Anna M. Borghi*[1,2], Ferdinand Binkofski[3], Cristiano Castelfranchi[2], Felice Cimatti[4], Claudia Scorolli[1], Luca Tummolini[2]

1 University of Bologna
2 ISTC-CNR. Rome
3 Aachen University
4 University of Calabria

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 has recently become a topic of intense debate, especially because of the spread of the embodied 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 in favour of this view, however, has been gathered with regard to concrete concepts. Given the relevance of abstract concepts for higher-order cognition, we argue that being able to explain how they are represented is a crucial challenge that any theory of cognition needs to address. The aim of this article is to offer a critical review of the latest theories on abstract concepts, focusing on embodied ones. Starting with theories that question the distinction between abstract and concrete concepts, we review theories claiming that abstract concepts are grounded in metaphors, in situations and introspection, and in emotion. We then introduce multiple representation theories, according to which abstract concepts evoke both sensorimotor and linguistic information. We argue that the most promising approach is given by multiple representation views that combine an embodied perspective with the recognition of the importance of linguistic and social experience. We conclude by discussing whether or not a single theoretical framework might be able to explain all different varieties of abstract concepts.

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Correspondence:
Anna M. Borghi
anna.borghi@gmail.com

The challenge of abstract concepts

The challenge

What do we talk about when we talk about "love"? There are many reasons why this question is difficult to answer. One important reason, though probably not one that makes for interesting literature, is that the word "love", in common with concepts referring to commendable virtues such as "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 –we can, for example, see and move a table, and we can see and caress a cat and hear it meowing. In contrast, abstract concepts such as "fantasy", "freedom" and "justice", lack bounded and clearly perceivable referents, even if they might evoke situations, scenes, introspection and emotional experiences. This makes it harder to understand what we are talking about when we talk about "love", "fantasy", "freedom" and "justice" than when we talk about "cats". Furthermore, abstract concepts are more detached by sensorial experience: for example, a model based on five features related to sensorimotor experience (sound, color, visual motion, shape, and manipulation), was able to successfully predict brain patterns of concrete concepts, but not of abstract ones (Fernandino, Humphreys, Seidenberg, Gross, Conant, Binder, 2015).
Concrete and abstract concepts do not represent a dychotomy, even if they differ. All concepts are highly dependent on context and are variable. However, abstract concepts are less stable over time and are more shaped by current life experiences, situations, and culture compared to concrete concepts (Barsalou, 1987). Moreover, abstract concepts are also by far the most variable: people agree more with one another when asked 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 natural objects and artefacts (or living and non-living entities, such as "animals" and "furniture"). Abstract concepts come instead in a great variety, as the difference between "number", "opinion" and "philosophy" suggests.

The way in which abstract concepts are represented has been discussed in 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* (from now on referred to as embodied) approaches to cognition.
Embodied approaches consider human concepts to be influenced by the kind of body that organisms possess and 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 view, the concept of "cat" and the word "cat" acquire meaning by the internal simulation or re-enactment of the perceptual, motor and emotional experiences linked to seeing a cat, caressing it, or hearing it meowing (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. Even if the embodied approach has been recently under attack (e.g. Goldinger, Papesh, Barnhart, Hansen & Hout, 2015; Mahon, 2015; but see Barsalou, 2016, for a defence), many studies have demonstrated that concrete concepts (e.g. "bottle", "cat") do activate perceptual properties, actions and emotions. It is much more difficult to provide compelling demonstrations that abstract concepts such as "freedom" and "justice" are embodied, as they do not have a clearly identifiable referent. Many proponents of embodied theories have acknowledged this difficulty.

Unfortunately, this weakness has led others to suggest that embodied views cannot, in the end, explain the formation, use and representation of abstract concepts (e.g., Dove, 2009).

In this paper we argue that abstract concepts pose a challenge that can no longer be postponed. The challenge arises in demonstrating that not only concrete but also abstract concepts can be explained by adopting an extended embodied perspective: even if abstract concepts lack a bounded, identifiable and perceivable referent, they are grounded. We will contend that, beyond sensorimotor and emotional experience, language and sociality play a crucial role in grounding them.

Since distributional theories of meaning can easily explain how abstract concepts are represented (Andrews et al., 2014), it could be argued that abstract concepts constitute a problem only for the embodied approach. According to distributional or statistical approaches (e.g., Lund & Burgess, 1996, HAL; Landauer & Dumais, 1997, LSA), 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). Thus, the meaning of both concrete and abstract words is derived from their statistical distribution in large corpora. Since all meaning is captured by associations between words, distributional theories do not need to posit any difference between concrete and abstract words.

However, the explanation offered by distributional theories of both concrete and abstract concepts representation is incomplete, since they are unable to solve the "symbol grounding problem" (Harnad, 1990): to be understood and avoid circularity, symbols ultimately need to be grounded in their world referents. (Even if very powerful, notice however that Harnad's argument is not universally accepted). As soon as one recognizes that abstract concepts need to be grounded but do not have a bounded and perceivable referent, the challenge arises. In the review, we will argue that recent literature converges in showing that, in order to explain grounding of abstract concepts, the embodied perspective must be extended to take into account the important role of linguistic and social experience, and that the study of conceptual acquisition can widely contribute to account for abstract concepts representation.

More generally, the challenge to explain abstract concepts representation is crucial for a simple but pivotal reason: the ability to use abstract thought represents one of the most sophisticated abilities of our species. We are not arguing that other animals lack the capacity to represent at least some "abstract" concepts: for example, non-human animals are able to group stimuli together according to whether they "differ" or are "equal" (e.g. Flemming, 2012). Our point is that humans possess such a capacity at a qualitative and quantitative different level than non-human animals (Lupyan & Bergen, 2016). Any theory of higher-order cognition would be incomplete if it was unable to explain how we make use of abstract concepts.

In sum: providing an explanation of abstract concepts representation is crucial to further the understanding of higher-order human cognition. Importantly, such a challenge concerns not only a subset of theories, i.e. the embodied ones, since non-embodied theories also fail to provide a thorough explanation of concepts that addresses the symbol grounding problem.

In what follows we will present the current debate on abstract concepts representation (for recent reviews, see Borghi and Binkofski, 2014; Reilly, Peelle, Garcia, & Crutch, 2016; Pecher et al., 2011). We will focus, in particular, on the most recent embodied theories on abstract concepts, critically evaluating recent evidence supporting them, and discussing their strengths and their limitations. We will concentrate on embodied theories also because the majority of the behavioral studies on abstract concepts of the last years derive from the embodied cognition approach, or address embodied approaches. While thisreview focuses on abstract concepts, we will also discuss theories and evidence on the representation of abstract words. We do not intend to equate concepts and words: language influences categorization, it augments it, rendering word meaning more compact and discrete than concepts (Lupyan, 2012; Mirolli & Parisi, 2011). Where possible, we will distinguish between concepts and word meanings and focus on concepts; in most of the cases, however, it is impossible, because tasks on conceptual representation in human adults usually

involve the use of words. In such cases we will not distinguish between “abstract concepts” and “abstract word meanings”.

Since the literature on abstract concepts is heterogeneous, this review does not aim to be exhaustive. Specifically, we will not treat neuropsychological and brain imaging evidence in detail, unless the results of a study are crucial to test or support a specific proposal under review (for a recent review on insights from neuropsychology on abstract concepts, see Hoffman, 2015). Moreover, even if numbers and emotions represent important domains of abstract conceptualization, we will not consider theories that focus only on numerical cognition or only on the conceptualization of emotions, as these theories are beyond the scope of this work. We will refer to emotion and number concepts only when dealing with studies on wide samples of abstract concepts that include, among others, emotional and numerical concepts. As to the theories we have selected, while we will only briefly overview classical theories on abstract concepts, we have decided to describe the embodied theories proposed from 2004 to 2015-6, illustrating if possible both supporting and contradictory evidence. For very influential theories, as the Conceptual Metaphor theory, we will not review all the available evidence, as this would require a dedicated review. Instead, we have chosen to refer to some very influential studies, as well as to reviews of studies, when they are available.

In the review we will show that an important novelty of the literature of the last years is the emergence of approaches based on multiple strategies. In particular, it is becoming evident that in order to explain abstract concepts a standard embodied approach must be integrated with a perspective that emphasizes the importance of language for concepts. In the course of the review we will thus often refer to language and linguistic information. Linguistic information means different things in different theories. First, it can mean information that is conveyed solely through language without direct reference to the world (e.g., by pointing, gesture, or use of deictic terms). We will refer to this meaning as "linguistically conveyed information." Note that linguistically conveyed information might be embodied in its representation, that is, make use of sensorimotor and emotional systems. Second, linguistic information could refer to the literal words themselves and their representations. For example, a word can be a sequence of sounds or a sequence of visual forms. We will refer to this concept as "linguistic form information." Note that linguistic form information may very well be embodied. That is, the sounds may be represented in the auditory system and the visual forms in the visual system. Some theories, however, propose that linguistic form information is amodal, and so we will also use the terms "amodal linguistic form information" and "modal linguistic form information." Third, linguistic information might refer to notions other than words, such as syntactic relations. We will refer to this idea as "syntactic linguistic information".

The emphasis on language has long been one of the strong points of distributional theories. In our view, the most promising approaches take inspiration from distributional views in highlighting the role of language for abstract concepts. At the same time, they differ from distributional views as they do not focus simply on word associations, but consider language as a holistic experience, in its bodily and social aspects. From our birth – and even earlier (Moon, Lagercrantz, & Kuhl, 2013; Voulumanos & Werker, 2007) - we are immersed in a linguistic environment. Language has been defined as a mode of participation in the world (see Irwin, 2015, for developing this aspect in relation to the philosophy of Merleau-Ponty). Language, which is primarily a social experience, can become internalized and support our thought processes: speaking to ourselves helps us to better memorize and plan our actions (Vygotsky, 1986; Clark, 1998; Alderson-Day & Fernyhough, 2015). Recent proposals have shown that language is not only a communication system, but a control system that programs human mind manipulating sensorimotor experiences (Lupyan & Bergen, 2016). Language directed at others and inner speech provide an important means of building predictions: for example, listening to a word can help our visual system to process noisy inputs (Lupyan & Clark, 2015). Language also involves a bodily experience: we produce sounds, we listen to them, and it is possible that when we think of abstract words we internally reproduce their sound, re-enacting the experience of their acquisition, and explaining to ourself their meaning, formulating

predictions against which sensory experiences can be assessed. Importantly, it is highly plausible that the contribution of language to thought processes is particularly crucial for abstract concepts and for the corresponding words, given their lack of bounded and perceivable referents.
Our aim is to convince the reader that the debate on abstract concepts is not internal to embodied theories, but rather that it also involves distributional theories of meaning, and that the most exciting directions of research are emerging by bridging the strong points of these two approaches, i.e. the importance of grounding abstract concepts in perception, action and emotion systems and the crucial role of language in this process. However, we will also contend that integrating embodied and distributional theories is not sufficient to account for abstract concepts for at least three reasons. The first is that these approaches do not emphasize the role of language as a tool to improve thinking (e.g. Clark, 1998; Dove, 2015; Lupyan & Bergen, 2016; Vygotsky, 1986). The second, more crucial reason, it that, focusing on the combinatorial aspects of language, these approaches completely overlook the crucial role of the social dimension for language. The third is that they do not highlight the importance of the modality of acquisition of language, and in particular the pivotal role of social competences for word learning. In our view only new views and research directions that highlight these three aspects - i.e. that conceive language as a prediction and thought instrument, that emphasize the social dimension for concepts and language, and that take profound inspiration and insights from studies on language acquisition - will be able to meet the challenge to explain abstract concepts.

Classical theories of abstract concepts

A tale of two classical theories: CAT vs DCT

Concrete words have an advantage over abstract words: 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 the Context Availability Theory and the 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 (Schwanenflugel et al., 1988). Therefore, the Context Availability Theory explains the better recall of concrete than abstract concepts arguing that processing abstract words is slower because activating their context requires more effort.
An alternative theory, which has become far more influential, 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 Dual Coding Theory, all concepts are represented through the verbal system, but 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".
The Dual Coding Theory posits a negative relationship between abstractness and imageability: the more abstract a concept is, the less imageable it is. However, this intuitive relationship is problematic since, as was recently highlighted (Kousta et al., 2011), the two dimensions are correlated but not equivalent. An additional area of contention, shared by both Context Availability Theory and Dual Coding Theory, is the weak evidence-base for the 'concreteness effect'. While some research did not find this effect (Barca et al., 2012), controlling for word valence some studies found an opposite 'abstractness effect', i.e. a processing advantage of abstract over concrete concepts, (Kousta et al., 2011). Other studies replicated the abstractness effect in response times but found a reverse concreteness effect in event related potentials (ERPs) (Barber et al., 2013): abstract

words were processed faster than concrete ones, but concrete ones elicited larger N400 and N700 ERPs, typically associated with processing meaningful stimuli and with imagery.
Beside the concreteness effect, results of recent studies are also inconsistent with both Context Availability Theory and Dual Coding Theory. Connell and Lynott (2012), for instance, asked participants to rate concepts not only in terms of concreteness and imageability, but also in terms of auditory, gustatory, haptic, olfactory, and visual strength (see also Moffat et al., 2015). In contrast to Context Availability Theory, 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 the Dual Coding Theory. The results showed that imageability is not strongly correlated with perceptual experience, since it seems to reflect more the ease with which an image is generated, rather than whether a concept is 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 the Dual Coding Theory, 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 for an opposite neural pattern (Pexman et al., 2007; Kiehl et al., 1999).
It is important to note that 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, which have often used different methods to select 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 the basis of intuition of researchers. It is possible, therefore, that comparability of findings has been reduced by these inconsistences in the selection of stimuli. It is clear from the evidence mentioned above that future research needs to develop validated criteria for the selection of abstract concepts, which should then be implemented universally. In the final section of the review we will briefly illustrate promising recent directions trying to investigate different sub-types of abstract concepts, and at the same time to propose more general criteria to use for stimuli selection.

Embodied and grounded theories of abstract concepts

As suggested above, the issue of how abstract concepts are represented has been focus of 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 focus on contributions adopting this perspective and addressing the problem of abstract concepts representations. We will cover the main current proposals and evaluate the supporting evidence, while highlighting their strengths and limitations (see Table 1).

INSERT TABLE 1 ABOUT HERE

Within embodied theory, scholars are still divided into two schools of thought: one group focuses on the similarities between concrete and abstract concepts, while the other group emphasizes their differences. The latter either argues for a sharp distinction between concrete and abstract concepts,

or views them on a continuum which spans from less abstract to very abstract concepts (Wiemer-Hastings et al., 2001; Wiemer-Hastings & Xu, 2005).
One influential view which posits that abstract and concrete concepts are profoundly different comes from neuropsychology. We will describe it before starting to illustrate the embodied theories, because it cannot be considered an example of an embodied approach. According to this view, concrete and abstract concepts are characterized by qualitatively and structurally different 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 has also been found in healthy participants (see e.g. Crutch, Connell & Warrington, 2009). Dunabeitia et al. (2011) provided evidence that healthy individuals tend 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 to be more important for abstract concepts than for concrete ones. However, the evidence obtained both with clinical and with general populations is controversial. Failure to replicate the 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). Furthermore, some behavioral results contradicted the findings of Dunabeitia et al. (2011). Geng and Schnur (2015) asked Chinese-English bilinguals to match a Chinese auditory-presented word with one among several other visually-presented English words. This study found that related words are processed faster than unrelated words, but categorical relations (e.g. "idea-attitude") always led to a better performance compared to associative relations (e.g. "math-examination"). In a recent study with a semantic priming paradigm both within and across languages, a priming effect was observed for concrete words for both semantically similar and associative relations. For abstract words, instead, it was present only when prime and target words were associated (Ferré, Guasch, García-Chico, & Sánchez-Casas, 2015).
From these results, it could be concluded either that abstract and concrete concepts appear to be represented similarly both in terms of categorical and associative relations (see also Marques and Nunes 2012, Zhang, Han, & Bi, 2013, for a similar conclusion), or that associative relations are more relevant to characterize abstract concepts, but that for the representation of concrete ones both categorical and associative relations are relevant (Ferré et al., 2015)

Although evidence for the existence of a 'marked distinction' is conflicting, there is a compelling reason for these inconsistent results. Crutch and Jackson (2011) recently suggested 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, in what follows we will concentrate on embodied cognition studies adopting the idea of a continuum spanning from concrete to abstract items. The idea of a continuum is that most widely accepted by most researchers. The idea of a continuum presents a further important insight: that no real dichotomy exists between concrete and abstract concepts, since even concepts that are generally qualified as concrete have an abstract component and vice versa. Consider the concept of "cent" or "euro": It is mostly a concrete one since its referent has specific perceptual characteristics, as a given size, color, weight, but at the same time it has 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 differ substantially because they are both grounded in the same systems engaged during perception, action and emotion (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 are based on evidence on the Action-sentence Compatibility Effect (ACE, 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 whether the sentence makes sense or not 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 has been taken to suggest that the same action schema underlies representation of both concrete and abstract information (Glenberg et al., 2008a, 2008b).

Neuro-cognitive studies using Transcranial Magnetic Stimulation (TMS) complement these behavioral findings, as they have 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). ACE effects also apply to sentences involving time shifts (Sell & Kaschak, 2011): responses away from the body were faster with sentences involving the future, while responses towards the body were faster with sentences involving past events.

Further evidence supporting the view that concrete and abstract concepts do not differ substantially is provided by the approach-avoidance effect. This effect states that positive words (e.g. "gold", "sunshine") evoke an attraction movement, while negative words (e.g. "garbage", "virus") evoke a rejection movement, regardless of whether they are abstract or concrete (Chen & Bargh, 1999).

Studies of cognitive linguistics on force dynamics also provide converging evidence with these results. 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 states that abstract and concrete events rely on the same force mechanisms. In line with this view, research using a sentence sensibility task has shown that primes given by two shapes interacting following the 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.

To sum up, the evidence discussed so far is based on sound and compelling results, obtained both through behavioral and TMS studies. However, these results can be used to claim either that abstract concepts are grounded in similar systems as concrete ones, or, more strongly, that abstract and concrete concepts do not differ at all. Both of these interpretations will now be discussed.

Abstract concepts are grounded in the same processes of concrete concepts

Previous evidence indicates that abstract concepts activate perception and action systems as concrete concepts. Even if these findings are broadly consistent with an embodied approach to abstract concepts, it is difficult to foresee whether this strategy 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 (Sell & Kaschak, 2011), 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: for example, how can it account for concepts as "philosophy", "thought" or "freedom"? Similarly, current research suggests that Approach 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). Both lines of research are, however, limited to words or stimuli characterized by a positive or negative valence, or to novel words designed in such a way that the same kinematics used during deglution or expectoration (inward vs. outward movement) are reproduced in order to pronounce them (Topolinski et al., 2014). Moreover, even if the theory of force dynamics requires further experimental support, it is difficult to imagine that evidence based on force dynamics can be extended beyond the domain of events: for example, how can it explain concepts as "linguistics" or numerical concepts as "four"? Finally, similar results do not necessarily imply similar processes. An example is given by a recent study by Yao, Vasiljevic, Weick, Sereno, O'Donnell, and Sereno (2013). The authors found a size effect in word recognition: big words (e.g., jungle) were processed faster than small ones (e.g. needle), independently of concreteness level of words. However, the explanation of the effect might differ for concrete and abstract concepts. While the explanation is more intuitive for concrete concepts, it is possible that big abstract concepts (e.g., *disaster*) include a wider range of introspective, social, and situational associations compared to smaller concepts. Indeed, regression analyses revealed that subjective ratings of emotional arousal were the only significant predictor of size, and that arousal had a more crucial effect in the recognition of abstract than of concrete words. This is an example of a study in which apparently results do not differ between abstract and concrete concepts, but the processes they imply differ substantially.

Concrete and abstract concepts do not differ.

This second claim is not, in our view, justifiable by the available evidence. Firstly, 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 differences in performance. Secondly, people tend to evaluate and use concrete and abstract concepts differently - for example, they rate "justice" as more abstract than "bottle" – and this difference should be explained. Third, an increasing number of behavioral, neuropsychological and neuroimaging studies have demonstrated that these two kinds of concepts are differently processed and recalled. To make an example, in a recent study Binder, Conant, Humphreys, Fernandino, Simons, Aguilar and Desai (2016) designed a componential model of concepts based on functional divisions in the human brain. To this aim they used a large set of attributes related to different experiences and found that 57 of the 65 attributes distinguished abstract from concrete categories. More specifically, abstract concepts received higher ratings than concrete ones on attributes related to temporal and causal experiences, social experiences, and emotional experiences, while they received lower ratings in sensorial experiences. For all these reasons, we suggest that a systematic 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.

Recently there has been an interesting variation to the view that abstract and concrete concepts are similar. Guan et al. (2013) used EEG and found ACE effects with both concrete and abstract concepts (for a further ERPs study see D'Angiulli et al., 2015). The authors explained their results by arguing that both concrete and abstract words activate the motor system. However, while concrete concepts are grounded in specific sensorimotor simulations, as they re-enact 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: 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 of 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 of what follows from a process being democratic (e.g. concern for human rights, higher tolerance). Importantly, both kinds of components are grounded upon and refer to different characteristics and mechanisms of the motor system.
Compared to other views, this proposal has the advantage of suggesting a mechanism underlying abstract concepts that is supported by a functional architecture of brain organization: the role of forward models within the motor system, whose function is to anticipate the sensory consequences of actions (Wolpert et al., 2003; Glenberg & Gallese, 2012). The contribution of this theory thus consists in specifying the fine-grained mechanisms that underlie the involvement of the motor system in conceptual grounding. Even if the theoretical framework is clearly outlined, the extent to which 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 is not fully clear. Furthermore, even if, as argued by Guan et al. (2013), many abstract names are "names for processes" (e.g. democracy relies, among other processes, on the processes of counting and voting), this view is likely to be insufficiently general to be applied to all varieties of abstract concepts.

Concrete and abstract concepts are different

Taken together the evidence discussed so far does not support the view that there are no differences between concrete and abstract concepts. Therefore, in what follows we will concentrate on the most recent theories that provide evidence of differences between abstract and concrete concepts, and discuss and evaluate the mechanisms and cognitive components that might be responsible for such differences.

Conceptual Metaphor Theory (CMT).
Since the 80's, Conceptual Metaphor Theory (CMT), which is probably the most influential embodied theory on abstract concepts, has proposed that abstract and concrete concepts are indeed different (Lakoff & Johnson, 1980, 1999; Lakoff & Núñez, 2000). The Conceptual Metaphor Theory is primarily based on observations of 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 the Conceptual Metaphor Theory, metaphors concern not only the way in which we use language, but also the way in which we think of the world. Even if, for the most part, the supporting evidence is derived from linguistics, the Conceptual Metaphor Theory 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; Jamrozik, McQuire, Cardillo, & Chatterjee, 2016; Sato et al., 2015; Zhao, He & Zhang, 2016). Researchers favoring the Conceptual Metaphor Theory 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, the abstract concept of "communication" can be understood 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, for example, the abstract notion of "category" is understood with reference to the concrete concept of "container" (Boot & Pecher, 2011), the concept of "similarity" relies on that of "closeness" (Boot & Pecher, 2010), the notions of "good" and "bad" are associated to the right and left space (for a recent study showing that this effect is modulated by mental imagery, see de la Fuente, Casasanto, Martine-Cascales, & Santiago, 2016), and "power" is comprehended by referring to the vertical dimension (Zanolie et al., 2012; Lakens, Semin & Foroni, 2015), similarly to morality (Wang, Lu & Lu, 2016). Furthermore, we use abstract language to characterize phenomena that we consider to be more distant from us: for example, recent data from Twitter indicate that more abstract language is used

when referring to distant cities, to distant past or future time points, and to people who are socially distant from us (Snefjella & Kuperman, 2015).
Possibly, the concept which has been most extensively studied is the concept of "time": the underlying rationale is that, since "time" is an abstract concept, it can be understood 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) have shown 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, whereas when they are at the end of a trip, or of a line, they use a time moving perspective. This result indicates that space and time are strictly interwoven. The perspective adopted varies depending on the spoken language. Asking the 'same' ambiguous question to Mandarin Chinese and English speakers Lai and Boroditsky (2013) have found that while English speakers tend to adopt an ego moving perspective and Mandarin Chinese monolinguals a time moving one, bilinguals shift between the two perspectives.
The proposition that we use the concrete concept of space to reason and understand the abstract concept of time seems to be confirmed by the observation that in language use 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) have demonstrated the asymmetrical relationship between space and time, showing that distance affects duration, but duration does not influence distance.
That space and time are strictly related has been further supported by a variety of cross-cultural studies. 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". Consistent with the metaphors used, English-speakers estimates of time 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 behind us, the future is ahead of us), while the frequent use of vertical metaphors in Chinese has led Chinese Mandarin speakers also to conceive time 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 Mandarin 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 disposed horizontally, and bilinguals had an intermediate performance. Though this study has been seen as very influential by advocates of embodied cognition, a failure to replicate these findings has also led to skepticism (see Chen, 2007).
A recent study challenged the assumption made by the Conceptual Metaphor Theory that there is only an unidirectional influence from sensorimotor experience to metaphors (Slepian & Ambady, 2014). If participants had been exposed to the metaphor that the past is heavy, they tended to estimate old books as heavier, whereas if they had been exposed to the metaphor that the present is heavy, they perceived new books as heavier. Thus, novel metaphors can influence sensorimotor processes, which suggests that the influence between metaphors and sensorimotor states is bidirectional.
It should be noted that time is related not only to space, but also to number, and that 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 a point on 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 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 in 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. Recent evidence shows however that English-speaking people systematically combine future-in-front and future-to-right metaphors while gesturing, suggesting that the conceptual representation of time involves the activation of multiple metaphors rather than the selection of one single metaphor (Walker & Cooperrider, 2016). 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 Hebrew speakers (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 at the center 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 Theory of Magnitude (ATOM) and the Conceptual Metaphor Theory (CMT) views.

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 to be contrasting views, likely due to the different disciplines in which they developed (ATOM in neuroscience, CMT in linguistics and psychology) and to their differing focus. However, it is possible that they can be bridged: according to Winter et al. (2015), ATOM is better at explaining low level associations that are independent from language, while CMT is more precise in accounting for higher level associations mediated by language. This suggestion should be investigated further, as it would have interesting implications for our understanding of abstract and concrete concepts.

Strengths and limitations.

In comparison to other theories, the Conceptual Metaphor Theory has a number of advantages that have contributed to its standing as the most influential embodied theory on abstract concepts. Its most important strength is that it proposes a mechanism underlying the formation and use of abstract concepts, rather than arguing that a specific content characterizes them. However, the scope of such a mechanism is limited to specific conceptual domains. Using concrete-abstract mappings to understand the meaning of abstract concepts is possible only if there are adequate domains to be mapped in the first place. For example, one could question the adequacy of the space-time mapping. The very abstract idea of a general spatial container for all objects is neither simple nor direct, and it is debatable whether it can be considered as concrete.

Furthermore, it is unclear whether it is always possible to find concrete domains corresponding to abstract ones. For example, it is difficult to think of concrete domains suitable for mapping 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 stars": one crucial aspect of the sea is that it is liquid, but this aspect is not relevant for the mapped domain. 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 their differences: life after all 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)?

In sum, even if conceptual metaphors can play a role in the representation of abstract concepts, it is not necessarily so: many abstract conceptualizations do not seem to rely on concrete domains; furthermore, metaphorical mapping is likely to contribute 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, and not only 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 Conceptual Metaphor Theory.

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 around 10% of the words used by 2 years-olds 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 Conceptual Metaphor Theory, neural evidence is still lacking. For example, it is unclear how the Conceptual Metaphor Theory could explain the results of brain imaging studies showing that differences exist between metaphorical and abstract concepts (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 words with literal or metaphorical spatial associations (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 rapid and automatic manner.

In conclusion, the influence of the Conceptual Metaphor Theory is clear. However, while there is evidence supporting this theory, there are a number of gaps that suggest the need for a more systematic approach; in particular, it is difficult to foresee that metaphors can be used in all domains where abstract concepts exist, and it does not seem plausible that the meaning of abstract words can be entirely explained by metaphors.

Introspective and situational properties.

According to this view abstract concepts, in comparison to concrete 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.

Barsalou and Wiemer-Hastings (2005), for example, 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 focussed ''*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. These

results highlight that context availability per se is not unique to abstract concepts, since concrete concepts also 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; Gentner & Boroditsky, 2001; 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 in connecting 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 the recognition of superordinate category members more than of the members 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) casts doubt on the relational character of all abstract concepts, and also highlights that context impacts processing in only some kinds of abstract concepts. Participants were presented with short scenarios, and were then asked to perform a lexical decision task on abstract words that were not mentioned during the scenario description. The scenario 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) have provided evidence supporting the introspective and situational view, but also limiting its explanatory value 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 indicated 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").

Zwaan (2015) has built upon Barsalou and Wiemer-Hasting's view on abstract concepts and situations. He has 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, we can instead consider the expression "Now justice is served". This expression is characterized by a high level of ambiguity, as context to which it will be associated it is not yet clear . In such a case, the abstract concept can work cataphorically to provide a focus to help textual comprehension, in a similar way to pronouns. 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", that can help to integrate sensorimotor information acquired later (Zwaan, 2015). This interesting proposal points out that concepts can differ depending on whether or not they are presented in isolation, and when they are introduced in a discourse.

However, even if the author presents this explanation as an extension of the view according to which contextual information is less focal for abstract than for concrete concepts (Barsalou &

Wiemer-Hastings, 2005), this perspective seems to be more in line with the multiple representation theories. Zwaan (2015) appears indeed to assume that an interplay between sensorimotor, emotional and linguistically conveyed information occurs, at different moments in time, in line with such theories (see also Zwaan, 2014 and below).

Strengths and limitations.
In common with many of the theories evaluated within this review, the introspective and situational properties theory has strengths but also gaps in relation to its applicability and explanatory power. The hypothesis that abstract concepts activate introspective and social-situational components, has the advantage of being rather general and it can be applied intuitively to a wide range of concepts, from mental states to social concepts and to purely abstract concepts. However, as we have seen, the role played by context and by introspective properties varies in function of the content of specific concepts. A further limitation that weakens the validity of this theory is that, so far, evidence favoring this view has mainly been confined to property generation tasks (Pecher et al., 2011), and, further, that supporting evidence obtained with different paradigms is needed. More importantly, in this theory, introspection is conceived as a form of conscious self-awareness, which provides a severely biased image of the relevant process. Indeed, it is possible that a more implicit form of metacognition plays a more extensive role in grounding abstract concepts (Frith, 2012), similar to the role it plays in supporting social interaction (Bahrami et al, 2010). In other words, the main limit of this view is that the mechanisms of this internal grounding have not been fully elucidated. For example, it could be hypothesized that, the more abstract a concept is, the more it requires grounding on information of internal states and processes (and possibly also some forms of internal speech), or that the more abstract they are, 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.

Affective Embodiment Account (AEA).
A third perspective we will evaluate is the Affective Embodiment Account (AEA) and we will show that it provides important evidence that abstract and concrete concepts differ. The Affective Embodiment Account is a new theory which hypothesizes that abstract concepts evoke more emotions than concrete ones (e.g.Vigliocco et al., 2013; Kousta et al., 2011). The Affective Embodiment Account 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 experiences that characterize them. While perceptual and motor experience is more crucial for concrete concepts, affective experience and emotional development is more important for abstract concepts. Emotional development is presented as the basis for the acquisition of an abstract vocabulary: the Affective Embodiment Account proposes 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, we will assess the behavioral and brain-imaging evidence supporting this view. 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 such as familiarity, concreteness, abstractness, context availability (see Context Availability Theory, CAT), imageability (see Dual Coding Theory, DCT), and age of acquisition. Words were also controlled for mode of acquisition (Della Rosa et al., 2010; Wauters et al., 2003). Mode of acquistion determined whether the word was acquired perceptually (e.g. by interacting with the object it refers to; “bottle”), linguistically (e.g. by 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 to say, once imageability and context availability are 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, classical theories such as the Context Availability Theory or the Dual Coding Theory cannot account for these data. Even if the Dual Coding Theory 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, emotional connotations should be more frequent with concrete than with abstract concepts (Vigliocco et al., 2013). In addition, given that modality of acquisition was kept constant, they argue that differences in activation of linguistically conveyed information do not exhaust the differences between concrete and abstract concepts, and that emotions play a major role in abstract concept representation. Valence however does not seem to exhaust the meaning of abstract words: the advantage of abstract words in accuracy was still maintained even when the effect of valence was removed. This might be due to the role played by linguistically conveyed information for abstract concepts. Furthermore, controlling for valence can lead to conflicting results: in a recent ERPs study with stimuli controlled for imageability, context availability and valence, the abstractness effect was replicated in response times but a reverse concreteness effect was obtained with ERPs (Barber et al., 2013). fMRI results further support the Affective Embodiment Account, but here too there is controversial evidence on the role played by valence. 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) have been questioned by Skipper and Olson (2014) who confirmed that rACC responds to valence, but not to abstract words: controlling for valence they found that the right STS and right temporal pole were the only regions that remained exclusively responsive to abstract concepts.
Further evidence partially favoring the Affective Embodiment Account has been collected with patients with neurodegenerative diseases. Catricala' et al. (2014) submitted patients with Alzheimer's disease (AD) and with primary progressive aphasia (sv-PPA) to the same tasks (Della Rosa et al., 2014) using both concrete and abstract words. 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.

Strengths and limitations.
Overall, evidence favoring the Affective Embodiment Account is based on results obtained with different methods, from behavioral studies to fMRI investigations. An obvious conclusion 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 by arguing that emotion development precedes language acquisition. However, this could also be said for other cognitive abilities, for example novelty detection (see Crutch et al., 2013).

The Affective Embodiment Account, however, has three limitations with relevant implications. First, 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 with concrete but not with abstract words (Kuenecke, Sommer, Schacht, & Palazova, 2015). Another recent ERPs study with a lexical decision task with concrete and abstract verbs of different valence has 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). These results clearly contradict the Affective Embodiment Account, which would predict the opposite result. Second, the role of valence does not seem to account for all the variance, and thus it cannot offer an exhaustive explanation of the mechanisms underlying abstract concepts (see previous discussion of the behavioral results by Kousta et al., 2011, and of the fRMI results by Vigliocco et al., 2013). Third, it is possible that the results obtained were biased by the presence, within the sample of abstract concepts, of emotional concepts. Altarriba et al. (1999) (see also Setti and Caramelli, 2005) have contended that emotions represent a subset not to be included within abstract concepts, and have proposed that a trichotomy between abstract-concrete-emotional words exists rather than a simple abstract-concrete dichotomy.

Let us consider the issue from an embodied perspective. Emotions are very basic functions, activated by rather primitive stimuli, such as smell. Emotion concepts 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. It has been shown that the mechanisms underlying representation of emotions and of sensorimotor processes 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 play an important role in explaining purely abstract concepts, they are clearly insufficient to fully explain 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) have suggested that valence is not a characteristic limited to emotional words, but that it can be extended to many concepts. The claim that emotional aspects characterize abstract concepts is certainly plausible. However, it should be clarified whether the effects found depend on the inclusion of emotional concepts within the sample of abstract concepts, or whether they depend on a mechanism underlying the representation of all abstract concepts. Indeed, 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, rather, in terms of their specific characteristics. Unfortunately, they also share the same 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 is even more important to identify the mechanism underlying abstract concept formation and use, as well as which mechanism becomes more active as the abstractness level of a concept is raised.

Multiple representation theories

Multiple representation theories of abstract concepts represent a valuable and novel addition to current thinking and appear to be a promising avenue of research. Researchers who endorse this perspective have claimed that, even if abstract concepts are embodied in perception, action, and

emotion, they also rely more on re-enactment of linguistic experience. They also state that both sensorimotor and linguistically conveyed information is involved in the representation of concrete and abstract concepts, but that these pieces of information are differently distributed depending on the type of concept: perception and action information is more important for concrete concepts, emotion and linguistically conveyed information for abstract ones. As we will see, while all multiple representation views highlight the importance of language for abstract concepts representation, they characterize the role of language differently: language can be considered simply as a shortcut to access word meaning (LASS theory), or it can be given a more crucial role, as a means of improving thought processes (Dove's representational pluralism), and as a complex bodily and social experience (WAT theory).

This review will focus in particular on four multiple representation theories that are currently influential, or have the potential to be 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).

LASS (Language And Situated Simulation).

According to the Language And Situated Simulation (LASS) view (Barsalou et al., 2008), multiple systems underlie our conceptual knowledge. LASS focuses on the linguistic and the simulation systems, which continuously interact. Consider the word "cat". When we are presented with the word "cat", we first activate the linguistic system, recognizing the word form and producing associated words, such as "dog", "Siamese", etc. We then start to ground the concept, for example visualizing the cat and re-enacting our interaction with it.

As this example shows, according to the Language And Situated Simulation theory, the linguistic system is engaged to categorize words during their perception. During a linguistic task, such as lexical decision, the activation of linguistic forms peaks earlier, in line with the encoding specificity principle (Tulving & Thomson, 1973), While 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 the conceptual system more directly (Glaser, 1992; see also Paivio, 1986). Following 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, words work as "pointers" to the object, entity, or situation they refer to.

Property verification and fMRI research (review in Barsalou et al., 2008) has provided evidence for activation of the simulation system occuring in parallel with that of 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 localizer task, they were asked to produce word associations for different kinds of concepts (e.g. common objects such as "car", mental states such as "guess", abstract concepts such as "extension" etc.), and in the second task to imagine a situation containing the concept. Early phases of word generation in the silent property generation task activated the same brain areas involved during the first localizer task, i.e. areas typically involved during linguistic tasks, such as the left inferior frontal gyrus (Broca's area) and the right cerebellum. Late phases of word generation, however, instead activated the same brain areas involved during the second localizing task, i.e. brain areas that are typically active during mental imagery, such as precuneus and right middle temporal gyrus.

Although these findings are novel and very compelling, there exist some caveats. Given that fMRI has a scarce temporal resolution, further research on timing would complement and further the predictions of the Language And Situated Simulation view. 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 only activated later, during activation of the simulation system, as the LASS theorists suggest. The activation of Broca's area (see Rizzolatti & Craighero, 2004, for a review) could instead be evidence of the activation of the motor system to prepare for a situated action.

In addition, the Language And Situated Simulation theory 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, this conclusion is not proposed by the Language And Situated Simulation, even if is consistent with its principles. In contrast, LASS theorists claim, on the basis of fMRI evidence (Wilson-Mendenhall et al., 2013), that both concrete and abstract concepts activate a mixture of simulation and linguistic form information, that 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''). They were then asked to verify whether the concept applied to the picture of a scene (e.g., a politician speaking) presented to them. This study showed that the brain areas related to the content of the concept were active, and that concrete and abstract concepts activated non-linguistic semantic information. For example, the concept "convince" activates brain areas related to mentalizing, and the concept "arithmetic" areas related to numerical processing. However, the lack of activation of linguistically conveyed semantic information can be biased by the fact that in this study words were processed only in relation to a subsequently presented picture. 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 Language And Situated Simulation theory argues for "multiple representation" of both concrete and abstract concepts, stating 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 one simply to decide whether a word exists or not, activate the linguistic system more, while imagination tasks activate the simulation system preferentially.

Strengths and limitations.

The Language And Situated Simulation (LASS) is an important proposal because it is, to our knowledge, the first fully embodied theory that recognizes the importance for concepts of not only perception, action, and emotions, but also of language. Compared to the perspectives we have previously outlined in this review, LASS has a further strong advantage that 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 limitation of LASS is that it argues that language is simply used as a shortcut to access meaning, and it is implied that shallow linguistic tasks do not allow access to meaning. This is contradicted by evidence suggesting 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 the Language And Situated Simulation view, is devoted specifically 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). More recently, Dove (2011, 2014) has suggested that both abstract and concrete concepts are embodied, although to different extents. This

view can, however, be considered as being hybrid in nature, as 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 for some amodal representations.

Dove's theory relies on Paivio's (1986) Dual Coding Theory, and can be considered as the attempt to return some important aspects of DCT to the forefront by adopting an embodied framework. Dove clarifies that his theory departs from Paivio's view in that 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 in the same way as symbols. These symbols can be multimodal, schematic, and they are not necessarily conscious. Language plays a major role in abstract concepts representation. According to Dove, linguistic representations are only partially embodied. They are embodied because they rely on sensorimotor simulations, but they acquire meaning not because of this form of embodiment, but because of their relationship with other words. In this sense, this view is also close to distributional approaches, according to which meaning is derived from associations between words (e.g. Andrews et al., 2014).

The prevailing 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 Dove, a fully embodied account of the syntactic, morphological, and phonological structure of language is unattainable: 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 damage of the left hemisphere 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 concepts. His conclusions are further supported by fMRI studies that have shown 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 both with the view that linguistic representations are modal and with those claiming that they are 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 levels 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 Affective Embodiment Account: while it partially solves the problem of disembodiment, showing that abstract concepts are also grounded in bodily states, it seems unable to handle 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, such as "animal"?), and to explain why sensorimotor experience is so crucial for some concepts and less so for others.

Strengths and limitations.

The theory proposed by Dove has many advantages, among which is the important recognition of the role played by linguistic experience in conceptual processing. However, in common with many theories presented in 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). He then argued that even if abstract concepts activate sensorimotor simulations, 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 relation between this view and the fully embodied the Words as Social Tools (WAT) proposal, which will be discussed later in this review, should be further explored. At a general level, the two theories partly overlap, since both claim that concepts can either be associated mainly 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 Words as Social Tools (WAT) view, and it helps in clarifying why language is helpful to represent abstract concepts. However, the two theories differ in their level of embodiment and in the space they leave for amodal representations. According to Dove (2011), his accounts differs from the Words as Social Tools (WAT) view "*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 anoth*er *source of information about the world but is also another way of "thinking about the world.*" While we fully appreciate the idea that language can contribute to improve our thinking capabilities, we believe that proposing to leave room for amodal representations, as Dove does in his proposal, risks incuring the symbol grounding problem that we discussed in the Introduction. In our view, this is a problem shared by all non-embodied, but also by all hybrid approaches to cognition. The amodal and arbitrary nature of language has been recently questioned by studies on iconicity in spoken and sign languages, showing the similarity between some characteristics of words and some features of their referents. It is the case of sound-shape correspondences: for example, words with rounded vowels – such as "bouba" or "maluma" - as typically used to refer to rounded shapes, words with unrounded vowels – as "kikki", or "takete" - to jagged shapes) (Gentilucci & Corballis, 2006; Maurer, Pathman & Mondloch, 2006; Perniss & Vigliocco, 2014). In addition, we believe that not only amodal symbols, but also grounded symbols possess combinatorial properties and can exhibit productivity (Barsalou, 1999). Grounded linguistic symbols exhibit, in our view, all the properties allowing them to support our thought processes. Finally, if with amodal symbols Dove refers to symbols represented in brain areas where information is integrated, we prefer to intend convergence areas in the brain (Damasio,

1989) as areas where multimodal information converges. The debate is obviously open, and new evidence is needed to provide definite answers, but we think that the most promising direction of research to explain abstract concepts is one that not only emphasizes the importance of language, as Dove's theory does, but that also conceives language as a fully modal and embodied system, as Dove's theory does only in part.

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. In common with the Language And Situated Simulation (LASS) theory, it is a fully embodied view, since it maintains that sensorimotor simulations need to be activated in order to grasp meaning.

We, however, will consider this as a weak embodied view, similarly to the Language And Situated Simulation theory, because it argues that not only sensorimotor, but also linguistic areas – specifically, areas related to auditory processing, language production and phonology, etc. - and social areas, for example areas engaged during recognition of known others, are involved in representing the meaning of abstract concepts.

According to the Words as Social Tools (WAT) proposal both concrete and abstract concepts are embodied. At the same time in the case of abstract concepts grounding in sensorimotor systems is not sufficient. In contrast to other theories emphasizing the role of language, the Words as Social Tools view considers not only the importance of word associations in explaining meaning. Consider the distinction between kinds of linguistic information we proposed at the beginning of the review: this proposal assumes that embodied forms of all kinds of linguistic information, i.e. of linguistically conveyed information, linguistic form information and syntactic linguistic information, concur in their representation. Furthermore, this theory focuses also on the experience of language use itself, emphasizing the role of the social dimension in word acquisition. In this view, both concrete and abstract words are seen as social tools that help us to interact with others, and with the physical and social environment (for a more radical recent theory directly inspired by WAT that further elaborate similar themes see the Words as Cultivators (WAC) view - Schilhab, 2015a, b).

The Words as Social Tools (WAT) proposal has four main tenets, and these will be evaluated in light of recent evidence (for an overview of the theory, see Borghi & Binkofski, 2014). The first principle is that concrete and abstract concepts are characterized by different acquisition modalities (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 rather have sparse and diverse referents, they will be acquired both through sensorimotor experience and linguistic input. In addition, the physical environment is less available as a scaffold to support the acquisition of abstract concepts than is the case for concrete ones: language itself plays a scaffolding role for abstract concepts. Literature on Modality of Acquisition (MoA: Wauters et al., 2003) shows that some words are acquired mainly through sensorimotor experience (e.g. "bottle"), more abstract words are mainly acquired through linguistic input (e.g. "philosophy"), while still other words have an intermediate status (e.g. "tundra"). 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, at a time when children have already mastered many words. 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 Words As social Tools (WAT) view contends that, while for concrete words children may simply (or mostly) base themselves on associative mechanisms between words and their referents, learning abstract concepts is likely to require not only linguistic knowledge, but also sophisticated social abilities. Importantly, not only the linguistic but also the social competence (Tomasello & Akhtar 2000) are particularly relevant for learning abstract words, since the selection of their referent is more difficult: it is not by chance that they were called "hard" words! (Gleitman et al. 2005; Gentner, 2006; Gillette et al., 1999; Wauters et al., 2003). 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 concepts start to be comprehended in correspondence with the emergence of some important social abilities: the ability to follow the gaze of others; and the capability to develop forms of joint attention allowing children to determine what they and the adults "know together" (Carpenter et al., 1998). Literature on testimony found that pre-school children are willing to receive clarifications from adults, and that at around three or four years of age 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), such as those of abstract concepts.
The second principle of the Words as Social Tools (WAT) view is that different acquisition modalities influence the conceptual representation in the brain. Given the diversity and sparse character of their referents, abstract concepts should engage brain areas that are more distributed and less focused than those associated with concrete concepts (see Rodríguez-Ferreiro, Gennari, Davies, & Cuetos (2011) for consistent fMRI evidence with abstract verbs). According to the Words as Social Tools (WAT) view, 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 activation within the left inferior frontal gyrus (pars triangularis) and two foci within the left inferior parietal cortex, purely abstract word pairs (e.g. "to think of the idea") engaged the anterior part of left middle temporal gyrus, that is to say 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 limitation to the TMS study, as its interpretation remains partly speculative, since no control study was run with the mouth's MEPs. 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 concepts are represented in partially differing 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 the Words as Social Tools (WAT) view is that different acquisition modalities lead to different embodied counterparts. WAT predicts that, due to their link with language, abstract concepts activate the mouth-related motor system more, while concrete concepts, more linked to manipulative actions, activate hand-related motor system more. This prediction has been supported by two studies (Borghi et al., 2011; Granito et al., 2015) in which participants were taught new

categories and then novel labels and by a study in which participants were required to decide whether abstract and concrete definitions matched with concrete and abstract concepts (Borghi & Zarcone, 2016).

Borghi et al. (2011) operationalized concrete categories as novel 3D objects presented on the computer screen, which differed in color and shape, and 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. A subsequent property verification task ("is XX a property of CALONA?") revealed that, while responses to concrete words were faster with the hand, i.e. when participants had to press a key on the keyboard, abstract words were facilitated with responses with the mouth, i.e. 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 the Words as Social Tools (WAT) view was provided by Granito et al. (2015), who replicated the mouth advantage with abstract concepts. In this study novel names and explanations of the category meaning were introduced by a researcher in order to mimic the social situation that typically characterizes conceptual acquisition. Results revealed that, with abstract words, participants who had undergone the linguistic training performed better than the other participants when they were required to respond with the mouth (microphone) in a categorical recognition task ("Do XX and YY belong to the same category?") (Granito et al., 2015).

Further rating studies in which participants were asked how much different effectors were involved with action wth target words/sentences confirmed the association between abstract concepts and the mouth. Granito et al. (2015) and Borghi and Zarcone (2016) found that participants associated concrete categories with the hand, and abstract categories with the mouth. Ghio et al. (2013) found convergent results: they showed that while abstract concepts related to mental states and emotions are more associated with the mouth, number concepts are more associated with the hand, probably due to the influence of finger counting on numerical cognition (Fischer & Brugger, 2011; Ranzini et al., 2011; see also Moseley, Carota, Hauk, Mohr & Pulvermüller, 2012, for fMRI evidence showing that abstract emotional words, beyond limbic regions, engage areas of the precentral cortex activated somatotopically by mouth and hand words, and Moseley, Shtyrov, Mohr, Lombardo, Baron-Cohen, & Pulvermüller, 2015, for evidence on the reduced brain activation with abstract emotion words in motor areas and cingulate cortex in Autism Spectrum Condition). Consistent results with numbers were found by Grade, Badets, and Pesenti (2016) who recently asked participants to randomly generate numbers after observing stimuli representing aperture or closure of fingers, mouth and hand. They found that number meaning is mainly grounded in mechanisms linked to finger control; mouth influence was limited to opening, and led to an overproduction of large numbers. Borghi and Zarcone (2016) recently performed the first behavioral study in which the association between abstract words and the mouth was demonstrated with real words and with an implicit task in which response times were recorded. Participants were asked to decide whether abstract and concrete definitions presented as prime matched with abstract and concrete target words using a device to press within the teeth or pressing a keyboard with the index finger. Response times with the mouth were overall slower, likely due to the device used, but the advantage of the hand over the mouth responses was more pronounced with concrete than with abstract target-words.

fMRI studies have provided further evidence potentially in line with the Words as Social Tools (WAT) proposal, and have shown 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). The left inferior frontal gyrus region is involved in language production and phonological processing, in subvocalization (Fiebach et al., 2007), for example during processing of pseudo-words in lexical decision, or in working memory maintainance (Petrides, 1994); a TMS study has shown that lexical decision with abstract words was less accurate after stimulation of this area (Papagno et al. 2009).

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 from Hoffman et al. (2015) confirmed that concrete concepts are more associated with visual experience and abstract with acoustic experience, as revealed by the higher activation of dorsolateral temporal areas for abstract concepts and of ventromedial temporal areas for concrete ones, while both kinds of concepts converge in activation of ventrolateral anterior temporal lobe (ATL). Further fMRI evidence with an orthographic judgement task is in line with the Words as social Tools (WAT) view. It revealed that, compared to concrete concepts, additional language areas were engaged by abstract concepts in bilateral superior temporal and bilateral middle temporal region (Kumar, 2015).To summarize, fMRI studies converge in showing a higher engagement of the left inferior frontal gyrus, typically engaged for language production and phonological processing, of the superior temporal gyrus, involved in auditory processing but also in social cognition (see Martin, 2016, for showing how social/emotional concepts are grounded in a circuit connecting anterior temporal and prefrontal regions, crucial for social functioning), and of the middle temporal gyrus, which is engaged during language comprehension while reading and during known faces recognition. The behavioral results on the activation of the mouth and the activation of the brain areas we have described are compatible with the idea that to access the meaning of abstract words we re-enact previous acquisition experiences of the word, and also internally rehearse words or re-explain their meaning to ourselves. This can occur at least in part through internal language. Further fMRI data has revealed that not only linguistic areas are activated, but also areas related to experiential components, such 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). Overall, neural evidence reveals, in keeping with the Words as Social Tools (WAT) view, that 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 the Words as Social Tools (WAT) proposal is that given the crucial role of language in the formation of abstract concepts, these are more likely to be influenced by differences between languages than concrete concepts. For example, Malt et al. (1999) have shown that the concrete concept of "container" is highly variable across languages in terms of naming but not in terms of knowing: when Chinese-, Spanish- and English-speaking participants were asked to perform a sorting task, the crosslinguistic variability disappeared and they adopted the same criteria in grouping containers. In contrast, much evidence has revealed that the abstract 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 Mandarin Chinese, but the horizontal for North American participants (see Borghi & Binkofski, 2014, for an analysis in depth of this aspect).

Strengths and limitations.

The Words as Social Tools (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 the concepts are, the greater is the linguistically conveyed and linguistic form information that should be necessary to compensate the reduced perceptual experience and to keep together their different members. Being an embodied theory, the Words as Social Tools (WAT) view does not suggest that this mechanism, i.e. the activation of linguistically conveyed and linguistic form information, is in contrast with the fact that abstract concepts activate their content. Another strength of the Words as Social Tools (WAT) view over other theories, is that it focuses not only on conceptual representation but also on word acquisition. It has the potential, therefore, to unify two separate streams of research, the first being word acquisition in children and the second representation of abstract concepts in adults.

Evidence on both acquisition and brain organization confirms the importance of linguistically conveyed information and of linguistic form information for abstract concepts. However, while the claim that conceptual acquisition influences conceptual representation in the brain is very strong, it remains speculative, and should be further developed and investigated. In addition, the concept of modality of acquisition should be further analyzed to solve the dilemma of whether what counts is only the initial acquisition or also the 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 written texts, such as when we read information on Wikipedia?
One final limitation of the Words as Social Tools (WAT) proposal 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 infant and child acquisition should be conducted, as should 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 here is Grounding and Sign Tracking, which is very close to the Words as Social Tools (WAT) view we have just discussed. The philosopher 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 both concrete and 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: one person gets two cookies, another person three. Grounding concepts in situations might not, however, hold for all abstract concepts. Besides sign tracking, we may adopt other strategies which include metaphorical projection (see the Conceptual Metaphor 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 words we need to ground them. Crucially, Prinz has highlighted the importance of both mental imagery and verbal skills in accessing the concept meaning. Overall, he contends that comprehending abstract concepts implies the capacity ''to match mental images with reality and sentences with testimony'' (Prinz 2012). A novel aspect of his theory is that he underlines the importance of testimony for getting the conceptual gist: for example, to learn the concept of "democracy" we need to track definitions used by authoritative members of our community.
Strengths and limitations.
This theory proposed by Prinz has, in our view, many advantages. This perspective not only identifies some underlying mechanisms but highlights a range of 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 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 also extends to language. An important and novel aspect that characterizes his theory is the role it ascribes to testimony: in order to understand the meaning of abstract concepts we may need to refer to authoritative members of our community.
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 more of a proposal 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 a possible means to perform actions. However, the proposal could be extended to include these aspects.

Multiple representation views: further evidence.

As made clear in the course of the review, multiple representation views are emerging as the theoretical frameworks with the potential to solve the challenge of abstract concepts. Specifically, we believe that the most promising directions of research are inspired by those multiple representation views that combine a fully embodied approach with the recognition of the importance of language intended not only in terms of word associations but in its holistic aspects. We will now illustrate some recent studies that further support multiple representation views, showing that - depending on the task and on the level of processing it implies - different kind of information is activated. Specifically, we will focus on studies that highlight both the role of emotions and the pivotal role played by language for abstract concepts.

Recent 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 in general, also revealed that its relevance is not unique to abstract concepts. In a series experiments Moffat et al. (2015) instructed participants to complete four tasks; firstly to read aloud only abstract words, secondly to read aloud only concrete words, thirdly to name aloud all words that appeared on the screen, and finally to name aloud all words, when concrete and abstract words were separately presented and blocked for emotions. The 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. Context availability played a facilitatory role for both kinds of concepts: this suggests that it it is not a unique dimension of the first, but that it plays an important role for conceptual processing overall. Emotions instead both facilitated processing of abstract words and inhibited processing of concrete words: this reveals that emotions play an important role for abstract concepts (see also Newcombe et al., 2012). Even if this evidence is read by the authors as consistent with the emotion-based view, it seems to us that it is only partially consistent with it. Indeed, it shows that 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 abstract concepts benefit from rich linguistic contexts, while concrete concepts benefit from rich physical contexts. Thill and Twomey (2016) demonstrated that the variability of Age of Acquisition data can be hardly explained with traditional factors, and propose, in line with the Words As social Tools theory, that the degree of abstractness of a concepts depends on how much it goes beyond simple sensorimotor grounding, incorporating linguistic, social and also interoceptive features. In a recent study, Danguecan and Buchanan (2016) compared word recognition response times in four tasks requiring increasing depth of semantic processes, from standard lexical decision to sentence relatedness task. Manipulating abstractness (abstract vs. concrete words) and semantic neighborhood density (SND, high vs. low) they found that SND effects were always present with abstract concepts, but not necessarily for concrete ones. This evidence is clearly in line with the idea that linguistically conveyed information is crucial for the representation of abstract concepts (for converging evidence see also Goodhew et al., 2014).

Further evidence has 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, and 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 that evoked both a richer sensory experience and a more positive emotional experience. The results, which support multiple 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) showed an interplay between semantic and perceptual properties with abstract words referring to politics. Participants were more likely to evaluate words associated with conservatism as louder when presented to the right ear, and words associated with socialism as louder when presented to the left ear, even if the sounds did not differ in intensity. The association between left and socialism-related words and right and conservativism-related words was found also in a classification and a lexical decision task, controlling that the effects were not simply due to spatial compatibility (Farias, Garrido, Semin, 2016). Further work on political metaphors showed an influence of the left or right body balance on their attributions to political parties (Dijkstra, Eerland, Zijlmans, Post, 2014) Overall, 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 assessed in this section indicates that different experiential dimensions characterize abstract concepts. Multiple representation views, which are based on such an assumption, have for this reason multiple strengths. One of the most important is that by taking into account both linguistic and sensorimotor information, these proposals can provide a bridge between two approaches to meaning that were traditionally considered to be in opposition: the embodied and the distributional accounts.
As we have seen throughout this review, any embodied approach attempting to provide an explanation for abstract concepts, is facing 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, as anticipated in the introduction, distributional approaches are unable to solve the "symbol grounding problem" (Harnad, 1990) that asks: 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 the Affective Embodiment Account (AEA) and the Words as Social Tools (WAT) theories). 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 are not the only factors. Recent data, for example, has suggested that 60% of the temporal relations such 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, in our opinion, demonstrates that grounding of concepts is crucial to their full comprehension.
Multiple representation views have two further strenghts. The first is that they can utilize and explain neuropsychological evidence showing double dissociations between the mastering of abstract and concrete words. The second is that multiple representation views seem to us the only

approach able to deal with the different kinds and varieties of abstract concepts. We will discuss these issues in the next two sections.

Multiple representation views and neuropsychological evidence

Even if discussing this evidence in detail 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 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 herpes encephalitis (e.g., Warrington & Shallice, 1984): the results are rather inconsistent because according to some reports patients showed a mild reverse concreteness effect, i.e. their performance was better with abstract than with concrete concepts (e.g. Bonner et al., 2009). However, more recent studies in which imageability and frequency were controlled suggest that SD patients perform worse with abstract than with concrete words (Hoffman & Lambon Ralph, 2011; Giffard, Laisney, Desranges, & Eustache, 2015) (see also recent evidence on specific effects of mild amnesia while defining abstract words, Kim et al., 2015). The connectionist model proposed 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 weaker overall compared to concrete words.

It is worth spending 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 exists in the brain 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). Crucially for the present work, ATLs would play a pivotal role in representing abstract concepts (Pobric, Ralph, & Jefferies, 2009). Evidence on semantic dementia has been interpreted as favoring hybrid models, according to which modal and amodal systems concur in representing abstract concepts (e.g. Dove, 2015). We do not, however, believe that these data lead to an unequivocal conclusion. First, 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 only allow validation of a specific theory 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 remains open, even if explaining the impairment provoked by semantic dementia is certainly a challenge for embodied theories. Reviewing evidence on deep dislexia and semantic dementia, Shallice and Cooper (2013) contended that semantic representation of concrete and abstract words can be separable. They stated that the higher complexity of abstract concepts requires, at a minimum, mastery of high-level logical functions. For example, the concept of "bicycle" can be accounted for by the conjunction of features such as "is a vehicle", "has a seat and wheels", 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 have sufficient computational power 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, one 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 suggests that both concrete and abstract concepts are grounded in distributed action-perception circuits. A recent study on a double dissociation used a lexical decision task to show 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 indicates that sensorimotor systems are not peripheral for abstract concepts processing, and suggests that the two systems for concrete and abstract words are not completely separable but overlap at least partially. 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 characterizes the linguistic symbolic system, as suggested by Larry Barsalou in his seminal 1999 paper (Barsalou, 1999). A second possibility is to claim, as was 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 Dove (2015) considers this linguistic system to be amodal, we do not see the necessity to hypothesize a transduction from linguistic experience to an amodal form of representation.

Multiple representational view and multiple kinds of abstract concepts

Many studies favoring multiple representation views have contended that different systems might be activated, depending on the task. For example, according to the Language And Situated Simulation (LASS) view 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 lines, 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 on investigating fine-grained distinctions between sub-kinds of abstract concepts. It is indeed possible that, in a similar way to what happens with concepts referring to sensorial experiences such as taste (Simmons et al., 2005), or odor, and with perceptual properties, such as 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 that 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). This study indicated 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 to determine a validated selection criterion that should be used universally within research to allow for replication of findings.

A promising novel manner 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 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 the Words as Social Tools (WAT) proposal). On the basis of the ratings a high dimensional semantic space was generated, where the semantic relatedness between concepts was represented in terms of the 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 together in the semantic space. It was also tested using the eyetracker with a visual word paradigm (Primativo, Reilly & Crutch, 2016).

This method of investigating subsets of abstract concepts was also used by Ghio, Vaghi and Tettamanti (2013) to evaluate whether different abstract concepts (mental state-, emotion-, mathematics-related concepts) involved different parts of the body (mouth, hand). They found that the three kinds of concepts varied across different dimensions. For example, emotion and mental states were similarly rated in 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 than the other concepts (see also Ghio, Vaghi, Perani & Tettamanti, 2016 for an fMRI study on the same categories).

Further studies have made use of feature generation tasks to identify differences between subtypes of abstract concepts. For example, Setti and Caramelli (2005) used a feature production task and found 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.

A further novel and promising way to identify sub-sets of abstract concepts is to investigate how different kinds of abstract concepts are encoded into signs by sign languages. 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 (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. 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, consistent with views that assign an important role to linguistically conveyed 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. First, these results show that, even if all examples are consistent with an embodied view, none of the current theories or proposals are of a sufficiently general nature to be able to account for all examples of abstract concepts. Even the Conceptual Metaphor Theory, 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 concepts Italian Sign Language exploits linguistically conveyed 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 corresponding 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 we have outlined have no merit. Instead, we suggest that all of them, even if to a different degree, contribute to a better comprehension of abstract concepts. However, to date no approach has proven 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).

Among multiple representation approaches, in our view the most promising ones are those that a.take into account the important differences in conceptual acquisition between concrete and abstract concepts; b. stress the importance not only of the linguistic but also of the social dimension for abstract concepts. Such an approach would imply a tighter interconnection between research on human sociality and its development, developmental research on conceptual acquisition, and behavioral and neuroscientific research on abstract concepts. Such an approach would be completely novel, and would go well beyond the proposed integrations between distributional and embodied approaches to abstract concepts that are becoming increasingly popular (e.g. Andrews et al., 2014).

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). We will first summarize the main characteristics that a successful theory of abstract concepts should display, discussing them in light of the proposals we have reviewed. We will then draw some conclusions and point to some open issues.

Toward an successful theory of abstract concepts

a. Focus on mechanism rather than on content. We think that an ideal theory should identify a mechanism rather than simply a content which characterizes abstract concepts. The most promising research directions, in our view, are offered by the proposals according to which both sensorimotor and linguistically conveyed information characterize abstract concepts. Even if we think that these theories are those from which more fruitful research directions can be derived, much work needs to be done: a clear specification of the mechanisms underlying the activation of linguistic, emotional and social information is needed.

b. Link between acquisition and conceptual representation. Any thorough theory of abstract concepts should make precise predictions on conceptual acquisition, and on how the kind of acquisition influences conceptual representation. Both the Words As social Tools proposal (WAT) and (partially) the Affective Embodiment Account (AEA) focus on how concepts are acquired, and on how this influences their representation. WAT focuses on the different modality of acquisition, AEA on the bootstrapping mechanism played by emotions. However, much needs to be done to further elucidate the relationship between acquisition and brain representation.

c. Role of "introspective" information for grounding abstract concepts (introspective and situational theory). Some form of metacognition is a feature that a systematic theory of abstract concepts should take into account. Interoception (perception of one's internal states and processes) is a form of experience that might play an important role, especially for abstract concepts. The introspective and situational theory appears to focus on such a mechanism, even though the kind of conscious self-awareness it implies can be misleading.

d. Explanation of cross-linguistic variability. It is important for a thorough theory of abstract concepts to provide clear predictions and to be able to account for the variability of the different kinds of abstract concepts across languages. While discussing the Conceptual Metaphor Theory and (partially) the Words As social Tools proposals, we have seen that these views formulate specific predictions on cross-linguistic differences in abstract concepts representation.

e. Generabilizability. A thorough theory should be able to account for all abstract concepts, in their differences and varieties, and differences in their degree of abstractness. Theories based on mechanisms are more promising than content based theories, since they can be extended beyond specific domains. However, as anticipated, it is an open question whether to date theories are able to explain abstract concepts of different domains.

Where the field is going

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, and will then 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. The major novelty in the field over the last few years has been represented by these views;
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 capable of explaining 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 underline the role of language for abstract concepts acquisition, focusing on language in its multifolded aspects, as a bodily, social and emotional experience, as well as to underline the role of language as a medium of thought, able to extend our cognitive abilities. This idea of language as a bodily and social experience is fully compatible with results showing a higher activation of the mouth with abstract concepts, and with brain imaging studies that indicate a higher activation of social cognition areas, and of linguistic areas involved in language production, in auditory processing, and in semantic processing. 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 the Affective Embodiment Account (AEA) theory) and social and linguistic (see the Words as Social Tools (WAT) theory) information;
d. while the most interesting perspectives in our view converge in showing that, compared to concrete concepts, abstract concepts are more (but not exclusively) characterized by social, emotional and linguistically conveyed information than by sensorimotor information, the most recent studies are also starting 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 we 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, that states that explanations based on a single strategy are insufficient and that we are now compelled 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 linguistically conveyed information, embodied theories highlighted primarily the role of sensorimotor information, and views derived from Paivio's Dual Coding approach proposed that sensorimotor information was important for concrete concepts, linguistically conveyed 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 Affective Embodiment Account (AEA) and by the Words As social Tools (WAT) theories. In addition, the research direction that reconciles embodied and distributional

theories of meaning, ascribing importance to both sensorimotor and linguistically conveyed 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 linguistically conveyed 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 also holds for concrete concepts. We hope to have shown that, even if concepts are arranged along a continuum, the distribution of these experiences differs substantially: 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 would appear that these different strategies may have 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 could explain why we perceive, rate and use abstract concepts in a different manner than with 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 to be at the root of the recent success of hybrid approaches, such as the revitalization of the classic vision of Paivio (1986).

While it is largely 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; see for a very recent proposal Reilly et al., 2016). 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 of explaining abstract concepts. In addition, explaining abstract concepts would not require the adoption of 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 meaning through the associations between words (distributional views: e.g., Landauer & Dumais, 1997; Lund & Burgess, 1996), or as a way to provide us with further computational abilities (Dove, 2014; Clark, 1998). However, language can be all 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 is likely to possess emotional and affective implications (Vigliocco et al., 2014). Language can help us to formulate predictions, and contributes to control our behavior (Lupyan & Bergen, 2016; Lupyan & Clark, 2015) and to improve our thought (Vygotsky, 1986). 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 bridging, for example, research from both developmental studies on language acquisition and studies on conceptual representation in adults, which have been 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 the attempt to reunify 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 our view the activation of all sorts of linguistic information, i.e. of linguistically conveyed information, linguistic form information and syntactic linguistic information, becomes more important as the level of abstractness increases. Furthermore, from what we have discussed above it should be obvious that the activation of linguistic information, is not in contrast with the activation of 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 it rich individual and social experiences.

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(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 are those that assume that only sensorimotor areas are engaged during conceptual processing; weak embodied views are those that assume that both sensorimotor and linguistic areas are engaged during conceptual processing; hybrid views assume that both embodied and non-embodied representations are activated.

	Difference between abstract and concrete concepts	**Level of embodiment**	**Multiple representation**	**Role of acquisition**	**Kind of evidence**	**Mechanism or content?**
Motor theory	No: abstract = concrete concepts	Strong	No: sensorimotor	Unspecified	Behavioral (ACE effect, approach-avoidance effect)	Mechanism, but limited for content reasons (e.g. to transfer sentences, or to valenced stimuli)
Situation and introspective view	Yes: abstract concepts activate more social aspects of situations and introspective properties	Weak	Not specified	Unspecified	Behavioral (Feature generation)	M echanism, but possible content limitations (e.g. introspective properties mainly activated for mental state concepts)
Affective Embodiment Account (AEA)	Yes: abstract concepts activate more emotions	Weak	Yes: emotional and sensorimotor; also linguistic (but not fully discussed)	Emotions as bootstrapping mechanism	Behavioral (Lexical decision), fMRI, ERPs, patients	Possible mechanism, but limited for content reasons (e.g. emotional properties more activated for emotional concepts)
Conceptual Metaphor View (CMT)	Yes	Strong	No: sensorimotor	Non plausible developmental trajectory	Mainly behavioral, linguistics and psychology	Mechanism, but limited due to content reasons
Language And Situated Simulation (LASS)	Yes	Weak	Yes: sensorimotor and linguistic (language as shortcut to access meaning)	Unspecified	Behavioral (feature generation), fMRI	Mainly content. Mechanism related to the task, not to the kind of

						concepts.
Representational pluralism: Dove	Yes: abstract concepts activate more linguistic information	Hybrid	Yes: sensorimotor and linguistic. Both modal and amodal codes. disembodied linguistic system.	Unspecified	Not direct (but indirect support from evidence supporting Paivio's dual coding model)	Mechanism
Grounding and sign tracking: Prinz	Yes	Weak	Yes: multiple strategies. Focus on sensorimotor, emotional, linguistic	Unspecified	Not direct (but indirect support from evidence on all the other theories)	Both content and mechanism, depending on the adopted strategy
Words As social Tools (WAT)	Yes: abstract concepts activate more linguistic, (emotional) and social information than concrete ones	Weak	Yes: sensorimotor, emotional, linguistic and social information	Very relevant: acquisition constrains representation	Behavioral (e.g. sorting, categorization, feature generation), fMRI, TMS, studies on sign languages	Mechanism:, not linked to the content but to the abstractness level (the more abstract concepts are, the more they activate linguistic and social information). It is not incompatible with content effect.