of abstract over concrete concepts. Building upon Kousta’s research (2011), Barber et al. (2013) used stimuli which were controlled for valence, context availability and imageability. They found an abstractness effect in response times but, like Kousta et al, found a reverse concreteness effect in ERPs.

Similar to concreteness effect, the research on the validity of both CAT and DCT is conflicting.For instance, Connell and Lynott (2012) (see also Moffat et al., 2015) asked participants to rate concepts not only in terms of concreteness and imageability, but also in terms of auditory, gustatory, haptic, olfactory properties and visual strength. In contrast to CAT, they found that concepts characterized by higher perceptual strength, which CAT would categorise as concrete, evoke a higher number of contexts compared to concepts with low perceptual strength. This study also strongly contradicts DCT.The results showed that imageability is not strongly correlated with perceptual experience, since it seems to reflect more the ease of image generation, rather than whether concept was abstract or concrete. In addition, imageability ratings appeared to be visually biased while perceptual strength was able to predict the results of lexical decision and naming tasks better than contextual availability and imageability.

Furthermore, there is conflicting evidence regarding the neural underpinnings of concrete and abstract words, which has led to much debate in the literature. For example, some brain imaging research supports DCT showing that processing concrete words led to more bilateral activation than processing abstract words (e.g. Binder et al. , 2005; Sabsevitz et al., 2005), which are more left-lateralized (e.g., Binder et al., 2005; Fiebach & Friederici, 2004), while other studies contradict this research as they found evidence of an opposite neural pattern (Pexman et al., 2007; Kiehl et al., 1999).

However it is vital to note that the inconsistencies in this research area (e.g. concreteness vs. abstractness effect, left- vs. right lateralization in the brain) (for a review see Borghi & Binkofski, 2014, chapter 5) could be due to methological differences between studies. Current research has used different methods of selection for stimuli: for example, some studies selected abstract words on the basis of the imageability ratings,others based their selection on abstractness/concreteness ratings, while other studies selected abstract words on intuitive bases. Therefore it is possible that comparability of findings has been reduced by these inconsistences in selection of stimuli.

It is clear from the evidence above that future research needs to develop validated criteria for the selection of abstract concepts which should then be universally implemented. Inconsistent evidence poses a serious threat to this area of research and may led to the acceptance of unsound theory or rejection of valid theories.

Embodied and grounded theories of abstract words

The issue of how abstract concepts are represented has been focusof intense debate over the last decade, mainly due to the increasing diffusion of embodied theories of cognition (Barsalou, 2008; Borghi & Caruana, 2015; Wilson, 2002). Our review will now focuson how researchers adopting an embodied perspective address the problem of abstract concepts representations. We will cover the main current proposals, evaluatethe supporting evidence,while highlighting their strengths and limitations (see Table 1).

INSERT TABLE 1 ABOUT HERE

Within embodied theory research, academics are still divided into two schools of thought: one groupfocuses on the similarities between concrete and abstract concepts and words, while the other group emphasizes their differences. The latter either argue for a sharp distinction between concrete and abstract concepts, or view them on a continuum which spans from less abstract to very abstract

concepts (Wiemer-Hastings et al., 2001; Wiemer-Hastings & Xu, 2005).The idea of a continuum is the most widely accepted by most researchers.

One influential view which posits that abstract and concrete concepts are profoundly different comes from neuropsychology. According to this view, concrete and abstract concepts are characterized by qualitatively and structurally different kinds of information (Crutch & Warrington 2005; 2007; 2010): while concrete concepts mainly rely on categorical similarity relations (e.g. "theft-burglary"), abstract concepts primarily rely on semantic associations (e.g. "theft-punishment"). This distinction is derived from single-case studies on double dissociations: patients with semantic refractory access dysphasia showed greater interference for abstract words organized by associative relations, while the opposite pattern was found with concrete words. This distinction is not only found in individuals with cognitive impairments, but alsoin healthy participants (see e.g. Crutch, Connell & Warrington, 2009). Dunabeitia et al. (2011) found that healthy individuals tended to fixate more and earlier on pictures associated with abstract words than with concrete words (e.g. "nose-smell" compared to "baby-crib"). Hence associative relations are seen as more important for abstract concepts.

However, the evidence obtained both within clinical and general populations is controversial. Failure to replicate results of Crutch and Warrington (2005) with aphasic patients has challenged the hypothesis that abstract and concrete words differ in terms of the conceptual relations they evoke (e.g., Hamilton & Coslett, 2008; Hamilton & Martin, 2010). Moreover, some recent studies with healthy populations have contradicted the findings of Dunabeitia et al. (2011) as they did not find any activation of associative relations by abstract concepts. In addition, they could not prove that concrete concepts evoke categorical relations. For instance, Geng and Schnur (2015) asked Chinese-English bilinguals to match a Chinese auditory-presented word with one among more visually-presented English words. This study found that related words are processed faster than unrelated words, but categorical relations (e.g. "idea-attitude") always lead to a better performance compared to associative relations (e.g. "math-examination"). From these results, it could be

concluded that abstract and concrete appear to be represented similarly both in terms of categorical and associative relations (see also Marques and Nunes 2012, for a similar conclusion).

Although there is conflicting evidence for the existence of a 'marked distinction', there is a possible valid reason for these differing results. Crutch and Jackson (2011) recentlysuggested that the relationship between concreteness and categorical and semantic associations is not binary but rather graded. Therefore the range of results in the literature may actually provide evidence that these associations are on a continuum. Drawing on this conclusion, this review will now concentrate on embodied cognition studies adopting this idea of a continuum spanning from concrete to abstract items. The idea of a continuum presents a further important insight: that no real dichotomy exists, since even concepts that are generally qualified as concrete own some abstract components and viceversa. An example of this, is the concept "cent" or "euro".It is mostly concrete and its referent has specific perceptual characteristics, as a given size, color, weight, but at the same time it possesses an exchange value that cannot be easily pinned down to the concrete aspects of its referent (see Guan et al., 2013).

Strong embodiment: Concrete and abstract concepts do not differ

According to some embodied theories, concrete and abstract concepts do not substantially differ because they are both grounded in sensorimotor and emotional systems (e.g., Chen & Bargh, 1999; Connell & Lynott, 2012; Glenberg et al., 2008a, 2008b). The advocates of this perspective seek to demonstrate that the arousal of perceptual states, actions and emotions is not solely limited to concrete concepts, but is also possible for abstract concepts. Embodied theories which support this perspective utilize evidence on the ACE (Action-sentence Compatibility Effect, Glenberg & Kaschak, 2002), on the approach-avoidance effect (Chen & Bargh, 1999), and on force dynamics (Talmy, 1988).

The ACE shows that, when a sentence implies action in one direction (e.g. the sentence “give the cards to somebody”implies action away from the body), the participants are slower in judging that the sentence makes sense if they are required to respond performing a movement in the opposite direction. This effect is equally present for both concrete and abstract transfer sentences (e.g., “give the cards” and “give the responsibility”). This behavioural evidence suggests that the same action schema underlies representation of both concrete and abstract information (Glenberg et al., 2008a, 2008b).

Neuro-cognitive results using Transcranial Magnetic Stimulation (TMS) complement these behavioral findings, as they observed higher Motor Evoked Potentials for transfer sentences than for non transfer ones. The absence of a difference between sentences related to transfer of objects (concrete) and of information (abstract) indicates that in both cases the motor system is activated (Glenberg et al., 2008a). These findings on ACE effects also apply to sentences involving time shifts. Sell and Kaschak (2011) evaluated the sensibility of sentences by asking participantsto press a button that required a movement toward or away from their bodies The results from this study showed that responses away from the body were faster with sentences involving the future, responses toward the body with sentences involving past events. It should be noted that these findings only occurred for large time shifts (months) (Sell & Kaschak, 2011). Further evidence thatconcrete and abstract concepts do not substantially differ is provided by the Approach-Avoidance Effect. This effect states that that positive words (e.g. “gold”, “sunshine”) evoke an attraction movement while negative words (e.g. “garbage”, “virus”) a rejection movement, regardless whether they are abstract or concrete (Chen & Bargh, 1999).

Studies of cognitive linguistics on force dynamics also provide converging evidence with ACE and Approach-Avoidance Effect. According to Talmy (1988), events, be they physical, psychological or social, can be viewed as oppositions between conflicting forces, for example, between an agonist and an antagonist force (e.g. “The ball kept on rolling along the green”; “John can’t go out of the house”; “She’s got to go to the park”). Force dynamics state that abstract and concrete events rely

on the same force mechanisms. The only difference between these events is thatthe agonist tends more toward rest or tends to perform less‘‘physical’’ actions within abstract events when compared with concrete events (see for a thorough review, see Pecher et al. 2011). In line with this view, research using a sentence sensibility task showed that primes given by two shapes, that interactedfollowingthe same force dynamics pattern, evoked faster responses than two shapes that did not follow the same pattern (Madden and Pecher, 2010, reported in Pecher et al., 2011); as predicted by Talmy (1988), the results were the same with concrete and abstract sentences.

Strengths and limitations.

In sum, evidence discussed so far is based on sound and compelling results, obtained both through behavioral and TMS studies. However, there are strengths and limitations to these studies and the evidence can be used to claim, either that abstract concepts are grounded like concrete ones, or that abstract and concrete concepts do not differ. Both of these interpretations will now be discussed.

Abstract concepts are grounded like concrete ones. The evidence reported here is useful to demonstrate that also abstract concepts activate perception and action. This finding allows us to use an embodied approach to cognition to explain abstract concepts. However, this evidence has a possible limitation: it is difficult to foresee whether it can be extended to account for all abstract concepts. For example, ACE has been found with concrete and abstract transfer sentences, e.g. sentences referring to exchange of objects vs. of information, with sentences referring to past and future events, and also with sentences referring to increasing or decreasing quantities (e.g. Guan et al., 2013). Yet, it is difficult to think that it can apply to all domains in which abstract concepts exist. Similarly, current research suggests thatApproach Avoidance-Effect can be found with a variety of words (e.g. Förster & Strack, 2006;Freina et al., 2009; Eder & Hommel, 2013; Neumann & Strack, 2000; Seibt et al., 2008; van Danzig et al., 2008; for a recent meta-analysis on approach avoidance and affective stimuli in response times tasks, see Phaf et al., 2014).

However, these results are limited to words or stimuli characterized by a positive or negative valence, or to novel words built in a way that, to be pronounced, the same kinematics used during deglution or expectoration (inward vs. outward movement) is reproduced (Topolinski et al., 2014). There are significant gaps in experimental results inspired by the theory of force dynamics which warrant further investigation, but it is difficult to foresee whether evidence based on force dynamics can be extended beyond the domain of event concepts.

Concrete and abstract concepts do not differ. This second claim is in our view not justified by the evidence we reported. First of all, it is universally acknowledged that it is statistically unsound to infer that two concepts (e.g. abstract and concrete) can be equated with one another, simply from the absence of differencesin performance. Second, people tend to evaluate and use differently concrete and abstract concepts - for example, they rate “justice” as more abstract than “bottle”. Third, an increasing amount of behavioral, neuropsychological and neuroimaging studies has demonstrated that these two kinds of concepts are differently processed and recalled. For all these reasons, we suggest that a thorough theory of abstract concepts should not only assume that differences between concrete and abstract concepts exist, but also be able to explain why these differences occur. There has been a recent interesting variation to this view that both abstract and concrete concepts are grounded in perception and action systems.Guan et al. (2013) provided evidence for this, using EEG and finding ACE effects with both concrete and abstract concepts (for a further ERPs study see D’Angiulli et al., 2015). The authors explain their results arguing that both concrete and abstract words activate the motor system. However, while concrete concepts are grounded in specific sensorimotor simulations, as they reactivate previous experiences with the category members, abstract concepts are mainly grounded in the process of prediction. Examples introduced by the authors provide weight to this argument and clarify their point: the concept of “banana” activates the simulation of eating it, which may involve seeing its shape and color, peeling it, and tasting it (vision, action, taste). Even if it is mainly concrete, the concept of “banana” has an

abstract component as well, consisting in the prediction that eating it will reduce hunger. On the opposite site of the coin, an abstract concept such as "democracy" involves some concrete components (e.g. the simulation of voting), but most of its meaning derives from abstract components linked to predictions (e.g. concern for human right). Importantly, both kinds of components are grounded and refer to different characteristics and mechanisms of the motor system.

Compared to other views, this proposal has the advantage to be based on a mechanism underlying abstract concepts and to refer to a specific theory on how the brain works: it is based on forward models, which would characterize the motor system and have the function to anticipate the sensory consequences of actions (Wolpert et al., 2003; Glenberg & Gallese, 2012). However, there are gaps and limitations within this proposed explanation. Even if the theoretical framework is clearly outlined, it is not fully clear to what extent the predictions derived from this view differ from those stemming from the view according to which abstract concepts, similarly to concrete ones, are represented simply in terms of their content, and are grounded in the motor system. Furthermore, even if, as argued by Guan et al. (2013), many abstract names are "names for processes" (e.g. democracy relies on the processes of counting and voting), this view is likely not sufficiently encompassing to be applied to all varieties of abstract concepts.

Concrete and abstract concepts are different

It is clear that there is contradictory evidence within the literature regarding how different or similar concrete and abstract concepts are. Therefore, this review will now concentrate on the most recent theories which provide evidence for the differences betweenabstract and concrete concepts and discuss and evaluate the mechanisms and cognitive components that might be responsible for such differences.

Conceptual Metaphor Theory (CMT).

The first theory we will outline isthe Conceptual Metaphor Theory (CMT), which proposed that abstract and concrete concepts differed in the 80's (Lakoff & Johnson, 1980, 1999; Lakoff & Núñez, 2000),and is likely the most influential embodied theory on abstract concepts. CMT is based on observations on language use. This theory posits that when talking about abstract concepts people tend to use metaphors derived from concrete domains: for example, we say that "life is a journey". According to CMT metaphors do not only concern the way in which we use language, but also the way in which we think of the world. While initially the most part of the collected evidence derived from linguistics, CMT has benefited from empirical evidence obtained without linguistic stimuli, mainly deriving from behavioral studies (for reviews, see Gibbs, 1994; 2006; for examples of very recent work e.g., Casasanto & Bottini, 2014; Sato et al., 2015). Researchers who favor the CMT, argue that abstract concepts are understood by placing them in concrete knowledge domains, and that this mapping guarantees their grounding. Important abstract concepts are understood through multiple conceptual metaphors: for example, communication can be intended as sending ideas from one container (head) to another, as well as feeding someone with thoughts (Lakoff, 2014). Recent behavioral evidence supporting this view shows that abstract notions are understood with reference to a concrete concepts. Examples of this is found in multiple studies: for example, the abstract notion of "category" is understood with reference to the concrete concept of "container"(Boot & Pecher, 2011), "similarity" relies on the concept of "closeness" (Boot & Pecher, 2010), and "power" is comprehended referring to the vertical dimension (Zanolie et al., 2012; Lakens, Semin & Foroni, 2015).

One concept which has been object of more extensive studies is the concept of time: the underlying rationale is that, as time is an abstract concept, it can be intended by mapping it on the more concrete concept of space (e.g., Boroditsky & Ramscar, 2002; Casasanto & Boroditsky, 2008; see Flusberg et al., 2010, for a connectionist model). Imagine presenting participants with an ambiguous question: "Next Wednesday's meeting has been moved forward two days. What day is

the meeting now that it has been rescheduled?“ Answering “Monday” implies adopting an ego-moving perspective, while answering “Friday” a time-moving perspective: in the first case forward is in the direction of motion of the observer, in the second case forward is in the direction of motion of time.Boroditsky and Ramscar (2002) showed that people, who are at the beginning of a train journey, of a lunch line, or people who had just flown in, tend to respond using an ego-moving perspective, while when they are at the end of a trip, or of a line, use a time moving perspective, i.e. refer forward to earlier (i.e., Wednesday). This result indicates that space and time are strictly interwoven.The perspective adopted varies depending on the spoken language of the individual. Lai and Boroditsky (2013) demonstrated this by asking the same ambiguous question.This study found that while English speakers tend to adopt an ego moving perspective and Mandarine monolinguals a time moving one, bilinguals tend to shift between the two perspectives.

The proposition that we usethe concrete concept of space to reason and understand the abstract concept of time seems to be confirmed by the observation that in language the relationship between space and time is asymmetrical: we tend to speak about time in terms of space more often than we speak about space in terms of time. Casasanto and Boroditsky (2008) demonstrated the asymmetrical relationship between space and time showing that distance affects duration, but duration does not influence distance. They presented participants with non linguistic stimuli, such as lines and dots on the computer screen, and asked them to reproduce their displacement or their duration. For example, they presented growing lines for different durations. To reproduce the length of the lines, participants had to click with the mouse first on the starting point and then on another point after they thought the distance was the same as that of the observed line; to reproduce their duration, they had to click twice with the mouse on a given point after a given amount of time. They found that spatial displacement affected estimates of duration, but the opposite was not true, in keeping with the idea that space and time are asymmetrically related.

That space and time are strictly related has been further evidenced by a variety of cross-cultural studies as well. Depending on the culture, time metaphors can refer to quantity or to distance: for

example, in English people typically say “a long meeting”, in Greek “a large meeting”. Consistently with the metaphors used, English-speakers time estimates are more influenced by length than by quantity, while for Greek speakers the opposite is true (Casasanto, 2008).

The way in which we think of the temporal flow, from the past to the future, is influenced by culture as well as by the characteristics of our own body (e.g. Bergen & Lau, 2012). For example, for English speakers time is conceptualized in terms of the front-back dimension (the past is back, the future is ahead of us), while the frequent use of vertical metaphors in Chinese has led Mandarine Chinese people to conceive time also in terms of the vertical dimension: the past is up, the future is down. This difference influences responses to implicit tasks, such as priming tasks. Boroditsky (2001) found that Chinese Mandarine speakers were faster to confirm that March comes earlier than April after being exposed to a prime where pairs of objects were vertically displayed (e.g. a black and white worm-ball). In contrast, English native-language speakers were faster when they were shown the same two objects (e.g. the black and white worms) disposed horizontally, and bilinguals had an intermediate performance. The results of this study were very influential to embodied cognition advocates, however it must be noted that these findings were criticized as they were not always replicated by future studies (see Chen, 2007).

A recent study challenged the assumption of CMT, that there is an unidirectional influence from sensorimotor experience to metaphors, and not viceversa (Slepian & Ambady, 2014). The authors asked participants to provide weight estimates of old and of new books after learning new metaphors concerning weight and time. If the participants had been exposed to the metaphor that the past is heavy, they tended to perceive old books as heavier, while if they had been exposed to the metaphor that the present is heavy, they perceived new booksas heavier. Thus, these results indicate that novel metaphors can influence sensorimotor processes, which suggests that the influence between metaphors and sensorimotor states is bidirectional. These results challenge CMT’s assumption of unidirectional influence and requiresit to be extended to account for such

bidirectional relationships. However, those in favor of CMT would likey counter this by arguing that the influence of metaphors on abstract concepts is asymmetrical, not unidirectional.

It should be noted that time is not only related to space, but also to number, and number is related to space, as evidenced by a growing body of research (for a review, see Winter et al., 2015; see also Jones, 2015). Lakoff and Nunez (2000) have demonstrated that to speak about numbers, people tend to use spatial metaphors: for example, they use the metaphor of numbers as point in a line, or metaphor of arithmetic as motion along a path (Nunez & Marghetis, 2014). The close interaction between space, time and number is also revealed by the similarities between the so called Spatial Numerical Association of Response Codes, or SNARC effect (Dehaene, Bossini et al., 1993), and the Spatial Temporal Association of Response Codes, or STEARC effect (e.g. Ishihara et al., 2008, Santiago et al., 2007; Torralbo et al., 2006).

The SNARC effect reveals that people of Western societies associate small numbers with the left and large numbers with the right, as well as subtraction to the left and addition to the right (see also Lugli et al., 2013; Anelli et al., 2014). The STEARC effect shows that people tend to associate the future to the right and the past to the left. However, time does not always flow from left to right because the writing direction influences people's temporal concepts. For example, Spanish people are faster in responding with the right to words referring to the future and with the left with words referring to the past, but the opposite is true for Hebrews (Santiago et al., 2007; Flumini & Santiago, 2012; Ouellet et al., 2010; see also Fuhrmann & Boroditsky, 2011).

The relationships between concepts of space, time and number has been object of important recent debates (e.g. Lynott & Coventry, 2014; Santiago & Lakens, 2015; Winter et al., 2015). Two contrasting proposals highlighting the strict link between space, time and numbers have been advanced.

The ATOM view is a general theory of magnitude that predicts interactions between all domains involving magnitudes, while CMT predicts interactions between space-number and space-time, but not necessarily between number and time. Furthermore, CMT posits that space representations are

used asymmetrically to represent number and time, while no such asymmetry is assumed by the ATOM view. These two views have always been considered as contrasting views, likely also due to the different disciplines in which they developed (ATOM in neuroscience,CMT in linguistics and psychology) and to their different focus. However, it is possible that they can be bridged: according to Winter et al. (2015), ATOM is better at explaining low level associations which are independent from language, while CMT is more precise in accounting for higher level associations mediated by language.This suggestion should be further investigated as it would have interesting implications for our understanding of abstract and concrete concepts.

Strengths and limitations.

In sum, compared to other theories, CMT has a number of advantages, which have contributed to its standing as the most influential embodied theory on abstract concepts. The most important strength of this theory is that it proposes a mechanism underlying the building and use of abstract concepts, rather than arguing that a specific content characterizes them. However, the application of such a mechanism is limited for content reasons. Using concrete-abstract mappings to understand the meaning of abstract concepts is possible only if domains adequate to be mapped are available. For example, one could question the adeguacy of the space-time mapping. The very abstract idea of a general container for all objects – that is, SPACE - neither is simple nor is direct, and it is debatable whether it can be considered as concrete.

Furthermore, it is not clear whether it is always possible to find concrete domains corresponding to abstract ones. For example, it is difficult to think of concrete domains where to map abstract concepts such as “philosophy” or “linguistics” (for a similar critique, see Dove, 2009; Goldman and De Vignemont 2009). Furthermore, it should be better clarified whether the mapping always succeeds, and how it occurs. Consider metaphors such as “a sea of people”: one crucial aspect of the sea is that it is liquid, but this aspect is not captured in the metaphor formed. Similarly, which aspects of the notion of “journey” would be used to conceptualize “life”, or why is the notion of

"power" conceptualized only in terms of hierarchical structure/verticality? In addition, metaphors help to detect similarities between concepts, but not differences: for example, life is not really a journey: how do we represent what of life is not a journey? And how about the fact that, while time flies, space does not (see e.g. Galton, 2011, for such a critique)?

Even if metaphors can take part in the representation of abstract concepts, it is not necessarily so; furthermore, the metaphorical mapping likely contributes to the understanding of abstract concepts, but it hardly exhausts their meaning, since metaphors cannot substitute direct experience (Barsalou and Wiemer-Hastings, 2005). For example, neuronal regions dedicated to time processing, not to space, should be activated during comprehension of time concepts (Kranjec and Chatterijee, 2010). These questions remain unanswered, and cast doubts on the generalizability of the CMT.

Another important limitation of this view (see Dove 2009, for such a critique) concerns conceptual development: children start to use metaphors rather late, and their comprehension of metaphors remains quite poor until 8-10 years of age (Winner et al. 1976), while at around 2 years around 10% of the words they use are abstract ones. How can this developmental trajectory be reconciled with the idea that we use metaphors to understand abstract concepts (Murphy, 1996; 1997)?

Finally, while an increasing body of linguistic and behavioral evidence supports the CMT, the neural evidence is still lacking. For example, it is unclear how CMT could explain the results of brain imaging studies showing that differences between metaphorical and abstract concepts exist (e.g. Aziz-Zadeh et al., 2006; Boulenger et al., 2009; Boulenger et al., 2012; Desai et al., 2011; Rüschemeyer et al., 2007). Furthermore, recent evidence argues against a strong metaphoric account. Bardolph and Coulson (2015) recently recorded EEG as participants moved marbles either upwards or downwards while reading spatial words. They compared the effects of words where the spatial associations were literal or metaphorical (e.g., "ascend", "descend" vs. "inspire", "defeat"). They found early (200-300 ms after word onset) positive ERPs for literal words together with congruent movements, while metaphorical words influenced ERPs only 500 ms after word onset. Such a result suggests that participants were sensitive to the association between abstract concepts

and vertical space in line with the metaphor "Good is up", but that such an integration does not occur in a fast and automatic way. In conclusion, the influence of CMT is clear, and while there is evidence supporting this theory, there are a number of gaps which we have highlighted that warrant further investigation.

Introspective and situational properties.

According to this view, compared to concrete concepts, abstract concepts rely more on introspection and on social and institutional aspects of situations (Barsalou & Wiemer-Hastings, 2005). This view is supported mainly by behavioral evidence, based, for example, on tasks in which participants are asked to generate the characteristics of a given concept.

For example, Barsalou and Wiemer-Hastings (2005)asked participants to produce characteristics of three abstract (e.g. "truth"), concrete (e.g. "bird") and intermediate concepts (e.g. "farm"). Concepts were either presented in isolation or preceded by a short scenario. For example, for the concept ''truth,'' the situation described a boy who told his mother that he had not broken a vase, and his mother believing him. This study found that both concrete and abstract concepts evoke properties related to situations. However, with concrete concepts the participants tended to focus on entities within situations (e.g. "car-wheels"), while abstract concepts focus ''*on the social, event, and introspective aspects of situations (e.g., people, communication, beliefs, and complex relations).''* (p. 152) (e.g. "true-difficult to discuss after Postmodernism", "justice-beaurocratic"). Wiemer-Hastings and Xu (2005)provided further evidence of this with a larger sample of concepts and reported that the concrete ones elicited more item properties, whileabstract concepts evoked more introspective properties. They also observed that, while both concrete and abstract concepts activated situations, abstract concepts focused more than concrete concepts on the social aspects of situations.

These results highlight that context availability per se is not peculiar of abstract concepts, since also concrete concepts evoke situations (see Moffat et al., 2015, for convergent evidence). However,

even if abstract concepts do not evoke a higher number of contexts compared to concrete concepts, it is possible that the contexts they activate are more complex, since they involve more events and actions (Borghi et al., 2011; Borghi & Binkofski, 2014; Connell & Lynott, 2012). This would be in line with two unique aspects of abstract concepts. One unique aspect of abstract concepts is their "relational" nature (Gentner, 1981; Markman & Stilwell, 2001; Barsalou, 2003), i.e. the fact that they are often "*characterized by their links to external concepts rather than by intrinsic properties, unlike most concrete concepts."* (Wiemer-Hastings & Xu, 2005). The second unique characteristic is that their members are more diverse and heterogeneous than those of concrete concepts, thus the context can play an important role to connect them, acting as a sort of glue. A similar mechanism operates with members of superordinate level concepts (e.g. "animal", "vehicle"), which is the presence of a common and broad context, where many exemplars can coexist (e.g. "land" for animals). The presence of such a context facilitates more the recognition of superordinate categories members than those of basic concepts (e.g. "car", "dog") (Borghi, Setti & Caramelli, 2005; Heit & Barsalou, 1996; Murphy & Wisniewsky, 1989).

However, there are limitations to these conclusions and evidence obtained in a recent dissertation (King, 2013) cast doubts on the relational character of all abstract concepts, and alsohighlights that context impacts processing of only some kinds of abstract concepts. Participants were presented with short scenarios, then they were asked to perform a lexical decision task on abstract words which were not mentioned during the scenario description. The scenario had a different impact on different kinds of abstract concepts: it namely facilitated processing of "relational" abstract concepts (e.g., ''ignore,'' which describes an act, an actor, a patient being ignored, but no internal feeling), but it did not influence activation of mental states (e.g., ''depressed'').

Roversi, Borghi and Tummolini (2013) provide evidence which supports the introspective and situational view but alsolimits its explanatory capability to some kinds of abstract concepts. They asked participants to generate properties of concrete and abstract concepts of three different kinds: artefact, institutional and social concepts (e.g. "screwdriver-poetry"; "signature-ownership"; "party-

friendship"). They found that situations play an important role in characterizing abstract concepts. Their results also indicate that the distinction between abstract and concrete concepts was marked only in the case of social concepts, in which concrete concepts elicited more specific spatial and temporal relations, while abstract concepts evoked more general situational relations (e.g. "friendship-infancy") and free associations (e.g., "friendship-pool"). Importantly, this study also demonstrated that expertise influences the produced features. Further studies with experts of different domains should investigate the hypothesis that, the more abstract a concept is, the more expertise has an influence, since the correlational structure of the environment plays a minor role.This would imply that the concreteness or abstractness of a concept is not absolute, but it is also relative to the practice of the subject who uses such a concept.

Strengths and limitations.

Similar to many of the theories evaluated within this review, this theory has strengths but also gaps in relation to its applicability and explanatory power.This theory, which proposes thatabstract concepts activate introspective and social-situational components, has the advantage to be rather general and intuitively it can apply to a wide range of concepts, from mental states to purely abstract concepts to social ones. However, as we have seen the role played by context and by introspective properties led tovariation in function of the content of specific concepts. A further limitation which weakens the validity of this theory is that, so far, evidence favoring this view is mainly confined to property generation tasks (Pecher et al., 2011), and further research is needed in its support.While this theory seems to focus on explicit aspects of introspection, it is possible that implicit aspects characterize some form of internal grounding (Frith, 2012).The main limit of this view, however, is that the mechanisms of this internal grounding have not been fully elucidated. For example, it could be hypothesized that, the more concepts are abstract, the more they require internal grounding (and possibly, even not necessarily, some forms of talking to oneself), or that the more they are abstract, the more they need a complex context to put together the varied and sparse

category members.These are only two of the possible interpretations, therefore it is essential that further research is carried out to determine and evaluate the underlying mechanisms.

Rolf Zwaan (2015) built upon Barsalou and Wiemer-Hasting's view on abstract concepts and situations. He suggested that abstract concepts play a double role during discourse processing. They can assume an anaphoric function or a cataphoric function. This duality depends on whether longer parts of text are read or whether the abstract word is displayed early on in the discourse. When enough contextual information is provided, an abstract term such as "justice" activates a sensorimotor simulation. This simulation is then linked with symbolic representations, that work anaphorically as "pointers to previously formed situational representation". Extending this proposition further, consider instead the expression "Now justice is served". This expression is characterized by a high level of ambiguity, since it is not yet clear to which context it will be associated. In such a case, the abstract concept can work cataphorically to provide a focus to help textual comprehension, similarly to what pronouns do. The sensorimotor system, activated once the abstract word is encountered, would be quickly disengaged to integrate further sensorimotor information. The concept would thus work as "a placeholder in an active state in working memory", which can help to integrate later acquired sensorimotor information (Zwaan, 2015). The proposal is interesting, and it points out that concepts can differ depending on whether they are presented in isolation or not, and when they are introduced in a discourse.

However, there is a limitation to this explanation: even if the author presents it as an extension of the view according to which contextual information is less focal for abstract than for concrete concepts (Barsalou & Wiemer-Hastings, 2005), its relationship with multiple representation views is not fully fleshed out. Zwaan (2015) appears to assume that an interplay between sensorimotor, emotional and linguistic information occurs, at different moments in time. This perspective would be in line with the multiple representation theories.Thesetheories state that both sensorimotor and emotional and linguistic information co-occur in abstract concepts representation (see also Zwaan, 2014).

Affective Embodiment Account (AEA).

A third perspective we will evaluate is Affective Embodiment Account (AEA) and how it provides evidence that abstract and concrete concepts differ. AEA is a new theory which hypothesizes that abstract concepts evoke more emotions compared to concrete ones (e.g.Vigliocco et al., 2013; Kousta et al., 2011). The AEA view of abstract concepts, outlined by Kousta et al. (2011; see also Kousta et al. 2009) and by Vigliocco et al. (2013), proposes that abstract and concrete concepts differ in terms of the experiencesthat characterize them. While sensorimotor experience is more crucial for concrete concepts, affective experience and emotional development is more important for abstract concepts. Emotional development is presented as the basisfor the acquisition of an abstract vocabulary: AEAproposes that emotions can provide a bootstrapping mechanism which favors the acquisition of abstract words (e.g. Vigliocco et al., 2013). AEA theorists argue that this is demonstrated by the fact that emotional abstract words are learned earlier than neutral abstract words. To illustrate and explain these conclusions, the behavioral and brain-imaging evidence supporting it will be evaluated. These studies provide evidence that, for example, abstract words typically receive higher ratings for emotional associations and that areas involved in emotion processing are engaged during processing of abstract words (e.g. Vigliocco et al., 2014).

Kousta et al. (2011) used a large sample of abstract and concrete words, controlled for a variety of dimensions as familiarity, concreteness, abstractness, context availability (see CAT theory), imageability (see DCT theory) and age of acquisition. Words were also controlled for mode of acquisition (Della Rosa et al., 2010; Wauters et al., 2003). Mode of acquistiondetermined whether the word was acquired perceptually(e.g. interacting with the object it refers to;“bottle”), linguistically (e.g. listening to explanations;“philosophy”) or with a mixture of both modalities (e.g. being shown a picture and explained the word meaning;“tundra”). The authors found an advantage in lexical decision of abstract over concrete words. That is,once imageability and context availability were controlled for, the concreteness effect was substituted by an abstractness effect.

This same abstractness effect was found in regression analyses of lexical decision response times for a large sample of words (n. 2330).

The advantage of abstract over concrete words can be explained by the difference in valence between concrete and abstract concepts: Kousta et al. (2011) therefore proposed that affective and emotional information has a major weight in characterizing abstract words. They concluded that, because context availability and imageability were kept constant, neither CAT nor DCT can account for their results. Even if DCT recognizes the importance of emotions (Paivio, 2007; 2013), the presence of emotional connotations for non-emotional words would derive from their link with imagistic representations. Thus, they should be more frequent with concrete than with abstract concepts (see Vigliocco et al., 2013). In addition, given that modality of acquisition was kept constant, they argue that differences in activation of linguistic information do not exhaust the difference between concrete and abstract concepts andthat emotions play a major role in abstract concept representation. An interesting finding that should be noted is that when the effect of valence was removed, the advantage of abstract words was still maintained in accuracy. This might be due to the role played by linguistic information for abstract concepts. Furthermore, in a recent ERPs study with stimuli controlled for imageability, context availability and valence, the abstractness effect was replicated with response times but a reverse concreteness effect was obtained with ERPs (Barber et al., 2013). A further recent ERPs study with a lexical decision task with concrete and abstract verbs of different valence revealed that the emotion related EPN effect, i. e. an early posterior negativity effect associated with attention to word meaning, emerged earlier for concrete than for abstract verbs (Palazova, Sommer & Schacht, 2013; see also,

fMRI results further support this view. Vigliocco et al. (2014) performed an fRMI study with a lexical decision task and stated that, while concrete and abstract concepts activated the visual processing system involving occipital, temporal and subcortical areas, only abstract concepts engaged the rostral anterior cingulated cortex (rACC). rACC plays a regulatory role during emotions processing. However, the conclusions drawn by Vigliocco et al. (2014) were questioned

by Skipper and Olson (2014) who argued that abstract words had higher valence than concrete words. Hence rACC would respond to valence, not to abstract words. Controlling for valence Skipper et al. (2014) found that the right STS and right temporal pole were the only regions that remained exclusively responsive to abstract concepts.While they confirmd that the rACC region responded to emotional valence, they found no difference between abstract and concrete stimuli. Instead the opposite effect was identified in that the rACC responded more to concrete words than to abstract ones.

Further evidence partially favoring the AEA was collected with patients with neurodegenerative diseases. Catricala' et al. (2014) submitted the same task to patients with Alzheimer's disease (AD) and with primary progressive aphasia (sv-PPA) using both concrete and abstract words. For abstract concepts patients were required to perform 3 tasks, which were then validated with Italian healthy subjects and AD patients (DeCAbs battery, Della Rosa et al., 2014) identifying 5 different categories (traits: e.g. "weakness"; actions: e.g. "seduction"; emotions: e.g. "fear"; social concepts: e.g. "friendship"; cognitions: e.g. "ideal"). Tasks included a sentence completion task in which participants had to add a missing word (e.g., "At the end of the war, the two countries signed an agreement to keep the ---peace"), a multiple choice verbal matching task in which a definition was presented and participants had to find a matching word among a series of words (e.g. "an event that cannot be clearly and rationally explained": "mystery", "plot" - semantically related word, "solution" - word opposite in meaning, "identification" – word semantically related to the opposite meaning) and an association task, matching a word with 3 possible targets (e.g. "friendship-bond", highly associated; "embrace", low associated; "color", distractor). Overall, results showed that AD patients differed from controls in all tasks with concrete and abstract items, while the sv-PPA group differed from controls in all concrete tasks but only in the sentence completion task for abstract concepts, that is, only in production and not in comprehension tasks.

The authors deepened their analysis by categorising abstract concepts into two types: social concepts and emotions. They demonstrated that sv-PPA patients were impaired only in social concepts, and AD patients in all abstract concepts with the exception of emotion concepts.

Strenghts and limitations.

Overall, evidence favoring the AEA view is based on results obtained with different methods, from behavioral studies to fMRI ones. One conclusionis evident, that is the importance of emotions for abstract concepts.The AEA researchers have also identified a bootstrapping role played by emotions to facilitate learning of abstract concepts. They add weight to this conclusion byarguing that emotion development precedes language acquisition. However, this could be said for other cognitive abilities as well, for example novelty detection (see Crutch et al., 2013).

The AEA view, however, has three potential limitations which have serious implications. Firstly, the evidence supporting it is not fully consistent. For example, ERP studies revealed a dissociation between an abstractness effect in RTs and a concreteness effect in ERPs. A very recent study in which facial muscle activity was measured during visual word recognition found a valence effect in the m. corrugator supercilii only with concrete and not with abstract words (Kuenecke, Sommer, Schacht, & Palazova, 2015). This clearly contrasts with AEA, which would predict the opposite result. Secondly, the role of valence does not seem to account for all the variance, thus it cannot offer an exhaustive explanation of the mechanisms underlying abstract concepts (see previous discussion of the results by Kousta et al.,2011).Thirdly, it is possible that the results obtained are biased by the presence, within the sample of abstract concepts, of emotional concepts. Altarriba et al. (1999) (see also Setti and Caramelli, 2005) contend that emotions represent a subset not to be included within abstract concepts and propose that a trichotomy between abstract-concrete-emotional words exists rather than a simple abstract-concrete dichotomy.

Consider the issue from an embodied perspective. Emotions can be seen as either a peculiar or a separate subset within abstract concepts, for which an embodied explanation is more

straightforward and intuitive than for other abstract concepts, because they are typically associated with specific bodily expressions/states. Emotions can be seen as more abstract than sensorimotor experiences. However, it has been shown that the mechanisms underlying their representation is the same, and are based on simulation and re-enactment of the situations experienced while interacting with the world (Wilson-Mendenhall et al., 2011). While such mechanisms may also play a role in explaining purely abstract concepts, they may not be sufficient at fully explaining them.

In sum: all emotional concepts are to a certain extent abstract, but it not clear whether all abstract concepts have affective/emotional connotations. Kousta et al. (2009) demonstrated that valence is not a characteristic limited to emotional words, but that it can be extended to many concepts. The claim that all emotional concepts are evaluated as abstract is certainly plausible. However, the contention that emotional valence increases with abstractness needs to be corroborated by further investigation.

The two last theories evaluated here share a common strength.They do not characterize abstract concepts in terms of what they miss, but in terms of their specific characteristics.Unfortunately, they also share a potential limitation. Data collected so far convincingly demonstrates that abstract concepts evoke more introspective and situational aspects, as well as more emotions. However, this result can be linked to the specific content of the concepts included in the database. For example, introspective properties might be more frequently evoked by abstract mental state concepts, such as “meditation” or “thought”, than by other abstract concepts such as “situation” or “event”. It is certainly important to distinguish concepts on the basis of their content, but it iseven more important to identify the mechanism underlying abstract concept formation and use,as well as what mechanism becomes more active the higher the abstractness level of concepts is. There are a number of merits to these theories, but they require further investigation to conclusively prove their conclusions as well as to address the weaknesses in their explanatory ability.

Multiple representation theories

Multiple Representation Theories of abstract concepts represent a valuable novel addition to current thinkingand appear to be a promising research avenue. Researchers who endorse this perspectiveclaim that, even if abstract concepts are embodied and grounded in perception, action and emotion, they also evoke a network of associate words. They also state that both sensorimotor and linguistic information is involved in the representation of concrete and abstract words, but they are differently distributed depending on type of concept: perception and action information is more important for concrete concepts, linguistic information for abstract ones.

Specifically, this review will focus on four Multiple Representationtheories that are currently influential, or have the potential to do so: the LASS (Language And Situated Simulation) view (e.g., Barsalou et al., 2008), the representational pluralism view proposed by Dove (2009; 2011; 2014), the WAT (Words As social Tools) view (Borghi, 2013; Borghi & Binkofski, 2014; Borghi & Cimatti, 2009), and the grounding and sign tracking proposal by Prinz (2002, 2012). Each theory will be illustrated and evaluated usingcurrent literature.

LASS (Language And Situated Simulation).

The first Multiple representation theory discussed is LASS and itproposes that multiple systems underlie our conceptual knowledge. LASS focuses on the linguistic and the simulation systems, which continuously interact. The clearest way to explain this viewpoint is through illustration, here the example of the word ”cat” will be used.Whenwe arepresented with the word “cat”, we first activate the linguistic system recognizing the word form and producing associated words, such as “dog”, “Siamese”, etc. We thenstart to ground the concept, for example visualizing the cat and re-enacting our interaction with it.

From this example, it can be seen that according to LASS theory, when we perceive words, the linguistic system is engaged to categorize them. During a linguistic task, such as lexical decision, the activation of linguistic forms peaks earlier. This happens in line with the encoding specificity

principle (Tulving &Thomson, 1973), according to which recall is most effective when information available at encoding is also present at retrieval. Importantly, at this level words are processed only in a shallow way. When the simulation system is involved, processing is deeper, in line with the idea that, compared to words, images access more directly the conceptual system (Glaser, 1992; see also Paivio, 1986). After word recognition, the simulation system is activated, i.e. the brain simulates the sensorimotor and mental states active during interactions with the referents of the word. Word associations (e.g. "dog-dog's bed") can thus provide a shortcut, allowing fast access to conceptual information (Barsalou et al., 2008, and converging evidence: e.g., Pecher & Boot, 2011; Louwerse & Connell, 2011; Connell & Lynott, 2013).

Put simply, according to LASS, the words work as "pointers" to the object, entity, situation they refer to. Property verification and fMRI research (review in Barsalou et al., 2008) has provided evidence for activation of the simulation system which occurs in parallel with the linguistic system but slightly more slowly. Simmons et al. (2008) conducted an fMRI study where participants performed a silent property generation task. Then, in a subsequent scanning section, they underwent two localizer tasks. In the first they were asked to produce word associations for different kinds of concepts (e.g. common objects as car, mental states as guess, abstract concepts as extension etc.), in the second to imagine a situation containing the concept. The early phases of word generation activated the same brain areas involved during the first localizing task, i.e. areas typically involved during linguistic tasks, as the left inferior frontal gyrus (Broca's area) and the right cerebellum.The late phases of word generation activated instead the same brain areas involved during the second localizing task, i.e. brain areas that are typically active during mental imagery as precuneus and right middle temporal gyrus.

Although these findings are novel and very compelling, there are some caveats that need to be noted. Given that fMRI has a scarce temporal resolution, further research on timing would complement and further the predictions of LASS. Most importantly, even if the reported results provide evidence that the linguistic system is engaged earlier than the imagery system, this does not

necessarily imply that meaning is activated only later, during activation of the simulation system, as the LASS theorists suggest. The activation of the Broca's area (see Rizzolatti & Craighero, 2004, for a review) could instead be proof of the activation of the motor system to prepare for a situated action.

In addition,LASS is not specifically aimed at explaining abstract concepts. In principle, one could conclude from its principles that, while concrete concepts activate the simulation system, abstract concepts activate the linguistic one. However, it must be noted that this conclusion is not proposed by LASS but rather a logical conclusion that has been drawn from evaluation of LASS research.In constrast, LASS theorists claim, on the basis of fMRIevidence (Wilson-Mendenhall et al., 2013) that both concrete and abstract concepts activate a mixture of simulation and linguistic information, which are differently distributed depending on the task.They also argue that different brain areas are activated depending on the conceptual content.

Wilson-Mendenhall et al. (2013) asked participants to think deeply about an abstract concept (e.g. ''convince''), then they were asked to verify whether it applied to the picture of a scene (e.g., a politician speaking) presented after. This study showed that the brain areas related to the content of the word were active, and that concrete and abstract words did not differ in the activation of linguistic information. For example, the concept "convince" activates brain areas related to mentalizing, the concept "arithmetic" areas related to numerical processing. However, the absent activation of linguistic information can be biased by the fact that processing a word in relation to an image differs from processing it in the context of other words, and such a control condition was not present.

To summarize, the LASS view argues for "multiple representation" of both concrete and abstract concepts, stating that that each concept, be it concrete or abstract, activates different brain areas depending on its content. It is the task, not the kind of concept, that determines a higher engagement of linguistic vs. sensorimotor areas. For example, lexical decision tasks, that require to simply

decide whether a word exists or not, activate more the linguistic system, while imagination tasks activate more the simulation system.

Strengths and limitations.

The LASS theory is important because, to our knowledge, it is the first fully embodied theory that recognizes the importance for concepts not only of perception, action and emotions but also of language.Compared to the perspectives we have previously outlined within this review, LASS has a further strong advantage which sets it apart: it identifies a mechanism underlying conceptual representation, i.e. the parallel - but also slightly different in time - activation of the linguistic and sensorimotor system. However, such a mechanism is not specifically applied to the representation of different kinds of concepts but rather to the adopted task.

One final potential limitationof LASS, is that itargues that we do not need to process the meaning of words when we are performing simple linguistic tasks. In this way language is simply used as a shortcut to access meaning, and it is implied that some linguistic tasks do not allow access to meaning. This is contradicted by research which demonstrates that access to meaning is very fast, as it can occur 150 ms after word onset (e.g. Hauk et al., 2004).

Representational pluralism**.**

The second Multiple Representation theory presented here is Representational Pluralism. This theory was proposed by Dove (2009, 2011, 2014), and unlike LASS, is specifically devoted to the explanation of abstract concepts. In its original formulation this view argued that, while concrete concepts could be explained through an embodied view, abstract concepts could not (Dove, 2009). This theory has evolved and Dove (2011, 2014) now proposes that both abstract and concrete concepts are embodied, although to different extents. However, this view can be considered as a hybrid one, since it combines embodied and non embodied aspects. Dove is namely committed to

representational pluralism, and proposes that to account for the representation of abstract concepts we must leave room to some amodal representations.

Dove's theory relies heavily on Paivio's (1986) DCT, and can be considered as the attempt to to bring back to the forefront some important aspects of DCT by adopting an embodied framework. Dove clarifies that his theory departs from Paivio's view as he takes an embodied stance, proposing that perceptual symbols (Barsalou, 1999) rather than mental images are the basic units of both verbal and non-verbal representations. Perceptual symbols are perceptual experiences that involve all senses and can be combined as symbols do. These symbols can be multimodal, schematic, and they are not necessarily conscious. However, it appears that the dualistic stance present in Paivio's research is still present here, regardless of whether its supporters wish to acknowledge it.According to Dove, linguistic representations are embodied but only to a certain extent. They are embodied because they rely on sensorimotor simulations, but they acquire meaning not because of this form of embodiment, but because of their relations with other words. In this sense, this view is close also to distributional statistic views, according to which meaning is derived from associations between words (e.g. Andrews et al., 2014).

The importance of language defines what abstract concepts are, allowing them to be distinguished from concrete concepts. Language plays an essential role as it empowers our cognitive capabilities by serving as a medium of thought thanks to its combinatorial characteristics (Dove, 2011, 2014). According to Dove, when we acquire language, we acquire a new and powerful representational system, which interacts with other embodied systems, but does not overlap with them. This system consists of simulations that can be selective and partial, and do not involve forms of inner speech, since simulations can be completely unconscious. Language in his view is "*is an internalized amodal symbol system that is built on an embodied substrate."* According to him, it would be quite difficult to provide a fully embodied account of syntactic, morphological and phonological structure: even psycholiguistics accounts that posit significant interaction between comprehension and production systems (such as Pickering & Garrod's theory, 2013) are not fully embodied, since

they generally rely on intermediate representations that work as a bridge between production and comprehension (Dove, 2013).

Although Dove does not directly produce evidence to support his theory, he discusses recent evidence that demonstrates the importance of imageability for conceptual processing. He reports studies on double dissociations showing that, while left hemisphere damage leads to a selective semantic impairment for high imageable words, the opposite case is also observed. Furthermore, he discusses ERPs studies showing a larger and more anterior N400 for abstract compared to concrete words, which would suggest that different systems are employed for the two kinds of words. His conclusions are further evidenced by fMRI studies which have reported a higher engagement of superior regions of the left temporal lobe and inferior regions of the left prefrontal cortex for abstract compared to concrete words, and right hemisphere or bilateral activation in the case of concrete words. Dove notes that while the evidence he uses clearly shows that two different neural systems are engaged (e.g. Adorni & Proverbio, 2012), it is compatible with both the view that linguistic representations are modal or amodal, and further research is needed to disentangle this complex issue.

Dove (2015) further contributed to the debate surrounding embodied cognition by suggesting that abstract concepts pose three different problems to embodied cognition, for which different solutions can be available. The first problem he notes is generalization, which is the problem of how we are able to represent information that goes beyond our experience. The second issue is the problem of flexibility, which arises because it is possible that embodied representations are activated differently, or at different level of depth, depending on the context and task. The third and final challenge is the problem of disembodiment: the "embodied" nature of abstract concepts needs to be demonstrated, and represents a challenge for embodied cognition. All three problems pertain to both concrete and abstract concepts, but are particularly urgent and marked for the latter.

However these issues are not without solutions and each theory can be suitable to handle and solve different problems. Consider for example the emotion-based AEA theory: while it partially solves

the problem of disembodiment, showing that also abstract concepts are grounded in bodily states, it has more difficulties in handling the problems of flexibility (why should emotional systems be differently activated depending on the task and context?), of generalization (e.g. how to account for the formation of high level superordinate concepts, like “animal”?), and in explaining why sensorimotor experience is so crucial for some concepts and less for others.

Strengths and limitations.

The theory proposed by Dove has many advantages, among which the important recognition of the role played by linguistic experience for conceptual processing. However, similar to many theories presented within this review, further research is required to provide conclusive evidence in favour of this theory. This limitation is particularly marked for this theory as it is not directly supported by empirical work, even if the author illustrates and discusses convergent evidence. Furthermore, much of the behavioral and neuroscientific supporting evidence he reports relies on the important role of imageability. However, it has been recently shown that imageability is correlated but cannot be conflated with abstractness (e.g., Kousta et al., 2011; see above). An additional limitation is that this theory focuses on concept representation in adults, without considering how concepts are acquired. Furthermore in its different formulations it remains ambiguous as to the role played by amodal and perceptual symbols.

Another limitation of this theory, is that Dove initially claimed that abstract concepts are represented through amodal symbols (Dove, 2009), then he argued that abstract concepts do activate sensorimotor simulations, but this is not the way in which they acquire their meaning (Dove, 2011), and claimed that language learning would lead to the acquisition of a "new dis-embodied semantic system". In this respect, the differences between this view and the fully embodied WAT proposal, which will be discussed later within this review, should be further clarified. At a general level, the two theories partly overlap, since both claim that concepts can either be mainly associated with non-linguistic experience of the world or with experience of

language. Furthermore, the conception of language as an instrument that extends thought capabilities is fully compatible with the WAT view and it helps clarifying why language is helpful to represent abstract concepts. However, the two theories differ in their level of embodiment and in the room they leave for amodal representations. According to Dove (2011), "*My account differs from Borghi and Cimatti's because it holds that the acquisition of language creates a new dis-embodied semantic system, one that has many of the properties usually associated with the amodal symbol systems favored by traditional cognitive science. In other words, natural language on my view is not merely another source of information about the world but is also another way of thinking about the world*." (Dove, 2011). While we fully appreciate the idea that language can contribute to improve our thinking capabilities, in Dove's proposal we do not understand why, once he accepts that perceptual symbols exist, he still wants to leave room for amodal representations and does not accept that language can be a fully modal and embodied system. We believe indeed that also grounded symbols, and not only amodal ones, possess combinatorial properties and can exhibit productivity (Barsalou, 1999).

WAT (Words As social Tools).

WAT (Words As social Tools) (Borghi & Binkofski, 2014; Borghi & Cimatti, 2009; Borghi, 2013) proposes that concepts are couched in representations that derive from both perceptual/motor and linguistic experiences. Similarly to the LASS theory, it is a fully embodied view, since it maintains that sensorimotor simulations need to be activated to grasp meaning.

We will however consider this a weak embodied view, similarly to LASS, because it argues that not only sensorimotor but also linguistic areas are involved to represent the meaning of abstract concepts.

According to WAT both concrete and abstract concepts are embodied. At the same time, grounding in sensorimotor systems is not sufficient in the case of abstract concepts. In contrast to other

theories emphasizing the role of language, WAT considers not only the importance of word associations to explain meaning, but also focuses on the holistic linguistic experience, emphasizing the role of the social dimension in word acquisition. Language is thus intended as a mode of participation in our word (see Irwin, 2015, for developing this notion referring to the philosophy of Merleau-Ponty, in an enactivist perspective). Both concrete and abstract words are seen as social tools that help us to interact with the others and with the physical and social environment (along the same line, a more radical recent theory directly inspired by WAT, the WAC, proposes that words "do something" as they work as cultivator of other minds, see Schilhab, 2015a, b). There are four main tenets of WAT and these will be evaluated in light of recent evidence (for an overview of the theory, see Borghi & Binkofski, 2014).

The first principle of this theory is that different acquisition modalities characterize concrete and abstract concepts (e.g. Bergelson & Swingley, 2013; Borghi et al., 2011; Granito et al., 2015). This implies that given that abstract concepts do not have single, concrete referents but have sparse and diverse referents, they will be acquired both through sensorimotor experience and through linguistic input. In addition, the scaffolding role of the physical environment is less powerful to support the acquisition of abstract compared to that concrete concepts: hence, it is language that plays a scaffolding role. Literature on modality of acquisition (MoA: Wauters et al., 2003) shows that some words are acquired mainly through sensorimotor experience (e.g. "bottle"), other words - the more abstract ones - are mainly acquired through linguistic input (e.g. "philosophy"), while other have an intermediate status (e.g. "tundra").

MoA ratings gradually change over grades: while in early grades words are mainly acquired through perceptual modality, in Grade 6 texts the majority of words are learnt through linguistic input. Modality of acquisition and age of acquisition are correlated but not overlapping dimensions. However, studies on age of acquisition indicate that abstract concepts are acquired later than concrete ones, when children have already mastered many words. Studies investigating the early comprehension of abstract concepts (e.g. Bergelson & Swingley, 2013) reveal that abstract concepts

(e.g. “all gone”) emerge at around 10 months and become more stable at around 14 months. Abstract words start to be comprehended in correspondence with the emergence of some important social abilities:the ability to follow the gaze of others, the capability to develop forms of joint attention allowing children to determine what they and the adults “know together” (Carpenter et al., 1998).

One influential hypothesis on conceptual development maintains that, in order to acquire abstract words, children need to master a consistent amount of words and of linguistic knowledge, and that the acquisition of syntax and semantics are strictly interwoven (Gleitman et al., 2005). The core of WAT contends that, while for concrete words children may simply (or mostly) base themselves on associative mechanisms between words and their referents, learning “hard words” such as abstract ones likely requires not only linguistic knowledge but also sophisticated social abilities.

Both the social (Tomasello & Akhtar 2000) and the linguistic inputs might be particularly relevant for learning abstract words, since the selection of their referent is more difficult. It is not casual that they were called “hard” words! (Gleitman et al. 2005; Gentner, 2006; Gillette et al., 1999; Wauters et al., 2003). Literature on testimony found that preschool children are willing to receive clarifications by adults, and that around three or four yearsold they are able and keen to monitor the accuracy of the information they receive (Corriveau & Harris, 2009; Sabbagh & Baldwin, 2001). Crucially, testimony is particularly relevant in domains where the environmental inputs are insufficient (Harris & Koenig, 2006), as those of abstract concepts.

The second principle of WAT is that the different acquisition modalities influence the conceptual representation in the brain. Given the diversity and sparse character of their referents, they should engage brain areas more distributed and less focused compared to concrete concepts (see Rodríguez-Ferreiro, Gennari, Davies, & Cuetos. 2011, for consistent fMRI evidence with abstract verbs). According to WAT, while both concrete and abstract concepts activate sensorimotor networks, the areas that are part of the language processing system are more activated by abstract than by concrete concepts processing. To verify this

hypothesis, Sakreida et al. (2013) and Scorolli et al. (2012) performed an fMRI and a TMS study based on a previous behavioral study (Scorolli et al., 2011) using sentences in which both the noun and the verb could be concrete or abstract (e.g. “to caress the dog/the idea”, “to think of the dog/the idea”). The fMRI study demonstrated that abstract concepts activated the core sensorimotor areas, i.e. the left lateral (precentral gyrus) and the medial (supplementary motor area) premotor cortex. While the purely concrete expressions (e.g. “to caress the dog”) elicited activations within the left inferior frontal gyrus (pars triangularis) and two foci within the left inferior parietal cortex, the purely abstract word pairs (e.g. “to think of the idea”) engaged the anterior part of left middle temporal gyrus that is part of the language processing system. Consistently, in the TMS study phrases containing both concrete and abstract verbs activated the hand-related motor system (MEPs, motor evoked potentials), but the activation of this system was delayed with phrases containing abstract verbs.This might be due to a cascade flow of activation from the mouth- to the hand-related motor areas. There is a limitations to these studies as this interpretation remains speculative, since no control study with the mouth’s MEPs was run. Furthermore, results of the TMS study converged with the ones of the behavioral study (Scorolli et al., 2011) in showing that response times were faster for congruent pairs (abstract verb-abstract noun, concrete verb-concrete noun) than for non congruent ones (Scorolli, 2014). This suggests that abstract and concrete words are represented in partially different circuits, and that switching from one circuit to the other (e.g. from the core sensorimotor to the linguistic system; see Sakreida et al., 2013) implies a cost in terms of processing time.

The third principle of WAT is that different acquisition modalities lead to different embodied counterparts.WAT predicts that abstract concepts, due to their link with language, activate the mouth-related motor system more, while concrete concepts, more linked to manipulative actions,

activate hand-related motor system more. This prediction was evidenced by two studies (Borghi et al., 2011; Granito et al., 2015) in which participants were taught new categories and then novel labels.

Borghi et al. (2011) operationalized concrete categories as novel 3D objects presented on the computer screen, which differed in color and shape, abstract words as groups of moving objects that interacted in novel ways. Participants were asked to "manipulate" the concrete objects by moving them on the computer screen, and to observe the interaction of the members of abstract categories. The efficacy of this operationalization was tested in a subsequent feature generation task: participants produced more perceptual properties with concrete objects, similarly to what happens with real categories (Borghi et al., 2011). This study showed that, both before and after language learning, it was more difficult to categorize abstract than concrete categories, even if the disadvantage of abstract categories was slightly reduced after category learning. More crucially, a property verification task ("is XX a property of CALONA?") confirmed that, while concrete categories were responded to faster with the hand, by pressing a key on the keyboard, abstract categories were facilitated quicker with responses with the mouth, when participants had to say "yes" on the microphone. The advantage of the mouth was more pronounced when abstract concepts were introduced using not only names but also explanations of their meaning.

Further evidence supporting this principle of WAT was provided by Granito et al. (2015) who replicated the mouth advantage with abstract concepts, operazionalizing concrete and abstract categories as novel objects vs. novel relations between objects. All stimuli were built with Lego. The distinction was based on the claim of Gentner and Boroditsky (2001) that, differently from object words, relation words, generally expressed through verbs or prepositions, refer to complex patterns which are not immediately individuated in the physical world, hence they are more abstract. In this second study the novel names and explanations of the category meaning were introduced by a researcher, to mimic the social situation that typically characterizes conceptual acquisition. Then both participants who had been taught labels and descriptions for concrete and

abstract categories and participants who had not were submitted to a categorical recognition task ("Do XX and YY belong to the same category?").The results revealed that, with abstract words, participants who had undergone the linguistic training had a better performance than the other participants when they were required to respond with the mouth (microphone) (Granito et al., 2015). A following image-word matching task ("is XX a CALONA?") tested participants who had acquired language earlier or later. Participants who benefited more from linguistic information with abstract concepts were those whose initial categories differed more from those defined by the experimenters, confirming the role of language in filling the gaps left by the correlational structure of the environment.

In a further experiment, Granito et al. (2015) used common everyday abstract and concrete categories and asked participants how much the mouth and the hand were involved in a possible action with the target word: they found that participants associated concrete categories with the hand, and abstract categories with the mouth. Ghio et al. (2013) rating study found convergent results andshowed that, while abstract concepts related to mental states and emotions are more associated to the mouth, number concepts are more associated to the hand, probably due to the influence of finger counting on numerical cognition (Fischer & Brugger, 2011; Ranzini et al., 2011).

fMRI studies have provided further evidence potentially in line with WAT and showed that abstract concepts activate the left inferior frontal gyrus and the left middle temporal gyrus (for meta-analyses see Wang et al., 2010; Binder et al., 2009). Importantly, it has been shown that the left inferior frontal gyrus region is involved in subvocalization (Fiebach et al., 2007), for example during processing of pseudo-words in lexical decision, or in working memory maintainance (Petrides, 1994). Papagno et al. (2009) found with TMS that lexical decision with abstract words was less accurate after stimulation of the left inferior frontal gyrus. The activation of this region suggests that the linguistic areas related to the vocal and motor aspects of word processing are activated (Lieberman, 2009). Recent fMRI evidence by Hoffman et al. (2015) confirmed that concrete concepts are more associated with visual experience and abstract with acoustic one, as the higher activation of dorsolateral areas for abstract concepts and of ventromedial areas for concrete words reveals, while both kinds of concepts converge in activation of ventrolateral ATL. Further fMRI evidence with an orthographic judgement task is in line with WAT. It reveals that, while bilateral inferior frontal gyrus, left superior parietal, left fusiform gyrus and bilateral middle

occipital were activated by both concrete and abstract words, additional language areas were engaged by abstract concepts in bilateral superior temporal and bilateral middle temporal region (Kumar, 2015).

However, further fMRI data revealed that not only linguistic areas are activated, but further areas related to experiential components, as the right hemisphere (superior frontal gryus, precuneus, D'esposito et al., 1997, anterior cingulated cortex, amygdala, parieto-occipital junction,Perani et al., 1999), occipital gyrus (Jessen et al., 2000). This evidence reveals, in keeping with WAT, that both areas related to both sensorimotor and linguistic experiences are activated by abstract concepts, that the role of linguistic areas is more important for abstract than for concrete concepts, and it suggests that these linguistic areas can involve subvocalization.

The fourth principle of WAT is that given the crucial role of language for abstract concepts, the latter are more likely to be influenced by differences between languages than concrete ones: for example, concepts as "time" are more variable across languages compared to concepts as "container" (Malt et al., 1999). For example, Malt et al. have shown that the concept of "container" in highly variable across languages in terms of naming but not in terms of knowing: when Chinese, Spanish and English-speaking XX participants are asked to perform a sorting task, the crosslinguistic variability disappears and they adopt the same criteria in grouping containers. In contrast, nuch evidence has revealed that the concept of "time" varies across languages not only in terms of naming, but also in terms of the conceptual content: for example, time evokes the vertical dimension for Mandarine Chinese, the horizontal for North American participants (see Borghi & Binkofski, 2014, for an review and an analysis in depth of this aspect).

Strengths and limitations.

The WAT view has a number of strengths. The first and most important is that it is based on a mechanism that characterizes abstract concepts: the more abstract concepts are, the more linguistic information should be necessary to compensate the reduced perceptual experience and to keep

together their different members. Being an embodied theory, WAT does not speculate that this mechanism, i.e. the activation of linguistic information, is in contrast with the fact that abstract concepts activate their content. Another strength of WAT over other theories, is that it focuses not only on conceptual representation but also on words acquisition. It has therefore the potential to unify two separate streams of research, the first on word acquisition in children and the second on brain representation of abstract concepts in adults.

Evidence on both acquisition and brain organization confirms the importance of linguistic information for abstract concepts. However, the claim that conceptual acquisition influences conceptual representation is very strong yet remains speculative, and should be further developed and investigated. In addition, the concept of modality of acquisition should be further analyzed to answer the dilemma of whether what counts is only the initial acquisition or alsothe successive times in which a given word is used, re-negotiating its meaning. Furthermore, should such acquisition necessarily occur through a social process or could it also occur through texts, as when we read information on Wikipedia?

One final limitation of WAT is that the main evidence collected so far derives from studies on word acquisition in adults and studies on the neural underpinnings of abstract concepts; further studies on infants and children acquisition should be conducted, as well as further cross-cultural studies, to test the hypothesis that abstract concepts are more affected by linguistic variability than concrete ones.

Grounding and sign tracking

The fourth Multiple Representation theory discussed is Grounding and Sign Tracking, which is very close to the WAT view we have just discussed.The philosopher Jesse Prinz (2002, 2012) has recently proposed that we understand words using a tracking strategy: to capture their meaning, we need to anchor and link them to something non-verbal, their referents. The same process holds for concrete and for abstract categories, which, similarly to concrete ones, are correlated with features

that are perceivable and which can work as signs to track the category. Prinz outlines different strategies that can be used to understand abstract concepts.

One possible strategy is to ground them in concrete scenarios: for example, “justice” can be simulated with a scenario reproducing inequality: a person gets two cookies, another person three. Grounding concepts in situations might however not hold for all abstract concepts. Beyond sign tracking, we may adopt other strategies which include metaphorical projection (see CMT theory), the reference to internal states and emotions, and labeling. Concepts such as “meaningful activity” are comprehended introspecting motivations and emotions, while other concepts, such as “truth” and “identity”, can be understood through labeling, thanks to a network of associate words. Linguistic associations alone, however, are not sufficient to wholly capture meaning: in order to fully understand labels we need to ground them. Crucially, Prinz highlights the importance of both mental imagery and verbal skills to access the concept meaning: for example, to learn the concept of “democracy” we need to track definitions used by authoritative members of our community. Overall, he contends that comprehending abstract concepts implies the capacity ‘‘to match mental images with reality and sentences with testimony’’ (Prinz 2012).

Strengths and limitations.

This theory proposed by Prinz in our view has many advantages. This perspective not only identifies some underlying mechanisms but highlights a rangeof different possibilities that can underlie the formation of abstract concepts. It therefore points out the flexibility of our conceptual system. Another strength of this theory is that these mechanisms are differently activated depending on the kind of concepts. This points out to an important aspect, the fact that abstract concepts are very diverse and heterogeneous and that different kinds of explanations can be used to account for them. Furthermore, although Prinz identifies different strategies, this is a fully embodied view, which extends to language as well.

Although it is evident that there are a number of merits to Prinz's work, the major weakness of this theory, is that in its present form it is still a proposal more than a structured theory. Furthermore, the proposal does not consider some important aspects, such as the link between concepts acquisition and concepts representation. In addition, it highlights the role of words only in terms of the past experiences they re-enact, not as possible means to perform actions. However, the proposal could be extended to include these aspects.

Multiple representation views: further evidence.

Further evidence supports the Multiple Representation views which argue thatabstract concepts evoke multiple forms of representations (based on linguistic, emotional, social, sensorimotor experience). We will now illustrate some recent studies, showing that - depending on the task and on the level of processing it implies - different kind of information is activated.

Current studies have investigated the role of emotions and context availability for concrete and abstract concepts (Moffat et al., 2015; Newcombe et al., 2012; Siakaluk et al. 2014). Moffat et al. (2015) reported evidence that, while confirming the important role of context availability for conceptual processing, revealed that it is not uniqueof abstract ones. In different experiments Moffat et al. (2015) instructed participants to complete four tasks; firstly decide and then read aloud only abstract words, secondly read aloud only concrete words, thirdly name aloud all words that appeared on the screen, and finally name aloud all words, when concrete and abstract words were separately presented and blocked for emotions.

This study concluded that, compared to other variables, context availability and emotions play an important role in characterizing concepts. With abstract words both emotions and context availability played a facilitatory role, such that higher ratings on these two dimensions were associated with faster responses. With concrete words the pattern of results differed: context availability continued to have a facilitatory effect, while emotions played an inhibitory role, such

that higher ratings were associated with slower and less accurate responses. The fact that context availability played a facilitatory role for both kinds of concepts suggests that it it is not a dimension unique of the first, but that it plays an important role for conceptual processing overall. The fact that emotions both facilitated processing of abstract words and inhibited processing of concrete words reveals that emotions play an important role for abstract concepts (see also Newcombe et al., 2012). Even if this evidence is consistent with the emotion-based view, emotions did not always play a role: when participants were simply required to name words, which were presented together and not blocked for emotions, only context availability and not emotions influenced processing.

Further studies have revealed the importance of a variety of semantic dimensions for representation of abstract concepts. Recchia and Jones (2012) asked participants to generate 10 features for concrete and abstract concepts, in order to allow another participant to guess the target-word from their description. They found that for abstract words the number of semantic neighbors (i.e. words that share the context with many/few other words) and the contextual dispersion (i.e. number of content areas to which a word is connected) were significant predictors of the performance in a lexical decision task, while the number of features was not. For concrete concepts, contextual dispersion and the number of features predicted the performance in lexical decision, but the number of semantic neighbors did not. This asymmetrical pattern suggests that abstract concepts benefit from rich linguistic contexts, while concrete concepts from rich physical contexts. This evidence is clearly in line with the idea that linguistic information is crucial for the representation of abstract concepts (for converging evidence see also Goodhew et al., 2014).

Further evidence in support of Multiple Representational theories was been provided by Zdrazilova and Pexman (2013) who examined the effect of different semantic richness variables (context availability, semantic neighborhood, number of associates, sensory experience rating, valence, arousal) on lexical decision and semantic categorization tasks with abstract concepts. They found faster response times (RTs) in lexical decision for abstract words which evoked more contextual information, and faster RTs in semantic categorization for abstract words which evoked richer

sensory experience as well as a more positive emotional experience. The results, whichsupportmultiple representation views of abstract words, indicate that different dimensions – perceptual, emotional and linguistic - have a different and dissociable influence on tasks.

In the same vein, a recent study by Farias et al. (2013) shows an interplay between semantic and perceptual properties with abstract words referring to politics. Participants were more likely to evaluate words associated with conservatorism as louder when presented to the right ear, words associated with socialism as louder when presented to the left ear, even if the sounds did not differ in intensity. This evidence highlights the multimodal character of abstract words; furthermore, it suggests that "*an opposition between symbolic representational and modality specific representations is misleading at best*" (Farias et al. 2013, p. 5).

Strengths and limitations.

The evidence we have critically evaulated within this reviewpoints to the fact that different experiential dimensions characterize abstract concepts. Multiple representation views, which are based on such an assumption, have multiple strengths which are unique to it when compared to other theories. One of the most important is that taking into account both linguistic and sensorimotor information they can provide a bridge between two approaches to meaning that were traditionally considered as opposing: the embodied and the distributional accounts.

According to distributional or statistical approaches (e.g., Lund & Burgess, 1996, HAL; Landauer & Dumais, 1997, LSA), language meaning is computed statistically. Meaning is given by the co-occurrence of words in large masses (corpora) and it derives from the relationship between associated words rather than between words and their referents (for a recent overview, see Andrews et al., 2014; see also work by Max Louwerse: e.g., Louwerse & Jeauniaux, 2010). As we have seen throughout this review,any embodied approach attempting to provide an explanation for abstract concepts, which do not have bounded and concrete referents, represents a major challenge.

Distributional approaches do not share this problem, since they derive the meaning of both concrete and abstract words from their statistical distribution across languages (Andrews et al., 2014).

However, distributional approaches are not able to solve the "symbol grounding problem" (Harnad, 1990) which argues: how can the meaning of a word be explained only through reference to other words? And moreover, how could we understand what "bottle" means if we could not see, touch and experience bottles? Furthermore, distributional approaches do not take into account the emotional and social aspects that accompany language acquisition and use (see EAE and WAT). Finally, while distributional approaches are quite successful in explaining experimental results, they cannot predict results at the same level of detail and precision which characterizes embodied account. Even authors who propose that language encodes perceptual, spatial and temporal information, recognize that the language statistics cues can contribute to meaning comprehension, but not to all: for example, recent data suggests that 60% of the temporal relations as the distance between cities or the chronological sequence of days and historical figures can be accessed through statistics (e.g. Louwerse, Raisig, Tillman, & Hutchinson, 2015). This demonstrates, in our opinion, that grounding of concepts is crucial to fully comprehend them.

A further strength of multiple representation theories is that they can utilize and explain neuropsychological evidence showing double dissociations between mastering of abstract and concrete words. Even if discussing in detail this evidence is beyond the scope of the present work (see Borghi & Binkofski, 2014, chapter 5, for details), it is important to consider the effect linked to two syndromes as well as their implications for the debate on concrete and abstract concepts (see the review by Shallice and Cooper, 2013, but see also studies on Parkinson patients by Fernandino et al., 2013a; 2013b).

The first syndrome is deep dyslexia: patients make errors while reading aloud, but the majority of errors are made with words with concrete, or highly imageable, meaning (Shallice & Warrington, 1975; Coltheart et al., 1987). The second syndrome is semantic dementia (Warrington, 1975) and erphes encephalitis (e.g., Warrington & Shallice, 1984): patients show the so-called reverse

concreteness effect, i.e. their performance is better with abstract than with concrete concepts (Bonner et al., 2009; Hoffman & Lambon Ralph, 2011) (see also recent evidence on specific effects of mild amnesia in definition task of abstract words, Kim et al., 2015). The connectionist model by Plaut and Shallice (2003) provides a possible explanation for this impairment with abstract words, as it assumes that a reduced number of features of abstract words renders their representation overall weaker compared to concrete words.

Even if treating in depth this issue is far beyond the scope of the present review, it is important to spend a few words on the role played by semantic dementia, caused by the bilateral degeneration of the anterior temporal lobes (ATLs), in the debate between embodied and amodal theories of semantics. Because the selective damage of a specific brain area causes semantic dementia, it has been proposed that a single neural area in the brain exist, where all modalities are integrated: the anterior temporal lobe would work as a hub integrating white matter connections (spokes) and modality specific associative cortices (hub-and-spoke model, Patterson et al., 2007). ATLs would thus play a pivotal role in representing abstract concepts. This kind of evidence has been interpreted as favoring hybrid models, according to which modal and amodal systems concur in representing abstract concepts (e.g. Dove, 2015). However, the evidence provided has been recently discussed (e.g. Gainotti, 2012; Simmons & Martin, 2009); furthermore, the pattern of data is complicated, firstly due to the limits of localization data, that do allow to validate a specific theory only in an indirect way, and also because of the behavioral results: semantic dementia does not impair all abstract concepts – for example, it spares numerical concepts. Finally, proponents of embodied theories tend to represent association areas (Damasio, 1989) where information converge as multimodal (Simmons et al., 2005), or "heteromodal" (Bonner, Peelle, Cook & Grossman, 2013) (for a recent critical review, see McCaffrey, 2015). Hence, the debate is open, and new evidence is needed to come to a univoque conclusion.

Reviewing evidence on these two syndromes Shallice and Cooper (2013) contend that semantic representation of concrete and abstract words can be separable. They state that the higher

complexity of abstract concepts requires at a minimum mastery of high-level logical functions. Some examples can be used to illustrate this.The concept of “bicycle” can be accounted by the conjunction of features as “is a vehicle”, “has a seat, wheels”, “can be ridden”, etc. while to capture a concept such as “hope” we would need a logical structure as “*Hope* (X) if and only if *desire* (X) AND *believe* (*possible* (X))”. According to the authors, neither feature-based theories (e.g. Plaut & Shallice, 2003) nor embodied theories are sufficiently computationally powerful to be able to account for how we compile the meaning of abstract words such as “hope”.

How can researchers who endorse an embodied approach counter such objections? Different arguments can be advanced. First of all, once could question the “separability” of the two systems. it should be noted that not only behavioral and brain imaging studies (see above) but also neuropsychological evidence suggest that not only concrete but also abstract concepts are grounded in distributed action-perception circuits. A recent study on a double dissociation has shown with a lexical decision task that a patient with a lesion in dorsolateral central sensorimotor systems was impaired in recognizing tool words, while a patient with rather specific focal lesion centered in the left supplementary motor area had a deficit with abstract-emotional word processing (Dryer et al., 2015). This clearly suggests that sensorimotor systems are not peripheral for abstract concepts processing, and suggests the two systems for concrete and abstract words are not completely separable but at least partially overlap. Second, one should better consider the potentialities of perceptual symbols and of linguistic symbols. One response, that Shallice and Cooper (2013) do not seem to consider, is to argue that perceptual symbols have the computational power which characterize the linguistic symbolic system, as suggested by Larry Barsalou in his seminal 1999 paper (Barsalou, 1999). A second possibility is to claim, as recently done by Dove (2015), that the language system can offer the computational abilities necessary for the separate system proposed by Shallice and Cooper (2013). While according to Dove (2015) this linguistic system is amodal, we do not see the necessity to hypothesize a transduction from linguistic experience to an amodal form of representation.

Multiple kinds of abstract concepts: multiple approaches?

Many studies favoring multiple representation views contend that different systems might be activated, depending on the task. For example, according to LASS the linguistic system is more activated during lexical decision tasks, which make small demands on semantic processing, while the simulation system is more activated during tasks that imply a deeper semantic comprehension such as semantic decision tasks. Along the same line, Zdrazilova and Pexman (2013) demonstrated that different measures of semantic richness are activated depending on the task.

However, it might be also suggested that different representation systems are activated to a different extent, depending on the kind of abstract concepts we consider. Abstract concepts can be very different from each other: they include, for example, number concepts, emotional concepts (e.g. "love"), mental state concepts (e.g., "thought"), and purely abstract concepts (e.g., "truth"). Recently, the focus of research has been shifting and more arebeginning to investigate fine-grained distinctions between sub-kinds of abstract concepts. It is indeed possible that, similarly to what happens to concepts referring to sensorial experiences such as taste (Simmons et al., 2005) orodor, and to perceptual properties, suchas color and shape (e.g. Martin et al., 1996; Martin, 2007), different distributed patterns of experiential information characterize different kinds of concepts.

Wilson-Mendenhall et al. (2013) conducted a fMRI study which showed that concepts such as "convince" are represented in areas related to mentalizing and social cognition (e.g., medial prefrontal cortex, superior temporal sulcus), while the concept "arithmetic" engages brain regions underlying numerical cognition (e.g., bilateral intraparietal sulcus) (Wilson-Mendenhall et al., 2013). This study indicates that concepts are represented in a distributed manner that depends on their content. Further research should be devoted to identify eventual sub-sets of abstract concepts and determine a validated selection criteria which should be used universally within research to allow for replication of findings.

A promising novelmanner to investigate subsets of abstract concepts, which is linked by different degrees of semantic relatedness, is to use multidimensional ratings in order to examine the contribution of different dimensions in abstract concept representation. (e.g. Crutch et al., 2012, 2013 ; Troche et al., 2014). For example, Crutch et al. (2013) asked participants to rate concepts on a 7 point scale by dimensions as sensation, emotion, action, thought, social interaction, morality, executive function, quantity, time, space, and polarity. They used this approach starting from the hypothesis that further dimensions beyond sensorimotor and emotional features characterize abstract concepts; for example, the social dimension (see WAT). On the basis of the ratings a high dimensional semantic space was generated, where the semantic relatedness between concepts was represented in terms of distance between them. The validity of this representation was tested and validated showing that the performance of a patient affected by global aphasia was worse when she had to identify a target presented within word pairs that were close in the semantic space.

This method of investigating subsets of abstract concepts wasalso used by Ghio, Vaghi and Tettamanti (2013) to evaluate whether different abstract concepts (mental state-, emotion-, mathematics-related concepts) involved different body parts (mouth, hand). They found that the 3 kinds of concepts differed across different dimensions. For example, emotion and mental states were similarly ratedin concreteness, context availability and familiarity. Emotion sentences were more associated with mouth, hand and leg movements than mental-state and mathematics-related sentences, while math related sentences involved more hand movements compared to the other concepts.

Further studies have made use of feature generation tasks to identify differences between subtypes of abstract concepts. For example, Setti and Caramelli (2005) found with a feature production task that concepts referring to nominal kinds (e.g. “error”), states of the self (e.g. “worry”), cognitive processes (e.g. “memory”), and emotions (e.g. “fear”) were characterized by different conceptual relations. In particular, emotion terms differed more from the other three subtypes (see also Roversi et al., 2013, for the distinction between artefact, social and institutional concepts).

A further novel and promising way to identify sub-sets of abstract concepts is to investigate how different kinds of abstract concepts are conveyed by sign languages. In a recent paper, Borghi, Capirci, Gianfreda and Volterra (2013) analyzed examples of abstract concepts taken from LIS(Lingua dei Segni Italiana), the visual-gestural language used within the Italian Deaf community. The rationale beyond this analysis is that investigating the way in which this sign language encodes concepts into signs can contribute to the comprehension of how abstract concepts are represented (for a similar attempt, see Roush, 2011, who analyzed starting from the Conceptual Metaphor Theory how concepts of politeness are represented in American Sign Language, ASL). The analysis suggests that a framework based on a single dimension, i.e. linguistic, sensorimotor or emotional, does not fully capture the meaning of abstract concepts. Instead, multiple sources of experiences converge, in different distributions, to represent abstract concepts.

Many signs in LIS provide support for the Conceptual Metaphor Theory, as they make use of body parts in an iconic way to refer to underlying metaphors, such as “knowing is seeing”, “the chest contains feelings and emotions” or “the head is a container”: for example, in the sign TO LEARN all the extended digits rapidly touch each other and move toward the signer’s forehead, as when bringing something from the external space to the head. Even if iconicity is a distinctive characteristic of sign language(s), it is important to note that not all signs can be explained through the mechanisms identified by the CMT.

There are a range of LIS signs which can be viewed as supporting evidence for a number of theories discussed within this review. For example, the sign TO CONSTRAIN can provide support for the view that argues there is no difference between concrete and abstract concepts exists, since both are grounded in the motor system: here the hand posture, displaying a precision grip, move toward the signer’s neck or toward another point in space, as when grabbing somebody’s by the throat. The sign TO EXPRESS ONESELF can be easily explained by the emotional theory: the hands move up and outward from the chest, i.e. the space where emotions are contained, toward external space. Evidence favoring the view according to which abstract concepts rely on social aspects of situations

can, for example, be found in the sign glossed as IMPOSSIBLEH-FFF. In this sign the extended fingers perform an upward circular movement. The sign likely originates from a specific situation, the blessing gesture typically performed by Catholic priests in front of dead people, who are precluded further possibilities during life (Wilcox et al. 2010). Finally, consistently with views that assign an important role to linguistic information (WAT, Dove), purely abstract signs such as TRUE and TRUTH (VERO and VERITA' in Italian) or as LANGUAGE/LINGUA are conveyed in LIS using a strategy known as "initialization.", i.e. reporting the initial letter of the correspondent word, as the letter V (vero, truth) or L (lingua, language).

The results of this study on sign language led to two important conclusions. Firstly, these results show that, even if all examples are consistent with an embodied view, none of the current theories or proposals are sufficiently general to be able to account for all examples of abstract concepts. Even CMT, which could be the most important and influential theory, due to the fact that in sign languages meanings have to be expressed through iconic gestures, does not exhaustively explain the meaning of all concepts. Importantly, the results suggest that to express purely abstract conceptsItalian Sign Language exploits linguistic information, regardless of whether it is derived from the same sign language, from a foreign sign language as ASL (Americal Sign Language) or from the correspondent spoken/written language (Italian, in this case).

Overall, the reviewed studies reveal that abstract concepts can differ widely in terms of content, and cast some doubts on whether a single theory might be able to explain all varieties of abstract concepts. We do not intend to claim that the proposals, theories and perspectives we have outlined have no merit. Instead, we suggest that all of them, even if to a different degree, are promising approaches that contribute to a better comprehension of abstract concepts. However, to date no approach has yet proven to be able to account for all abstract concepts. This opens the possibility that multiple representation approaches are necessary to account for specific abstract concepts features and content, in their varieties and differences (Borghi et al., 2014; Ghio et al., 2013; Crutch et al., 2013; Wilson-Mendehall et al., 2013).

Conclusion

Being able to explain how we form and use abstract concepts is pivotal to understand one of the most sophisticated abilities possessed by our species (Wang et al., 2015). Our analysis of the literature can help to comprehend where the field is, and where it is going. We will summarize below our main conclusions, then we will discuss them more in depth:

a. views according to which abstract concepts representation can be explained exclusively on the basis of their grounding in sensorimotor systems or in linguistic systems are not empirically supported;
b. multiple representations views represent a viable alternative, since they highlight the importance of different kinds of experiences: linguistic, emotional, social and sensorimotor ones. The major novelty in the field in the last years is represented by these view;
c. among multiple representation views, we believe that the evidence so far has shown that an embodied view that takes into account the importance of language experience can be able to explain abstract concepts representations. In our perspective while it is crucial to recognize the pivotal role language plays for abstract concepts, there is no need to posit that language makes use of amodal representations. It is important, instead, to underlie the role of language for abstract concepts acquisition, and to focus on language in its multifolded aspects, as a bodily, social and emotional experience, and to underline its role as a medium of thought, that can extend our cognitive abilities. However, in the field opinions diverge as to the modal or amodal character of the language medium, and more research and theories are needed to disentangle this complex issue. Further research is also needed to explore more in depth the role played by emotional (see EAE theory) and social and linguistic (see WAT theory) information;
d. while the most interesting perspectives in our view converge in showing that, compared to concrete concepts, abstract ones are more (but not exclusively) characterized by social,

emotional and linguistic information than by sensorimotor one, very recent studies are starting also to identify sub-types of abstract concepts, in terms of the different distribution of the experiential information they evoke. This is a very fruitful research direction, useful to prepare a solid ground for the development of more compelling multiple representation views.

While we hope to have been able to convey the message summarized in the above four points, we believe that some issues deserve more discussion. Our analysis of the literature comes together to form one central conclusion which states that explanations based on a single strategy are not sufficient and that it is now compelling to recognize that different experiences (emotional, social, linguistic, sensorimotor) play a role in abstract concepts representation. This claim can seem obvious, but we believe it is not. Until some years ago theories on abstract concepts were divided: distributional theories focused solely on the importance of linguistic information, embodied theories highlighted primarily the role of sensorimotor information, and views derived from Paivio's DCT approach proposed that sensorimotor information was important for concrete concepts, linguistic information for abstract ones. More crucially, the pivotal role played by emotional and social information for abstract concepts has been underlined only very recently, respectively by the AEA and by the WAT theories. In addition, the research direction that reconciles embodied and distributional theories of meaning, ascribing importance to both sensorimotor and linguistic information, provides a novel way to account for all concepts; the insights of distributional theories are however particularly useful to explain abstract concepts, for which linguistic information has a major relevance.

Still, one could argue that it is self-evident that concepts rely on different sources of information and different kinds of experiences, and that this holds for concrete concepts as well. We hope to have shown that the distribution of these experiences substantially differs: while concrete concepts are grounded primarily in perception and action system, abstract ones re-enact more – but not exclusively - social, emotional and linguistic experiences. It appears that these different strategies

mayhave different activations depending not only on the kind of task, but also on the kind of abstract concept. Further research is essential to deepen our understanding and should focus on investigating and defining the fine-grained distinctions among abstract concepts, similar to those present for distinguishing between concrete ones.

While the activation of a network of differently distributed brain areas - depending on the conceptual content - is in line with an embodied view, it remains to be clarified whether there is something distinctive about abstract concepts, which couldexplain why we perceive, rate and use abstract concepts in a different manner to concrete concepts.

An increasing amount of evidence, obtained with different techniques and methodologies, indicates that both linguistic and non-linguistic experiences contribute to the representation of both abstract and concrete concepts. This consideration is likely at the root of the recent success of hybrid approaches, such as the revitalization of the classic vision of Paivio (1986), who proposed that concrete concepts activate sensorimotor information, while abstract concepts evoke linguistic one (Paivio, 1986).

While it is rather established that multiple forms of representation are needed to account for the complexity of abstract concepts, not all researchers in this area share the view that all systems are modal and the modality of systems remains an issue for further research (see Tomasino and Rumiati, 2013; Dove, 2009, 2015). We believe instead that there is no need to call for amodal representations and that a fully embodied view has the potential to meet the challenge to explain abstract concepts. In addition, explaining abstract concepts would not require adopting a unique strategy.

We have seen the advantages of multiple representation views when combined with an embodied approach, and we have seen that studies on activation of different dimensions are flourishing. We have argued within this review that multiple representation theories can account for the variability of information activated across both tasks and concepts. However, it is important to note that there are weaknesses in this area and both “linguistic information” and “linguistic experience” must be

better defined. Language can be seen simply as a shortcut to access the simulation system (Barsalou et al,, 2008), as a way to access to meaning through the associations between words (distributional views: e.g., Landauer & Dumais, 1997; Lund & Burgess, 1996), as a way to provide us with further computational abilities (Dove, 2014; Clark, 1998). However, language can beall of this, but also much more: words are social tools to act in the world, and language is an important embodied social experience (Borghi & Cimatti, 2009; Borghi & Binkofski, 2014), which likely possesses emotional and affective implications (Vigliocco et al., 2014). Language can provide a glue to keep together different category members (Borghi & Binkofski, 2014), as well as a means to introspectively reason on them (Barsalou and Wiemer-Hastings, 2005).

Such a perspective could encourage collaboration between a range of specialties within psychology, for example,bridging research from both developmental studies on language acquisition and studies on conceptual representation in adults, which were the main focus of this review. Curiously so far studies on abstract concept acquisition and representation represent two separate lines of research (see Granito et al., 2015, for developing this issue). One of the main challenges is to try reunifying them under a unitary approach.

Importantly, the influence of language on concepts can be seen as a powerful mechanism, useful for the comprehension of abstract words of all kinds. In line with distributional views, we do not think that it makes sense to speak in terms of "necessary" features: in our view the activation of linguistic information is not "necessary" to represent abstract concepts, but it becomes more important, the higher the level of abstractness is. Furthermore, from what discussed above it should be obvious that the activation of linguistic information is not in contrast with the activation of the conceptual content, since the embodied approach posits that abstract concepts evoke and re-enact previous experiences.

Such a mechanism is not linked to a specific content, rather it helps to fill the absence of content. It is plausible that, the less sensorimotor and affective information is activated, the more language is needed, since it can play a scaffolding role to allow the acquisition of abstract words. Importantly,

this instrument is not simply a means to access meaning but it brings with itself rich individual and social experiences.

References

Adorni, R., & Proverbio, A. M. (2012). The neural manifestation of the word concreteness effect: An electrical neuroimaging study. *Neuropsychologia*, *50*(5), 880-891.

Altarriba, J., Bauer, L.M., Benvenuto, C (1999).Concreteness context availability and imageability ratings and word associations for abstract, concrete, and emotion words. *Behavioral Research Methods, 31*(4): 578–602. doi: 10.3758/bf03200738.

Altarriba, J., Bauer, L.M. (2004).The distinctiveness of emotion concepts: a comparison between emotion, abstract, and concrete words. *American Journal of Psychology, 117*(3), 389–410. doi: 10.2307/4149007.

Andrews, M., Frank, S., & Vigliocco, G. (2014). Reconciling embodied and distributional accounts of meaning in language. *Topics in cognitive science, 6*(3), 359-370.

Andrews, M., Frank, S., & Vigliocco, G. (2014). Reconciling embodied and distributional accounts of meaning in language. *Topics in cognitive science*, *6*(3), 359-370.

Anelli, F., Lugli, L., Baroni, G.,Borghi, A.M., Nicoletti, R. (2014). Walking boosts your performance in making additions and subtractions. *Frontiers in Psychology, 5,1459. doi:10.3389/fpsyg.2014.01459***.**

Aziz-Zadeh L, Wilson SM, Rizzolatti G, Iacoboni M. (2006). Congruent embodied representations for visually presented actions and linguistic phrases describing actions. *Current Biology, 16*,1818–1823.

Barber, H. A., Otten, L. J., Kousta, S. T., & Vigliocco, G. (2013). Concreteness in word processing: ERP and behavioral effects in a lexical decision task. *Brain and language, 125*(1), 47-53.

Barca, L., Burani, C., & Arduino, L.S.(2002).Word naming times and psycholinguistic norms forItalian nouns. *Behaviour Research Methods, Instruments & Computers, 34*, 424-434.

Bardolph, M., & Coulson, S. (2014). How vertical hand movements impact brain activity elicited by literally and metaphorically related words: an ERP study of embodied metaphor. *Frontiers in human neuroscience, 8*. doi: 10.3389/fnhum.2014.01031.

Barsalou, L.W. (1987). The instability of graded structure: Implications for the nature of concepts. In U. Neisser (Ed.), *Concepts and conceptual development: Ecological and intellectual factors in categorization* (pp. 101-140). Cambridge: Cambridge University Press.

Barsalou, L. W. (1999). Perceptions of perceptual symbols. *Behavioral and brain sciences, 22*(04), 637-660.

Barsalou, L. W. (2003). Abstraction in perceptual symbol systems. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *358*(1435), 1177-1187.

Barsalou, L. W. (2008). Grounded cognition. *Annual. Review of Psychology*, *59*, 617-645.

Barsalou, L.W. (2012). The human conceptual system. In M. Spivey, K. McRae, & M. Joanisse (Eds.), *The Cambridge handbook of psycholinguistics* (pp. 239-258). New York: Cambridge University Press.

Barsalou, L.W., & Wiemer-Hastings, K. (2005). Situating abstract concepts. In D. Pecher&R.Zwaan (Eds.), *Grounding cognition: The role of perception and action in memory, language, and thought* (pp. 129–163). New York: Cambridge University Press.

Barsalou, L. W., Santos, A., Simmons, K. W., & Wilson, C. D. (2008). Language and simulations in conceptual processing. In M. De Vega, A. M. Glenberg, & A. C. Graesser (Eds.), *Symbols, embodiment and meaning* (pp. 245–283). Oxford: Oxford University Press.

Bergelson, E., & Swingley, D. (2013). The acquisition of abstract words by young infants. *Cognition*, *127*(3), 391-397.

Bergen, B. K., & Lau, T. T. C. (2012). Writing direction affects how people map space onto time. *Frontiers in psychology*, *3*.

Binder, J. R., Westbury, C. F., McKiernan, K. A., Possing, E. T., & Medler, D. A. (2005). Distinct brain systems for processing concrete and abstract concepts. *Journal of Cognitive Neuroscience, 17,* 905–917. doi:10.1162/0898929054021102.

Binder, J.R., Desai, R.H., Graves, W.W., Conant, L.L. (2009) Where is the semantic system? A critical review and meta-analysis of 120 functional neuroimaging studies. *Cerebral Cortex,19*(12): 2767–2796. doi: 10.1093/cercor/bhp055.

Bonner, M. F., Vesely, L., Price, C., Anderson, C., Richmond, L., Farag, C., et al. (2009). Reversal of the concreteness effect in semantic dementia. Cognitive Neuropsychology, 26, 568–579.

Boot, I., &Pecher, D. (2010). Similarity is closeness: Metaphorical mapping in a perceptual task. *Quarterly Journal of Experimental Psychology, 63*, 942–954.

Boot, I., & Pecher, D. (2011). Representation of categories: Metaphorical use of the container schema. *Experimental psychology*, *58*(2), 162.

Borghi, A.M. (2005). Object concepts and action. In D. Pecher & R.A. Zwaan (Eds). Grounding Cognition: *The role of perception and action in memory, language, and thinking* (pp. 8-34). Cambridge: Cambridge University Press.

Borghi, A.M**.** (2013). Embodied cognition and word acquisition: The challenge of abstract words In: Cornelia Müller, Alan Cienki, Ellen Fricke, Silva H. Ladewig, David McNeill & Jana Bressem (Eds.) *Body-Language-Communication: An International Handbook on Multimodality in Human Interaction. Handbooks of Linguistics and Communication Scie*nce (HSK) 38/2 Berlin, Boston: De Gruyter: Mouton.

Borghi, A.M., & Binkofski, F. (2014). *Words as social tools: An embodied view on abstract concepts.* Berlin and New York: Springer.

Borghi, A.M., Caruana, F. (2015). Embodiment Theory. In: James D. Wright (editor-in-chief), *International Encyclopedia of the Social & Behavioral Sciences*,2nd edition, Vol 7. Oxford: Elsevier. pp. 420-426. ISBN: 978008097086.

Borghi, A.M., & Cimatti, F.(2009). Words as tools and the problem of abstract words meanings. In N. Taatgen& H. van Rijn (eds.).*Proceedings of the 31st Annual Conference of the Cognitive Science Society* (pp. 2304-2309). Amsterdam: Cognitive Science Society.

Borghi, A. M., Capirci, O., Gianfreda, G., & Volterra, V. (2014). The body and the fading away of abstract concepts and words: a sign language analysis. *Frontiers in psychology, 5*.

Borghi, A.M., Flumini, A., Cimatti, F., Marocco, D. & Scorolli, C. (2011). Manipulating objects and telling words: A study on concrete and abstract words acquisition. *Frontiers in Psychology, 2*:15. doi: 10.3389/fpsyg.2011.00015.

Borghi, A.M., Caramelli, N., & Setti, A. (2005). Conceptual information on objects' locations. *Brain and language*, *93*(2), 140-151.

Boroditsky, L. (2001). Does language shape thought? English and Mandarin speakers' conceptions of time. *Cognitive Psychology, 43*, 1–22.

Boroditsky, L., & Ramscar, M. (2002). The roles of body and mind in abstract thought. *Psychological Science, 13*(2), 185–188.

Boulenger V, Hauk O, Pulvermuller F. (2009). Grasping Ideas with the Motor System: Semantic Somatotopy in Idiom Comprehension. *Cerebral Cortex, 19*,1905–1914.

Boulenger, V., Shtyrov, Y., & Pulvermüller, F. (2012). When do you grasp the idea? MEG evidence for instantaneous idiom understanding. *Neuroimage*, *59*(4), 3502-3513.

Carpenter, M., Nagell, K., Tomasello, M., Butterworth, G., & Moore, C. (1998). Social cognition, joint attention, and communicative competence from 9 to 15 months of age. *Monographs of the society for research in child development*, i-174.

Casasanto, D. (2008). Who's afraid of the big bad Whorf? Crosslinguistic differences in temporal language and thought. *Language Learning, 58*, 63–79.

Casasanto, D., &Boroditsky, L. (2008). Time in the mind: Using space to think about time. *Cognition, 106*, 579–593.

Casasanto, D., & Bottini, R. (2014). Mirror reading can reverse the flow of time. *Journal of Experimental Psychology: General, 143*(2), 473.

Catricalà, E., Della Rosa, P. A., Plebani, V., Vigliocco, G., & Cappa, S. F. (2014). Abstract and concrete categories? Evidences from neurodegenerative diseases. *Neuropsychologia*, *64*, 271-281.

Chen, J. Y. (2007). Do Chinese and English speakers think about time differently? Failure to replicate Boroditsky (2001). *Cognition, 104*, 127–136.

Chen, M., & Bargh, J. A. (1999). Consequences of automatic evaluation: Immediate behavioral predispositions to approach or avoid the stimulus. *Personality and Social Psychology Bulletin,25*, 215–224.

Clark, A. (1998). Magic words: How language augments human computation. *Language and thought: Interdisciplinary themes*, 162-183.

Coltheart M., Patterson K., Marshall J. C. (1987). *Deep dyslexia since 1980*. In M. Coltheart, K. Patterson, J.C. Marshall, (Eds.).*Deep Dyslexia* (pp. 407-451).London, UK: Routledge.

Connell, L., & Lynott, D. (2012). Strength of perceptual experience predicts word processing performance better than concreteness or imageability. *Cognition, 125*(3), 452–465.

Connell, L., & Lynott, D. (2013). Flexible and fast: Linguistic shortcut affects both shallow and deep conceptual processing. *Psychonomic bulletin & review, 20*(3), 542-550.

Corriveau, K., & Harris, P. L. (2009). Choosing your informant: Weighing familiarity and recent accuracy. *Developmental Science, 12*(3), 426–437.

Crutch, S. J., & Warrington, E. K. (2005). Abstract and concrete concepts have structurally different representational frameworks. *Brain, 128*(3), 615-627.

Crutch, S. J., Ridha, B. H., & Warrington, E. K. (2006). The different frameworks underlying abstract and concrete knowledge: Evidence from a bilingual patient with a semantic refractory access dysphasia. *Neurocase, 12*(3), 151-163.

Crutch, S. J., & Warrington, E. K. (2007). Semantic priming in deep-phonological dyslexia: Contrasting effects of association and similarity upon abstract and concrete word reading. *Cognitive neuropsychology, 24*(6), 583-602.

Crutch, S. J., Connell, S., & Warrington, E. K. (2009). The different representational frameworks underpinning abstract and concrete knowledge: Evidence from odd-one-out judgements. *The Quarterly Journal of Experimental Psychology, 62*(7), 1377-1390.

Crutch, S. J., & Warrington, E. K. (2010). The differential dependence of abstract and concrete words upon associative and similarity-based information: Complementary semantic interference and facilitation effects. *Cognitive neuropsychology, 27*(1), 46-71.

Crutch, S. J., & Jackson, E. C. (2011). Contrasting graded effects of semantic similarity and association across the concreteness spectrum. *The Quarterly Journal of Experimental Psychology*, *64*(7), 1388-1408.

Crutch, S. J., Williams, P., Ridgway, G. R., & Borgenicht, L. (2012). The role of polarity in antonym and synonym conceptual knowledge: evidence from stroke aphasia and multidimensional ratings of abstract words. *Neuropsychologia*, *50*(11), 2636-2644.

Crutch, S. J., Troche, J., Reilly, J., & Ridgway, G. R. (2013). Abstract conceptual feature ratings: the role of emotion, magnitude, and other cognitive domains in the organization of abstract conceptual knowledge. *Frontiers in human neuroscience*, *7*.Damasio, A.R. (1989). The brain binds entities and events by multiregional activation from convergence zones. *Neural Computation, 1*(1), 123-132.

D'Esposito, M., Detre, J. A., Aguirre, G. K., Stallcup, M., Alsop, D. C., Tippet, L. J., & Farah, M. J. (1997). A functional MRI study of mental image generation. *Neuropsychologia*, *35*(5), 725-730.

Dehaene, S., Bossini, S., & Giraux, P. (1993). The mental representation of parity and number magnitude. *Journal of Experimental Psychology: General*, *122*(3), 371.

Della Rosa, P. A., Catricalà, E., Vigliocco, G., & Cappa, S. F. (2010). Beyond the abstract—concrete dichotomy: Mode of acquisition, concreteness, imageability, familiarity, age of acquisition, context availability, and abstractness norms for a set of 417 Italian words. *Behavior research methods*, *42*(4), 1042-1048.

Della Rosa, P. A., Catricalà, E., De Battisti, S., Vinson, D., Vigliocco, G., & Cappa, S. F. (2014). How to assess abstract conceptual knowledge: construction, standardization and validation of a new battery of semantic memory tests. *Functional neurology, 29*(1), 47.

Desai, R. H., Binder, J. R., Conant, L. L., Mano, Q. R., & Seidenberg, M. S. (2011). The neural career of sensory-motor metaphors. *Journal of Cognitive Neuroscience*, *23*(9), 2376-2386.

Dove, G. (2009). Beyond Perceptual symbols: a call for representational pluralism. *Cognition, 110*, 412-31.

Dove, G. (2011). On the need for embodied and disembodied cognition. *Frontiers in Psychology,1*, 242. doi:10.3389/fpsyg.2010.00242

Dove, G. (2013). Intermediate representations exclude embodiment. *Behavioral and Brain Sciences, 36* (4), 353-4.

Dove, G. (2014). Thinking in words: language as an embodied medium of thought. *Topics in cognitive science, 6*(3), 371-389.

Dove, G. (2015). Three symbol ungrounding problems: Abstract concepts and the future of embodied cognition. *Psychonomic bulletin & review*, 1-13.

Dreyer, F. R., Frey, D., Arana, S., von Saldern, S., Picht, T., Vajkoczy, P., & Pulvermüller, F. (2015). Is the motor system necessary for processing action and abstract emotion words? Evidence from focal brain lesions. *Frontiers in Psychology, 6*.

Duñabeitia, J. A., Avilés, A., Afonso, O., Scheepers, C., & Carreiras, M. (2009). Qualitative differences in the representation of abstract versus concrete words: Evidence from the visual world paradigm. *Cognition, 110*, 284–292.

Eder, A. B., & Hommel, B. (2013). Anticipatory control of approach and avoidance: an ideomotor approach. *Emotion Review*, *5*(3), 275-279.

Farias, A.R., Garrido, M.V., & Semin, G.R. (2013). Converging modalities ground abstract categories: the case of politics. *PloSone, 8*(4), e60971.

Fernandino, L., Conant, L.L., Binder, J.R., Blindauer, K., Hiner, B., Spangler, K., & Desai, R.H. (2013a). Parkinson's disease disrupts both automatic and controlled processing of action verbs. *Brain and language, 127*(1), 65-74.

Fernandino, L., Conant, L. L., Binder, J. R., Blindauer, K., Hiner, B., Spangler, K., & Desai, R. H. (2013b). Where is the action? Action sentence processing in Parkinson's disease. *Neuropsychologia, 51*(8), 1510-1517.

Fiebach C.J., Friederici A.D. (2004). Processing concrete words: fMRI evidence against a specific right-hemisphere involvement. *Neuropsychologia42*, 62–70 10.1016/S0028-3932(03)00145-3.

Fiebach C.J., Ricker B., Friederici A.D., Jacobs A.M. (2007). Inhibition and facilitation in visual word recognition: prefrontal contribution to the orthographic neighborhood size effect. *Neuroimage, 36*, 901–911. doi: 10.1016/j.neuroimage.2007.04.004

Fischer, M.H., &Brugger, P. (2011). When Digits Help Digits: Spatial–Numerical Associations Point to Finger Counting as Prime Example of Embodied Cognition. *Frontiers in Psychology, 2*, 260. doi: 10.3389/fpsyg.2011.00260.

Flumini, A., & Santiago, J. (2013). Time (also) flies from left to right if it is needed! In M. Knauff, M. Pauen, N. Sebanz, & I. Wachmuz (Eds.), In: *Proceedings of the 36th Annual Conference of the Cognitive Science Society* (pp. 2315–2320). Austin, TX: Cognitive Science Society.

Flusberg, S. J., Thibodeau, P. H., Sternberg, D. A., & Glick, J. J. (2010). A connectionist approach to embodied conceptual metaphor. Frontiers in Psychology, 1, 197. doi:10.3389/fpsyg.2010.00197.

Frith, C.D. (2012) The role of metacognition in human social interactions. *Philosophical Transactions of the Royal Society B, 367*(1599), 2213-2223.

Förster, J., & Strack, F. (1996). Influence of overt head movements on memory for valenced words: A case of conceptual-motor compatibility. *Journal of Personality and Social Psychology, 71*, 421–430.

Fuhrman, O., & Boroditsky, L. (2007). Mental time-lines follow writing direction: Comparing English and Hebrew speakers. In D.S. McNamara & J. G. Trafton (Eds.), *Proceedings of the 29th Annual Conference of The Cognitive Science Society* (pp. 1001–1007). Austin, TX: Cognitive Science Society.

Freina, L., Baroni, G., Borghi, A. M., & Nicoletti, R. (2009). Emotive concept-nouns and motor responses: Attraction or repulsion? *Memory & Cognition, 37*, 493–499.

Gainotti, G. (2012). The format of conceptual representations disrupted in semantic dementia: a position paper. *Cortex, 48*, (5), pp. 521- 529.

Gallese, V. (2008). Mirror neurons and the social nature of language: The neural exploitation hypothesis. *Social neuroscience*, *3*(3-4), 317-333.

Gallese, V., & Lakoff, G. (2005). The brain's concepts: The role of the sensory-motor system in conceptual knowledge. *Cognitive neuropsychology, 22*(3-4), 455-479.

Galton, A. (2011). Time flies but space does not: Limits to the spatialisation of time. *Journal of Pragmatics*, *43*(3), 695-703.

Geng, J., & Schnur, T. T. (2015). The representation of concrete and abstract concepts: Categorical versus associative relationships. *Journal of Experimental Psychology: Learning, Memory and Cognition, 41*(1), 22-41. doi: 10.1037/a0037430.

Gentner, D. (1981). Some interesting differences between verbs and nouns.*Cognition and Brain Theory, 4*,161–178.

Gentner, D. (2006). Why verbs are hard to learn. In K. Hirsch-Pasek & R. Golinkoff (Eds.), *Action meets words: How children learn verbs* (pp. 544–564). New York: Oxford University Press.

Gentner, D., & Boroditsky, L. (2001). Individuation, relativity and early word learning. In M. Bowerman & S. Levinson (Eds.), *Language acquisition and conceptual development* (pp. 215–256). Cambridge: Cambridge University Press

Ghio, M., Vaghi, M.M.S., & Tettamanti, M. (2013). Fine-grained semantic categorization across the abstract and concrete domains. *PloSone*, *8*(6), e67090.

Gibbs, R. W. J. (1994). *The poetics of mind: Figurative thought, language, and understanding.* New York: Cambridge University Press

Gibbs, R. W. J. (2006). *Embodiment and cognitive science*. New York: Cambridge University Press

Gillette, J., Gleitman, H., Gleitman, L. R., & Lederer, A. (1999). Human simulations of vocabulary learning. *Cognition, 73*, 135–176.

Gleitman, L.R., Cassidy, K., Papafragou, A., Nappa, R., & Trueswell, J.T. (2005). Hard words. *Journal of Language Learning and Development, 1*(1), 23–64.

Glenberg, A. M., & Gallese, V. (2012). Action-based language: A theory of language acquisition, comprehension, and production. *Cortex*, *48*(7), 905-922.

Glenberg, A. M., & Kaschak, M. P. (2002). Grounding language in action. *Psychonomic bulletin & review*, *9*(3), 558-565.

Glenberg, A. M., Sato, M., & Cattaneo, L. (2008a). Use-induced motor plasticity affects theprocessing of abstract and concrete language. *Current Biology, 18*(7), R290–R291.

Glenberg, A. M., Sato, M., Cattaneo, L., Riggio, L., Palumbo, D., & Buccino, G. (2008b).Processing abstract language modulates motor system activity. *Quarterly Journal ofExperimental Psychology, 61*, 905–919.

Goodhew, S. C., McGaw, B., & Kidd, E. (2014). Why is the sunny side always up? Explaining the spatial mapping of concepts by language use. *Psychonomic bulletin & review*, *21*(5), 1287-1293.

Goldman, A., & de Vignemont, F. (2009). Is social cognition embodied? *Trends in Cognitive Science, 13*(4), 154–159

Granito, C., Scorolli, C., & Borghi, A. M. (2015). Naming a Lego World. The Role of Language in the Acquisition of Abstract Concepts. *PloSone, 10*(1), e0114615.

Guan, C. Q., Meng, W., Yao, R., &Glenberg, A. M. (2013). The motor system contributes to comprehension of abstract language. *PloSone, 8*(9), e75183

Hamilton, A. C., & Coslett, H. B. (2008). Refractory access disorders and the organization of concrete and abstract semantics: Do they differ?*Neurocase*, *14*(2), 131-140.

Hamilton, A. C., & Martin, R. C. (2010). Inferring semantic organization from refractory access dysphasia: Further replication in the domains of geography and proper nouns but not concrete and abstract concepts. Cognitive neuropsychology, 27(8), 614-635.

Harnad, S. (1990). The symbol grounding problem. Physica D: Nonlinear Phenomena, 42(1), 335-346.

Harris, P. L., & Koenig, M. A. (2006). Trust in testimony: How children learn about science and religion. *Child Development, 77*, 505–524.

Hauk O, Johnsrude I, Pulvermüller F (2004) Somatotopic representation of action words in human motor and pre-motor cortex. *Neuron, 41*, 301–307. doi: 10.1016/s0896-6273(03)00838-9

Heit, E., & Barsalou, L. (1996). The instantiation principle in natural categories. *Memory, 4*, 413-451.

Hoffman, P. (2015). The meaning of 'life' and other abstract words: Insights from neuropsychology. *Journal of Neuropsychology*. doi: 10.1111/jnp.12065.

Hoffman, P., & Lambon Ralph, M. A. (2011). Reverse concreteness effects are not a typical feature of semantic dementia: evidence for the hub-and-spoke model of conceptual representation. *Cerebral Cortex, 21*, 2103–2112.

Hoffman, P., Binney, R.J., Lambon Ralph, M.A. (2015). Differing contributions of inferior prefrontal and anterior temporal cortex to concrete and abstract conceptual knowledge. *Cortex, 63*, 250-66. doi: 10.1016/j.cortex.2014.09.001.

Irwin, B.A. (2015). An enactivist account of abstract words: lessons from Merleau-Ponty. *Phenomenology and the Cognitive Sciences*, 1-21. Doi: 10.1007/s11097-015-9434-y

Ishihara, M., Keller, P. E., Rossetti, Y., & Prinz, W. (2008). Horizontal spatial representations of time: evidence for the STEARC effect. *Cortex*, *44*(4), 454-461.

Jessen, F., Heun, R., Erb, M., Granath, D. O., Klose, U., Papassotiropoulos, A., & Grodd, W. (2000). The concreteness effect: Evidence for dual coding and context availability. *Brain and language*, *74*(1), 103-112.Jones, M. (2015). Number concepts for the concept empiricist. *Philosophical Psychology*, 1-15.

Kiehl K. A., Liddle P. F., Smith A. M., Mendrek A., Forster B. B., Hare R. D. (1999). Neural pathways involved in the processing of concrete and abstract words. *Human Brain Mapping,7*, 225–233.

Kim, S. R., Kim, S., Baek, M. J., & Kim, H. (2015). Abstract Word Definition in Patients with Amnestic Mild Cognitive Impairment. *Behavioural neurology, 2015*.

King, L. (2013). *The importance of situational information for abstract concepts.* Dissertation, University of Western Ontario.

Kousta, S., Vigliocco, G., Vinson, D. P., & Andrews, M. (2009). Happiness is…an abstract word. The role of affect in abstract knowledge representation. In N. Taatgen & H. van Rijn (Eds.), *Proceedings of the 31st Annual Conference of the Cognitive Science Society*. Amsterdam: Cognitive Science Society.

Kousta, S. T., Vigliocco, G., Vinson, D., Andrews, M., & Del Campo, E. (2011). The representation of abstract words: Why emotion matters. *Journal of Experimental Psychology: General, 140*, 14–34. doi:10.1037/a0021446.

Kranjec, A., & Chatterjee, A. (2010). Are temporal concepts embodied? A challenge for cognitive neuroscience. Frontiers in Psychology, 1, 240. doi:10.3389/fpsyg.2010.00240.

Kuenecke, J., Sommer, W., Schacht, A. & Palazova, M.(2015). Embodied simulation of emotional valence: Facial muscle responses to abstract and concrete words. *Psychophysiology*. doi: 10.1111/psyp.12555.

Kumar, U. (2015). Neural dychotomy of word concreteness: a view from functional neuroimaging. Cognitive Processing

Lakoff, G. (2014). Mapping the brain's metaphor circuitry: metaphorical thought in everyday reason. *Frontiers in human neuroscience*, *8*.

Lakoff, G., & Johnson, M. (1980). *Metaphors we live by* Chicago. Chicago: Chicago UniversityPress.

Lakoff, G., & Johnson, M. (1999). *Philosophy in the flesh: The embodied mind and its challenge to western thought*. Basic books.

Lakoff, G., & Núñez, R. E. (2000). *Where mathematics comes from: How the embodied mind brings mathematics into being*. Basic books.

Lai, V.T., & Boroditsky, L (2013).The immediate and chronic influence of spatio-temporal metaphors on the mental representations of time in English, Mandarin, and Mandarin-English speakers. *Frontiers in Psychology, 4*:142. doi: 10.3389/fpsyg.2013.00142

Lakens, D., Semin, G. R., & Foroni, F. (2015). Why your highness needs the people. *Social Psychology*.

Landauer, T.K., &Dumais, S.T. (1997) A solution to Plato‘s problem: The latent semantic analysis theory of the acquisition, induction, and representation of knowledge. *Psychological Review, 104* (2), 211–240. doi: 10.1037/0033-295x.104.2.211

Louwerse, M., & Connell, L. (2011). A taste of words: Linguistic context and perceptual simulation predict the modality of words. *Cognitive Science*, *35*(2), 381-398.

Louwerse, M. M., & Jeuniaux, P. (2010). The linguistic and embodied nature of conceptual processing. *Cognition*, *114*(1), 96-104.Louwerse, M. M., Raisig, S., Tillman, R., &

Hutchinson, S. (2015). Time after Time in Words: Chronology through Language Statistics. *Proceedings of the Cognitive Science Society*.

Lynott, D., & Coventry, K. (2014). On the ups and downs of emotion: testing between conceptual-metaphor and polarity accounts of emotional valence–spatial location interactions. *Psychonomic bulletin & review, 21*(1), 218-226.

Lund, K., &Burgess, C. (1996) Producing high-dimensional semantic spaces from lexical co-occurrence. *BehaviorResearch Methods, Instruments & Computers, 28* (2), 203–208. doi: 10.3758/bf03204766.

Malt, B. C., Sloman, S. A., Gennari, S., Shi, M., & Wang, Y. (1999). Knowing versus naming: Similarity and the linguistic categorization of artifacts. *Journal of Memory and Language*, *40*(2), 230-262.

Markman, A. B., & Stilwell, C. H. (2001). Role-governed categories.*Journal of Experimental and Theoretical Artificial Intelligence, 13*,329–358.

Marques, F. J., & Nunes, L. D. (2012). The contribution of language and experience to the representation of abstract and concrete words: different weights but similar organization. *Memory and Cognition, 40*(8), 1266–1275.

Martin, A. (2007). The representation of object concepts in the brain. *Annual Review of Psychology*, *58*, 25-45.

Martin, A., Haxby, J., Lalonde, F.M., Wiggs, C.L., &Ungerleider, L.G. (1996) Discrete cortical regions associated with knowledge of color and knowledge of action. *Science, 270*, 102–105. doi: 10.1126/science.270.5233.102

McCaffrey, J. (2015). Reconceiving conceptual vehicles : Lessons from semantic dementia. *Philosophical Psychology, 28*, 3, 337-354.

Moffat, M., Siakaluk, P. D., Sidhu, D. M., & Pexman, P. M. (2015). Situated conceptualization and semantic processing: effects of emotional experience and context availability in semantic

categorization and naming tasks. *Psychonomic bulletin & review, 22*(2), 408-19. doi: 10.3758/s13423-014-0696-0.

Murphy, G. L. (1996). On metaphoric representation. *Cognition, 60*, 173–204.

Murphy, G. L. (1997). Reasons to doubt the present evidence for metaphoric representation. *Cognition, 62,* 99–108.

Murphy, G. L., & Wisniewski, E. J. (1989). Categorizing objects in isolation and in scenes: what a superordinate is good for. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *15*(4), 572.

Neumann, R., & Strack, F. (2000). Approach and avoidance: the influence of proprioceptive and exteroceptive cues on encoding of affective information. *Journal of personality and social psychology*, *79*(1), 39.

Newcombe, P. I., Campbell, C., Siakaluk, P. D., & Pexman, P. M. (2012). Effects of emotional and sensorimotor knowledge in semantic processing of concrete and abstract nouns. *Frontiers in human neuroscience, 6.*

Núñez, R., & Marghetis, T. (2014). Cognitive linguistics and the concept (s) of number. In *Oxford handbook of numerical cognition*. Oxford University Press Oxford.

Lieberman, P. (2009). *Human language and our reptilian brain: The subcortical bases of speech, syntax, and thought*. Harvard University Press.

Ouellet, M., Santiago, J., Israeli, Z., & Gabay, S. (2010). Is the future the right time? *Experimental Psychology, 57*(4), 308–314.

Paivio, A. (1986). *Mental representations: A dual coding approach*. New York: Oxford University Press.

Paivio, A. (2013). Dual coding theory, word abstractness, and emotion: a critical review of Kousta et al.(2011). *Journal of Experimental Psychology: General, 142*(1), 282-287.

Paivio, A., Yuille, J. C., &Madigan, J. A. (1968). Concreteness, imagery and meaningfulness values for 925 nouns. *Journal of Experimental Psychology,76*, 1–25. Palazova, M., Sommer, W., &

Schacht, A. (2013). Interplay of emotional valence and concreteness in word processing: An event-related potential study with verbs. *Brain and language, 125*(3), 264-271.

Papagno, A., Fogliata, E., Catricalà, C., & Miniussi. (2009). The lexical processing of abstract and concrete nouns. *Brain Research, 1263*,78–86.

Pecher, D., Boot, I., van Dantzig, S. (2011). Abstract concepts: sensory motor grounding, metaphors, and beyond. In B. Ross (Ed.), *The Psychology of Learning and Motivation*, Vol. 54, 217-48. Burlington: Academic Press.

Petrides M. (1994). Frontal lobes and working memory: evidence from investigations of the effects of cortical excisions in nonhuman primates.In F. Boller, J. Grafman (Eds.).*Handbook of Neuropsychology*. (pp. 59-82). Vol. 9, Amsterdam: Elsevier.

Perani, D., Cappa, S. F., Schnur, T., Tettamanti, M., Collina, S., Rosa, M. M., & Fazio, F. (1999). The neural correlates of verb and noun processing. *Brain*, *122*(12), 2337-2344.

Pexman, P. M., Hargreaves, I. S., Edwards, J. D., Henry, L. C., & Goodyear, B. G. (2007). Neural correlates of concreteness in semantic categorization. *Journal of Cognitive Neuroscience*, *19*(8), 1407-1419.

Phaf, R. H., Mohr, S. E., Rotteveel, M., & Wicherts, J. M. (2014). Approach, avoidance, and affect: a meta-analysis of approach-avoidance tendencies in manual reaction time tasks. *Frontiers in psychology*, *5*.

Pickering, M.J., & Garrod, S. (2013). An integrated theory of language production and comprehension. *Behavioral and Brain Sciences, 36* (4), 377-92.

Plaut D. C., &Shallice T. (1993). Deep dyslexia: a case study of connectionist neuropsychology. *Cognitive Neuropsychology,10*, 377–500.

Prinz, J. J. (2002). *Furnishing the Mind: Concepts and their Perceptual Basis*. Cambridge, MA: MIT Press.

Prinz, J. J. (2012). *Beyond human nature. How culture and experience shape our lives*. London; New York, NY: Penguin; Norton.

Ranzini, M., Lugli, L., Anelli, F., Carbone, R., Nicoletti, R., & Borghi, A.M. (2011) Graspable objects shape number processing. *Frontiers in Human Neuroscience, 5*, 147. doi: 10.3389/fnhum.2011.00147.

Recchia, G., & Jones, M. N. (2012). The semantic richness of abstract concepts. *Frontiers in human neuroscience, 6.*

Rizzolatti, G., & Craighero, L. (2004). The mirror-neuron system. *Annual Review of Neuroscience*, *27*, 169-192. Rodríguez-Ferreiro, J., Gennari, S. P., Davies, R., & Cuetos, F. (2011). Neural correlates of abstract verb processing. *Journal of cognitive neuroscience*, *23*(1), 106-118.

Roush, D. R. (2011). Language between bodies: a cognitive approach to understanding linguistic politeness in American Sign Language.*SignLanguage Studies,1*,329–374. doi: 10.1353/sls.2011.0000.

Roversi, C., Borghi, A. M., & Tummolini, L. (2013). A marriage is an artefact and not a walk that we take together: An experimental study on the categorization of artefacts. *Review of Philosophy and Psychology, 4*(3), 527–542.

Rüschemeyer, S. A., Brass, M., & Friederici, A. D. (2007). Comprehending prehending: neural correlates of processing verbs with motor stems. *Journal of Cognitive Neuroscience*, *19*(5), 855-865.

Sabbagh, M. A., & Baldwin, D. A. (2001). Learning words from knowledgeable versus ignorant speakers: Links between preschoolers' theory of mind and semantic development. *Child development*, 1054-1070.

Sabsevitz, D. S., Medler, D. A., Seidenberg, M., & Binder, J. R. (2005). Modulation of the semantic system by word imageability. *Neuroimage, 27*, 188–200.

Sakreida, K., Scorolli, C., Menz, M. M., Heim, S., Borghi, A. M., &Binkofski, F. (2013). Are abstract action words embodied? An fMR I investigation at the interface between language and motor cognition. *Frontiers in human neuroscience, 7*, 25.

Santiago, J., Lupáñez, J., Pérez, E., & Funes, M. J. (2007). Time (also) flies from left to right. *Psychonomic Bulletin & Review*, *14*(3), 512-516.

Santiago, J., & Lakens, D. (2014). Can conceptual congruency effects between number, time, and space be accounted for by polarity correspondence? *Actapsychologica, 156*, 179-191.

Sato, M., Schafer, A. & Bergen, B. (2015). Metaphor priming in sentence production: Concrete pictures affect abstract language production. *Acta Psychologica*, 156, 136-42.

Schilhab, T. (2015a). Double talk – both biological and social constraints on language. *Biologically Inspired Cognitive Architectures 13*, 1-8.

Schilhab, T. (2015b). Words as cultivators of others minds. *Frontiers in Psychology, 6,* 1690.

Schwanenflugel, P. J., Harnishfeger, K. K., & Stowe, R. W. (1988). Context availability and lexical decisions for abstract and concrete words. *Journal of Memory and Language, 27*, 499–520. doi:10.1016/0749-596X(88)90022-8

Schwanenflugel, P.J., Akin, C., & Luh, W.M. (1992) Context availability and the recall of abstract and concrete words. *Memory & Cognition, 20*(1), 96–104. doi: 10.3758/bf03208259

Scorolli, C. (2014). Embodiment and Language. In L. Shapiro (Ed.), *The Routledge Handbook of Embodied Cognition* (pp. 127-138). Routledge.

Scorolli, C., Binkofski, F., Buccino, G., Nicoletti, R., Riggio, L., &Borghi, A.M. (2011). Abstract and concrete sentences, embodiment, and languages.*Frontiers in Psychology, 2*, 227. doi: 10.3389/fpsyg.2011.00227.

Scorolli, C., Jacquet, P., Binkofski, F., Nicoletti, R., Tessari, A., Borghi, A.M. (2012). Abstract and concrete phrases processing differently modulates cortico-spinal excitability. *Brain Research, 1488,* 60-71. doi: 10.1016/j.brainres.2012.10.004.

Seibt, B., Neumann, R., Nussinson, R., & Strack, F. (2008). Movement direction or change in distance? Self-and object-related approach–avoidance motions. *Journal of Experimental Social Psychology*, *44*(3), 713-720.

Sell, A. J., & Kaschak, M. P. (2011). Processing time shifts affects the execution of motor responses. *Brain and language*, *117*(1), 39-44.

Setti, A., Caramelli, N. (2005) Different domains in abstract concepts. In B. Bara, B. Barsalou, M. Bucciarelli (Eds.). *Proceedings of the XXVII Annual Conference of the Cognitive Science*. Mahwah NJ: Erlbaum.

Shallice, T., & Cooper, R. P. (2013). Is there a semantic system for abstract words?. *Frontiers in human neuroscience*, *7*.

Shallice T., &Warrington E. K. (1975). Word recognition in a phonemic dyslexic patient. *The Quarterly Journal of Experimental Psychology,27*, 187–199. 10.1080/14640747508400479

Siakaluk, P. D., Knol, N., & Pexman, P. M. (2014). Effects of emotional experience for abstract words in the Stroop task. *Cognitive Science*. doi: 10.1111/cogs.12137

Simmons, W. K., Hamann, S. B., Harenski, C. L., Hu, X. P., & Barsalou, L. W. (2008). fMRI evidence for word association and situated simulation in conceptual processing. *Journal of Physiology-Paris*, *102*(1), 106-119.Simmons, W., Martin, A. (2009). The anterior temporal lobes and the functional architecture of semantic memory. *Journal of the International Neuropsychological Society, 15*(05), 645-649.

Simmons, W.K., Martin, A., & Barsalou, L.W. (2005) Pictures of appetizing foods activate gustatory cortices for taste and reward. *Cerebral Cortex, 15*, 1602–1608. doi: 10.1093/cercor/bhi038.

Skipper, L., & Olson, I.R. (2014). Semantic Memory: Distinct Neural Representations for Abstractness and Valence. *Brain and Language, 130*, 1–10. doi:10.1016/j.bandl.2014.01.001.

Slepian, M. L., & Ambady, N. (2014). Simulating sensorimotor metaphors: Novel metaphors influence sensory judgments. *Cognition, 130*(3), 309–314. Snefjella, B., & Kuperman, V. (2015). Concreteness and Psychological Distance in Natural Language Use. *Psychological science*, 0956797615591771.

Talmy, L. (1988). Force dynamics in language and cognition. *Cognitive Science, 12*, 49–100.

Tomasello, M., & Akhtar, N. (1995). Two-year-olds use pragmatic cues to differentiate reference to objects and actions. *Cognitive Development, 10*, 201–224.

Tomasino, B., & Rumiati, R. I. (2013). Introducing the special topic "The when and why of sensorimotor processes in conceptual knowledge and abstract concepts". *Frontiers in human neuroscience, 7*.

Topolinski, S., Maschmann, I. T., Pecher, D., & Winkielman, P. (2014). Oral approach–avoidance: Affective consequences of muscular articulation dynamics. *Journal of personality and social psychology*, *106*(6), 885.

Torralbo, A., Santiago, J., & Lupiáñez, J. (2006). Flexible conceptual projection of time onto spatial frames of reference. *Cognitive Science*, *30*(4), 745-757.

Troche, J., Crutch, S., & Reilly, J. (2014). Clustering, hierarchical organization, and the topography of abstract and concrete nouns. *Frontiers in psychology*, *5*.

Van Dantzig, S., Pecher, D., & Zwaan, R. A. (2008). Approach and avoidance as action effect. *Quarterly Journal of Experimental Psychology, 61*, 1298–1306.

Vigliocco, G., Kousta, S., Vinson, D., Andrew, M., & Del Campo, E. (2013). The representation of abstract words: what matters? Reply to Paivio's (2013) comment on Kousta et al. (2011). *Journal of Experimental Psychology: General, 142*(1), 288–291. doi:10.1037/a0028749

Vigliocco, G., Kousta, S. T., Della Rosa, P. A., Vinson, D. P., Tettamanti, M., Devlin, J. T., & Cappa, S. F. (2014). The neural representation of abstract words: the role of emotion. *Cerebral Cortex, 24*(7), 1767-1777.

Wang, J., Conder, J. A., Blitzer, D. N., & Shinkareva, S. V. (2010). Neural representation of abstract and concrete concepts: A meta-analysis of neuroimaging studies. *Human brain mapping*, *31*(10), 1459-1468.Wang, L., Uhrig, L., Jarraya, B. & Dehaene, S. (2015). Representation of numerical and sequential patterns in macaque and human brain *Current Biology,25 (15), 1966-74.* http://dx.doi.org/10.1016/j.cub.2015.06.035 (2015).

Warrington E. K., &Shallice T. (1984). Category specific semantic impairments. *Brain,107*, 829–853 10.1093/brain/107.3.829

Wauters, L. N., Tellings, A. E., Van Bon, W. H., & Van Haaften, A. W. (2003). Mode of acquisition of word meanings: The viability of a theoretical construct. *Applied Psycholinguistics, 24*(03), 385-406.

Wiemer-Hastings, K., Krug, J., & Xu, X. (2001). Imagery, context availability, contextual constraints and abstractness. In *Proceedings of the 23rd Annual Meeting of the Cognitive Science Society* (pp. 1106–1111). Hillsdale, NJ: Erlbaum.

Wiemer-Hastings, K., & Xu, X. (2005). Content differences for abstract and concrete concepts. *Cognitive Science, 29*, 719–727.

Wilcox, S., Rossini, P., & Antinoro Pizzuto, E. (2010). "Grammaticalization in sign languages," in D. Brentari (Ed.),*Sign Languages*. (pp. 332-354). Cambridge, UK: Cambridge University Press. doi: 10.1017/CBO9780511712203.016

Wilson, M. (2002). Six views of embodied cognition. *Psychonomic bulletin & review*, *9*(4), 625-636.

Winner, E., Rosenstiel, A. K., & Gardner, H. (1976). The development of metaphoric understanding. *Developmental Psychology, 12*, 289–297.

Wilson-Mendenhall, C. D., Barrett, L. F., Simmons, W. K., & Barsalou, L. W. (2011). Grounding emotion in situated conceptualization. *Neuropsychologia*, *49*(5), 1105-1127.

Wilson-Mendenhall, C. D., Simmons, W. K., Martin, A., &Barsalou, L. W. (2013). Contextual processing of abstract concepts reveals neural representations of nonlinguistic semantic content. *Journal of cognitive neuroscience*, *25*(6), 920-935.

Winner, E., Rosenstiel, A. K., & Gardner, H. (1976). The development of metaphoric understanding. *Developmental Psychology, 12*(4), 289–297.

Winter, B., Marghetis, T., & Matlock, T. (2015). Of magnitudes and metaphors: Explaining cognitive interactions between space, time, and number. *Cortex, 64*, 209-224.

Wolpert, D. M., Doya, K., & Kawato, M. (2003). A unifying computational framework for motor control and social interaction. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *358*(1431), 593-602.

Zanolie, K., van Dantzig, S., Boot, I., Wijnen, J., Schubert, T. W., Giessner, S. R., & Pecher, D. (2012). Mighty metaphors: Behavioral and ERP evidence that power shifts attention on a vertical dimension. *Brain and cognition*, *78*(1), 50-58.

Zdrazilova, L., & Pexman, P. M. (2013). Grasping the invisible: Semantic processing of abstract words. *Psychonomic bulletin & review, 20*(6), 1312-1318.

Zwaan, R. A. (2014). Embodiment and language comprehension: reframing the discussion. *Trends in cognitive sciences*, *18*(5), 229-234.

Zwaan,, RA. (2015). Situation models, mental simulations, and abstract concepts in discourse comprehension. *Psychonomic Bulletin & Review*.

(For recent special issues tackling this issue see Borghi, A.M. & Pecher, D. (2011), Frontiers in Cognition, and Tomasino, B. & Rumiati, R.I. (2013) Frontiers in Human Neuroscience.)

Table caption

Table 1. The main embodied theories of abstract concepts. As to level of embodiment, we consider the following categories: strong embodied views: they assume that during conceptual processingonly sensorimotor areas are engaged; weak embodied views: they assume that during conceptual processing both sensorimotor and linguistic areas are engaged; hybrid views: they assume that both embodied and non embodied representations are activated.