Anna M. Borghi[12], Chiara Fini[1], Luca Tummolini[2]

Abstract Concepts and Metacognition: Searching for Meaning in Self and Others

[1] Sapienza University of Rome, Italy; [2] Institute of Cognitive Sciences and Technologies, Italian National Research Institute

Accepted in June 2020 in the book:

Michael D. Robinson and Laura E. Roberts (Eds.): Embodied Psychology: Thinking, Feeling, and Acting. New York: Springer.

Abstract

Use of abstract concepts (e.g. truth) is one of the most sophisticated abilities that humans possess. Explaining how we develop this ability and how abstract concepts are represented constitutes one of the main challenges faced by theories of embodied and grounded cognition. In this chapter we address this issue by focusing on the mechanisms underlying the processing of abstract concepts. We propose that metacognition – the set of capacities through which an operating subsystem is evaluated and represented by another subsystem – can ground the meaning of concepts, and that this grounding is particularly important for abstract concepts. In addition, metacognition can be applied to concept use itself. In this connection, the monitoring component of metacognition is particularly relevant: it can provide awareness of the inadequacies of our knowledge of abstract concepts, expressing a judgment of scarce confidence. This monitoring process can lead to two different but not mutually exclusive outcomes. We propose that both these outcomes have an embodied counterpart, the activation of the mouth motor system. The first is the use of inner speech, which aims to search for possible further meanings and/or to further clarify the word meaning. The second is the preparation to request the help of other – better if authoritative – people (social metacognition): when our knowledge has gaps, the need of social deference is stronger.

Keywords: abstractness, abstraction, metacognition, social metacognition, grounding, deference, confidence, monitoring

Introduction: The Challenge of Abstract Concepts.

Using abstract concepts like “truth” might seem very complicated. And yet, more than 70% of the words used by adults are above the median of abstractness and can be considered abstract words (Lupyan & Winter, 2018). How are we able to develop such a sophisticated ability, and to use complex words in such a fluent way?

For current theories of cognition, and especially for embodied and grounded approaches, explaining abstract concepts is still an open challenge (Borghi et al., 2017). It is much easier to demonstrate that concrete concepts (e.g., "chair") are grounded in the sensorimotor system than abstract concepts, since the latter seem more detached from perceptual experiences. It is important to consider some of the conclusions arising from discussion of the embodiment of concepts. First, contemporary approaches reject a dichotomous contrast between concrete and abstract concepts: even concepts that appear more concrete involve abstract aspects and vice versa. Second, multiple views of representation have shown that the meaning of abstract concepts relies not only on sensorimotor experience, but also on other forms of experiences linked to language use (Dove, 2014; 2018; 2019), sociality (Borghi & Binkofski, 2014; Borghi & Tummolini, in press) and emotions (Newcombe et al., 2012; Vigliocco et al., 2014). Third, because abstract concepts are highly variable within and between individuals, it is crucial to study them in context rather than through isolated words (Barsalou et al., 2018).

Here, we focus on the mechanisms that might enable the complex ability to use abstract concepts. We will explore, in particular, the importance of metacognition for concepts in general and specifically for abstract concepts. After defining metacognition, we will illustrate its role at different levels. First, we will argue that metacognitive experiences and states can play an important but overlooked role in grounding the meaning of abstract concepts. Second, we will explore how metacognition can be applied to concepts themselves. We will contend that, because the meaning of abstract concepts generates higher uncertainty than that of concrete concepts, their use requires more extensive monitoring processes. These processes can be implicit, or they can have an explicit

outcome leading to the use of external resources to reduce uncertainty. In the conclusions, we will also highlight the importance of studying the dynamics of abstract concepts' use in real-time interactions (see Figure 1).

Metacognition: Grounding and Inner Search

Metacognition

Metacognition was classically considered as cognition about our own cognitive processes, "thinking about thinking" (Flavell, 1979) and "the monitoring and control of thought" (Martinez, 2006). Classical studies concerned how metacognitive strategies contribute to improving learning and memory. In keeping with this view, meta-memory and the implications of metacognition for learning and education were extensively investigated (Hacker et al., 2009). Studies on reading and writing in children have often emphasized the important function of metacognition for mastery of such abilities. For example, it has been shown that four- to six-year-olds who are fluent readers adopt more efficient metacognitive strategies than poor readers: instead of focusing only on phonological aspects to overcome comprehension difficulties, they integrate semantic, syntactic, and phonological cues (Brenna, 1995). Similarly, metacognitive abilities are considered crucial for writing skills, up to the point that Hacker et al. (2009) have defined writing as a form of applied metacognition.

In recent years, metacognition has also been investigated in relation to error detection and to the strategy changes adopted following the discovery of errors, such as slowing down response times (Yeung & Summerfield 2012). In this framework, metacognition does not refer only to higher order processes but more generally to "the set of capacities through which an operating subsystem is evaluated and represented by another subsystem in a context sensitive way" (Proust, 2013, p.4). It is a form of cognitive control in which one sensorimotor process implicitly represents a property of another (Shea et al., 2014).

Most studies have focused on two aspects of metacognition: the awareness of our cognitive processes and their control. Control processes involve two different components: the monitoring

component (e.g., awareness of whether cognitive processes are used in an effective way) and the regulative component (e.g., adoption of strategies to improve and repair eventual knowledge failures) (Williams & Hatkins, 2009).

In recent years other important areas of metacognition have also emerged. Many studies have focused on the relationship between metacognition and mindreading (e.g., Carruthers, 2009). Other studies have investigated meta-perception, that is, our judgments on how we are perceived by others (Lees & Cikara, 2019). Both areas can be relevant for abstract concepts—the first because of the importance of sociality for the acquisition and representation of abstract concepts, and the second because we might especially fear the judgment of others in relation to our competence in muddier and less clearly defined areas, such as those related to abstractness.

This chapter will address the relationship between metacognition and abstract concepts. We will start by proposing that metacognition can contribute to grounding of abstract concepts.

Metacognitive Grounding of Abstract Concepts

A basic tenet of embodied approaches to concepts is that our conceptual system is grounded in, and derives from, the perceptual and motor experiences that an organism recurrently has while interacting with its physical and social environment. According to one of the most influential theories (Barsalou, 1999; Barsalou et al., 2018), however, besides this well-explored sensorimotor grounding, concepts can also be grounded in the re-enactment of "introspective" states acquired during our experience *with our own mind and body*.

Although the domain of introspective experiences—at least according to Barsalou—is on par with those of perception and action, it has received much less attention in the literature. One possible reason for this limited interest is that under the label of introspection, Barsalou originally included a disparate set of processes belonging at least to three different domains: *motivational and affective information*, *interoceptive information* about the physiological condition of the body, and *metacognitive information* about other object-level mental states and processes like perception, memory, learning, reasoning, etc. Even if these domains of experience differ along multiple lines,

their being primarily oriented to our inner world—and only indirectly to the outer environment—has motivated the conjecture that introspective experiences might be "central to the representation of abstract concepts" (Barsalou, 1999, p. 600). Recent evidence has provided empirical support to this conjecture showing that, relative to more concrete ones, abstract concepts might in fact be more grounded on affective (Vigliocco et al., 2014) as well as on interoceptive experiences (Connell et al., 2018; Villani et al., under review). These forms of experience might be related: for example, according to James (1884), emotions are given by the awareness of our interoceptive feelings. Still, whether and how metacognition can ground abstract concepts in a similar way has not been systematically explored.

Intuitively, the primary semantic domain where metacognitive information could play a grounding role is in that of *mental state* concepts since they explicitly bear meta-level content—that is, their content is about mental states. The domain of concepts like "belief", "desire", "intention", "decision", etc. is the one that we employ to explain and justify our own mental states and behavior as well as those of others during social interaction. This is the kind of explicit mindreading that children begin to systematically display from age four on (Apperly & Butterfill, 2009; Wellman et al., 2001), and which, while crucial to competently participate in our society, does not necessarily reflect the actual functioning of the cognitive system (Frith, 2012). Indeed, it has even been argued that the mastery of this conceptual domain does not originate in an intimate experience with one's own mind at all but is instead a culturally inherited skill acquired through expert tuition and verbal instruction (Heyes & Frith, 2014). Assessing this and related proposals on the development of explicit mindreading (for another recent view see Tomasello, 2019) is beyond the scope of this chapter, but they are still sufficient to suggest that the grounding of mental state concepts might be much less transparent than often assumed.

There are more subtle ways, besides concepts with explicit metal-level content, in which metacognitive signals might be used to ground conceptual representations. Consider, for instance, the formation of predictions—the monitoring of prediction errors and their control to minimize

surprise—which is such a fundamental mechanism that it has been proposed as a unified principle of how the brain works at different hierarchical levels of organization (e.g., Friston, 2010). Signals monitoring errors in predictions and other mismatches are metacognitive signals (Shea, 2012). Since acquaintance with such (mis)match experience is available to infants from birth, if not before, it might be hypothesized that repeated metacognitive access to these internal events might actually lead to learning a "simulator" which can ultimately be used to ground high-level abstract concepts like "truth", "falsity", and any concept that entails a form of goal frustration like "anger" (Barsalou, 1999).

For another example consider how a basic understanding of "mine", "yours", and other concepts of property ownership might develop. Ownership of property has been considered as a prototypical abstract concept resisting an embodied explanation (Arbib et al., 2014) and a full-fledged ownership concept is probably the sophisticated product of cultural dynamics. However, some of its sensorimotor foundation has been uncovered (Constable et al., 2011), and it has been argued that the semantic core of ownership is ultimately related to the notion of control (Furby, 1980; Scorolli et al., 2018), which is fundamentally unobservable (Langacker, 2009). Tracing a plausible cognitive development of this control-based view, Furby has hypothesized that concepts of possession and ownership develop as a byproduct of the intrinsic motivation of children to effectively interact with the environment ('competence' motivation, White, 1959). Importantly, Furby has proposed that, during their first two years of life, infants learn to identify the objects in their environment that occasion feelings of efficacy and personal control to keep them apart from those that instead thwart such feelings. From the child's perspective, the former class of controllable objects becomes the category of objects that are understood as "mine", while the latter one includes those that are not. Crucially, casting this proposal in contemporary computational frameworks of reinforcement learning reveals that such a curiosity-based exploration of new skills relies on monitoring one's competence improvement (or lack thereof), which is a fundamentally metacognitive learning signal (Gottlieb et al., 2013; Mannella et al., 2018). Thus, in principle, even

metacognitive processes that monitor and control low-level cognitive processes can provide the kind of information that can be used to develop and ground higher-level abstract concepts.

Metacognition About Abstract Concepts: Current Literature

If metacognition about other target cognitive processes can ground abstract concepts, it can also be directed at concept use itself, and at the way we use abstract concepts in particular.
In the literature, the role of metacognition for concepts in general has not been systematically addressed. To our knowledge, the first proposal that directly links metacognition and concept use was advanced by Shea (2018; 2019). In his view, a concept has three potential sources of unreliability that may affect how it can be 'used' in cognitive functioning: how much information it encodes, how accurately it can categorize instances, and how "dependable" the concept is "as a basis for forming expectations" (Shea, 2019). A concept is more reliable the more correct expectations and the less prediction errors it generates. In his view basic level concepts not only maximize informativity and distinctiveness, they also elicit more expectations than superordinate level concepts. Notice, however, that lower level concepts might generate more expectations, but also generate a scarcer sense of confidence: for example, we might know what animals are, but we might not be able to define precisely what an ant-bear is.

These examples from Shea concern what we have called abstraction (Borghi et al., 2019; Borghi & Tummolini, in press). With 'abstraction' we refer to the fact that some terms, such as superordinate concepts, are more general than others (e.g., "animal-dog"); with 'abstractness' we refer to concepts such as "truth" and "freedom" that, differently from superordinates, do not activate a collection of single objects/entities. Elsewhere, we have claimed that abstractness and abstraction are interrelated but different.

Even if the relationship between metacognition and abstractness has so far received only scant attention (for exceptions, see Borghi et al., 2018; Shea, 2018), the role of metacognition has been underlined more generally for learning, including learning complex abstract abilities. One example is learning in the context of mathematical education. Holton and Clarke (2006), in their

analysis of mathematical education, distinguish conceptual and heuristic scaffolding, i.e., scaffolding related to the content to learn or to the strategies to adopt. This scaffolding can be provided by an expert, it can be reciprocal—in collective work, for example—or it can be individual. In their view, self-scaffolding can be considered the same as metacognition.

In sum: the relationship between metacognition and abstractness has not yet been extensively addressed. We contend that this is crucial to do and will motivate why.

Abstract Concepts and Uncertainty

Consider two different scenarios of understanding language. Someone says to his/her partner: "Coming back from work I bought zucchini for dinner" vs. "I am finally free (from a harsh deadline)". We do not argue that the first situation is entirely concrete and the second entirely abstract. In line with Barsalou et al. (2018), we think that the first statement involves some abstract elements: for example, the action of buying typically involves a monetary exchange, a buyer, and a seller. Similarly, the second situation is not completely abstract: it brings to mind a working place such as an office or factory the recipient will likely visualize that includes other actors such as a boss or colleagues with relations between them. Furthermore, both situations involve embodied aspects. However, in the first case it is easy to fix the reference of what has been said, while this is less true in the second case: what does it mean to be free? While in the first situation the concrete nature of the object referent might lead to a physical action of the recipient (or at least to its simulation), e.g., putting the zucchini in the fridge, the second will not. At the same time, an embodied response is possible in the second case too: the recipient might simulate the metacognitive experience of regaining a sense of agency, re-enacting interoceptive experiences. He/she might also start a linguistic action, by asking for clarifications, for example. In any case, in the second situation the listener/recipient is left with more uncertainty.

Consider now another example: the degree of uncertainty in the listener is higher if s/he hears "I saw an animal" compared to "a dog" or to "the dog of the neighbor". It is more difficult to prepare a (real or simulated) action toward an object/entity that is not clearly specified. This

uncertainty rests on the fact that the literal content of the sentence is more difficult to resolve, it is harder to link to a specific referent, and the linguistic meaning does not directly evoke a physical action. This might be different in the case of language production. If we see a visually degraded object, we can be more confident in saying, "it is a vehicle" (superordinate) than a "Fiat 500". Confidence might indeed be higher in using a superordinate than a lower level category (see Figure 2).

The aforementioned examples refer respectively to what we have called abstractness and abstraction (Borghi et al., 2019), arguing that they are two interrelated and yet distinct processes. However, the above examples show that both abstract and superordinate concepts ("freedom", "vehicle") generate higher uncertainty during word comprehension than concrete basic level concepts. A concrete basic level concept leads to less prediction errors and to a greater degree of confidence (Shea, 2019) in the listener.

Importantly, we are not claiming that implicit metacognitive evaluations only occur with abstract concepts. For example, we might be aware that the object in front of us is not a good member of the category "bottle" and we might not feel confident in forming a novel category. But the feeling of scarce confidence is likely more frequent with concepts whose referents are not clearly identifiable and perceptually bound. Take the notion of "metacognition" itself – we might be unsatisfied with its previous definitions, and be uncertain as to which processes belong to metacognition. The uncertainty on conceptual meaning might generate the need to learn more (Shea, 2019), a need that is particularly pronounced the lower our confidence in the conceptual meaning.

In our view more abstract words lead to a higher uncertainty, and this uncertainty has a double effect. On the one hand, we (at least implicitly) perceive this uncertainty, resulting in a confidence judgment. When we process abstract concepts, we might experience feelings of not knowing (or knowing) something, and tip of the tongue phenomena, all phenomena falling into the category of "procedural" metacognition (Proust, 2013). The outcome of these feelings results in

continuing the search. That is, when we are uncertain about the linguistic meaning, we continue searching for it. This search for meaning can occur in multiple ways – for example by using an online search engine, or by consulting a physical dictionary. We propose that another important way in which this search for meaning occurs is through inner speech, which allows us to access a range of meanings or to re-explain to ourselves the possible meaning. We contend that the identification of the meaning of concrete concepts, due to the availability of their referents, is considered reliable, hence assigned more weight. Ease of processing and better recall of concrete compared to abstract concepts—the well-known concreteness effect (Schwanenflugel et al., 1992; Paivio, 1990)—are signals of higher reliability and confidence. Why would we use inner speech to search for meaning? We hypothesize that using inner speech can play a predictive role, helping us to advance more possible alternatives, to better retain them in working memory thanks to the phono-articulatory embodied trace, and to better focus our attention. On the other hand, the feeling of scarce confidence can lead us to search for a solution outside ourselves, through a linguistic action directed to others. We will address this process in the section titled Social Metacognition.

Uncertainty and Inner Speech: Supporting Evidence

Two sources of evidence support the idea that we continue searching for meaning when encountering abstract concepts.

The first source of evidence is behavioral. We can ask participants to process concrete and abstract words using a task that interferes with inner speech in order to test whether this speech is activated: an ongoing inner speech process might reveal a further search for internal meaning. To explore this possibility, in a recent study (Zannino, Fini, Benassi, Carlesimo & Borghi, under review) we used articulatory suppression, asking participants to repeatedly pronounce a syllable at a fast pace while categorizing words as concrete or abstract. To control for possible dual task interference, we employed both articulatory suppression and an additional, nonverbal condition (Alderson-Day & Fernyhough, 2015; Baldo et al., 2005; Lidstone et al., 2010) in which participants were required to manipulate a softball. In a first experiment we directly compared concrete and

abstract concepts and found an interaction showing that articulatory suppression interfered more with processing abstract concepts, while the softball manipulation affected the processing of concrete concepts more. In a second experiment we introduced a baseline condition. In line with our predictions, we found that articulatory suppression, but not the softball manipulation, had a selective effect on processing abstract concepts, slowing down response times compared to the baseline condition. This evidence suggests that inner speech plays a substantial role during processing of abstract concepts.

The second line of evidence comes from neuroimaging. Brain imaging evidence highlights that during processing of abstract concepts we generally experience uncertainty. Meta-analyses (Binder et al., 2009; Wang et al., 2010) have revealed that, compared to concrete concepts, abstract ones activate primarily left inferior frontal areas. Specifically, most studies report selective activation of the left inferior frontal gyrus (LIFG) (mostly pars orbitalis, Broca area). LIFG activation is generally associated with phonological processes, lexical retrieval, and subvocalizations, and its activation in relation to abstract concepts has been associated with a longer time maintaining these concepts in phonological short-term memory (Binder et al., 2005). A searching process would be activated, similar to the one occurring with non-words (Acheson et al., 2011): abstract words would be kept in working memory, in a cycle involving both phonological encoding and articulatory planning. This view does not posit any separation between language comprehension and production (Pickering & Garrod, 2013). In keeping with it, evidence has shown that silent word reading (Topolinski & Strack, 2009; Topolinski et al., 2014) involves covert articulation of their sounds.

This evidence is in line with our proposal that abstract concepts are characterized by higher uncertainty, and to higher difficulty in prediction: we search longer for the word meaning, also through inner articulation. We hypothesize that this process of inner search involving the articulatory component of inner speech is strictly linked to semantics. Participants use inner speech

(Langland-Hassan, & Vicente, 2018; Vygotsky, 1934) to continue searching and trying to clarify to themselves word meaning.

Metacognition and Abstractness: Supporting Evidence

So far we have shown through implicit tasks that with abstract concepts we might search longer for the word meaning. The question arises, whether we are also aware that metacognition is especially crucial for more abstract concepts. To test for this, in a recent study we asked participants to evaluate 425 abstract words on a variety of dimensions, including abstractness, concreteness, imageability, mouth and hand activation, involvement of the 5 senses, interoception, emotional arousal, sociality, metacognition, and social metacognition (we will describe this dimension in the section titled Social Metacognition) (Villani et al., 2019). Relevant to this chapter is the relationship between judgments of abstractness/concreteness and of metacognition. Participants were required to evaluate the "metacognition valence" of words: they were told that their task consisted of rating how much the word evoked mental and cognitive processes or processes occurring in the brain more generally.

In line with our predictions, metacognition was positively correlated with abstractness ($r = 0.4$) and negatively correlated with concreteness ($r = -0.21$); it was also negatively correlated with age of acquisition and modality of acquisition ($r = -0.19$, $r = -0.22$, respectively), indicating that abstract terms scoring higher in metacognition were acquired later and through language more than through perception (Figure 3). Metacognition was more strongly correlated to other dimensions related to inner grounding, such as emotional arousal ($r = 0.65$) and interoception ($r = 0.5$); it was also positively correlated with contextual availability ($r = 0.43$), with audition, taste, and mouth involvement ($r = 0.28$, $r = 0.16$, $r = 0.42$, respectively)—suggesting that the monitoring process might have a sensorial component—and with sociality ($r = 0.27$) and social metacognition ($r = 0.19$). Overall, these results indicate that participants tend to associate metacognition with conceptual abstractness.

Development of Metacognition, Acquisition of Abstract Concepts

Abstract words are acquired later than concrete ones. Age of acquisition ratings indicate that at the age of 4 less than 10% of known words are abstract; abstract vocabulary has a dramatic increase and reaches more than 40% of words by the age of twelve (Ponari et al., 2018). In adults, words more abstract than the median represent more than 70% of the vocabulary (Lupyan & Winter, 2018). Interestingly, the pattern of development of abstract words has some similarities with that of acquisition of metacognitive abilities.

While according to early studies explicit metacognitive abilities (Proust, 2013) developed quite late, recent ones emphasize that even preschoolers older than three possess important metacognitive abilities such as the capability to regulate their thoughts and their emotional and affective states. Developmental studies provide some contrasting evidence, but all models postulate substantial improvement in metacognition during the first six years of life, with a dramatic increase at ages three to four. For example, Schraw and Moshman (1995) propose that six-year-olds already reflect on the accuracy of their knowledge, consolidating these abilities around eight to ten. Next appears the ability of regulating cognition, with a marked development around ages ten to fourteen. Relevant for us are studies linking metacognition with epistemological comprehension (Kuhn & Dean, 2004): around age four children start to acknowledge that one person might be right and another wrong and with adolescence they develop diversity of opinions.

Overall, the pattern of development of metacognitive abilities seems to reflect that of abstract concepts, with a marked improvement around four to five years of age and then after eight (Ponari et al., 2018). One could speculate that the necessity to develop metacognitive abilities is among the causes of the later acquisition of abstract compared to concrete concepts.

Summary

Abstract concepts are more difficult than concrete ones, owing to their higher detachment from sensory modalities and to the fact that they refer to varieties of sparse situations rather than to a single, concrete referent. We propose that metacognition has a multifold function. First, it might provide an additional but often overlooked experiential domain to ground the meaning of abstract

concepts. Second, using abstract concepts generates more uncertainty and less confidence, hence they require a more efficient and longer internal monitoring process than concrete concepts. Moreover, participants recognized the link between metacognition and abstractness as revealed by ratings showing a correlation between the two dimensions. We argue that this monitoring process leads to a long-lasting inner search for meaning. External signals of this inner search can be found in longer times to process and recall abstract concepts (concreteness effect). We propose that the inner search for meaning likely occurs through inner speech. It might consist of considering a range of different meanings, or in clarifying to ourselves their possible meaning. Alternatively, this search for meaning might lead us to ask information of others, in order to fill our knowledge gap. We will develop this issue in the next section.

Social Metacognition

System 2 Metacognition

So far we have discussed two main functions of metacognition with respect to abstract concepts: it can contribute to their grounding, and it has an important monitoring and regulating role. We will now discuss the cases in which metacognitive feelings of scarce confidence lead us to rely on others. Other people can help us to ground concepts thanks to their expertise (Prinz, 2002; 2012). Notice that we do not necessarily need to be aware of these metacognitive feelings of self-confidence, as long as the uncertainty signal is picked up by one system and fed into another that triggers the uncertainty-reduction.

One influential proposal includes the characterization of "system 2 metacognition" (Frith, 2012; Shea et al., 2014). Indeed, "when sensorimotor systems have to be coordinated between two or more interacting agents" (Shea, 2014, p. 188) it is no longer possible to use internal, implicit metacognitive information. At the same time, inter-agent control would be more effective when relying on metacognitive representations. Shea et al. (2014) propose that system 2 explicit metacognition is not only for representing others' mental states (mindreading), but also for communicating the agents' metacognitive states themselves, e.g., their confidence. Experiments

show advantages in joint actions when participants communicate their confidence to others (Fusaroli et al., 2012). System 2 metacognition renders metacognitive representations available for communication and can lead to the individuation of solutions (e.g., finding an expert or an online source to arrive at the meaning). According to Shea et al. it is uniquely human and has evolved for supra-personal cognitive control to allow individuals to cooperate in sophisticated ways. Importantly, it can work both synchronically, when two people work on the same task, or diachronically to improve future task performance.

Let us apply this notion to a dialogue in which concrete and abstract words are exchanged. Both the speaker and the recipient implicitly refer concrete words to objects. With abstract words, the speaker and especially the recipient experience feelings of uncertainty and of scarce confidence, leading to prediction errors. When they fail to find the meaning of abstract concepts, they might revert to system 2 metacognition. System 2 metacognition can derive metacognitive information from the single systems, for example by relying on the degree of confidence reported by the involved agents.

Social Metacognition and Abstract Concepts

Frith (2012) and Shea et al. (2014) have highlighted the benefits of explicit metacognition in enhancing collaborative decision-making. Because of the complexity of abstract concepts, we have proposed that a mechanism similar to the one they illustrate is at play during use of abstract concepts (see also Shea, 2018). We have called it social metacognition (Fini & Borghi, 2019; Borghi et al., 2018; Borghi et al., 2019). It consists of a process in which we monitor our concepts and, in cases in which we find they lack sufficient clarity and detail, we refer to others (Prinz, 2012; Shea, 2018). Its function is to detect eventual inadequacies of our knowledge and to induce us to prepare to ask information of others. We call it social because it can be seen as a bridge between ourselves and other people. This mechanism is both implicit and explicit. It is implicit because we are not (necessarily) aware of our knowledge gaps, even if we may have a general sense of scarce

confidence in processing certain words. It is explicit because according to our hypothesis it leads us to prepare ourselves to ask information of others.

Social Metacognition and Reliance on Others: Supporting Evidence

We hypothesize that the higher the abstractness of words, the higher is the sense of scarce confidence and the more we need others to support us. Recent evidence in our lab supports this hypothesis.

In a first study (Fini, Era, Darold, Candidi & Borghi, submitted) participants were submitted to a concept guessing task: they were presented with pictures referring to situations linked to concrete/abstract concepts (e.g., bottle: to drink; freedom: to run on the grass) and they were required to guess to which word the image referred. When they were not able to infer the word immediately, they could ask a confederate for suggestions**.** Then participants had to rate to what extent they needed others in order to guess the concept associated with the blocks of abstract/concrete pictures. Abstract concepts were associated with significantly higher values than concrete concepts, suggesting that when participants were asked to guess abstract concepts, they subjectively perceived the necessity to rely more on others' help.

The second study is one we previously described (Villani et al., 2019) in which participants were asked to rate 425 abstract words on different dimensions. Among the considered dimensions participants were also asked to provide a judgment of social metacognition: they were told that they had "to rate how much the linguistic competence of other people is useful for understanding the meaning of a series of words." Then the instructions continued: "Your task is to rate how much you think you need to consult other people to understand this word." Social metacognition correlated very strongly with abstractness ($r = 0.5$), with sociality ($r = 0.33$), with modality of acquisition (linguistic) ($r = 0.22$) and with late age of acquisition (late) ($r = 0.12$). A Principal Component Analysis (PCA) on the ratings led to a three-components solution, i.e., concreteness-abstractness, sensorimotor (five senses and hand), and inner grounding (sociality, metacognition, introspection, emotion, and mouth). Importantly, social metacognition was included in the abstractness-

concreteness component: consistent with our hypothesis, abstractness was characterized by late age of acquisition, linguistic modality of acquisition, and social metacognition. It contrasted with concreteness, characterized instead by body object interaction (BOI, Siakaluk et al., 2008), higher contextual availability (Schwanenflugel et al., 1992) and higher imageability (Paivio, 1990). These two studies clearly indicate across two different tasks that participants are aware that the help of others is needed in particular for more abstract words.

Embodied Social Metacognition

We propose that social metacognition has an embodied counterpart. When we become aware of the inadequacies of our knowledge, we prepare ourselves to ask information of others, pre-activating our mouth motor system. Whether this is an explicit, deliberate process or an implicit one is currently unclear. A variety of studies in our lab and in other labs have shown that, during processing of abstract concepts, the mouth motor system is activated. We will briefly summarize this evidence (see Figure 4).

In two studies we mimicked acquisition of concrete and abstract words using artificial stimuli. Participants first perceived and categorized novel stimuli, then they were taught their (novel) name. In the first study concrete words were operationalized as novel manipulable objects, in the second as nonmanipulable objects that interacted in novel ways (multiple referents). In subsequent feature verification tasks responses to concrete concepts were faster with the hand whereas response to abstract concepts were faster with the mouth (Borghi et al., 2011). In the second study (Granito et al., 2015), the members of concrete concepts consisted of perceptually similar objects and those of abstract ones having similar relations between their parts. After familiarization with the categories, half of the participants received linguistic training in which they had the meaning of the concept explained and were taught its novel name. In a subsequent categorical recognition task, the performance of participants who had received linguistic training was better for abstract than for concrete concepts. Furthermore, participants who had not received linguistic training provided faster responses with the hand than with the mouth, whereas this

difference disappeared when participants had undergone linguistic training. Hence, these studies indicate that language was more crucial to learn novel abstract concepts than novel concrete ones and that linguistic training led to the activation of the mouth.

In further studies we used real abstract and concrete words and found that mouth responses to abstract concepts were facilitated. When participants had to decide whether an explanation fit a target word or not, responses with the hand were faster with concrete words, whereas responses with the mouth (participants had to press a device with the teeth) were faster with abstract ones (Borghi & Zarcone, 2016). Mazzuca et al. (2018) did not find the interaction in a lexical decision task, but in a subsequent recognition task found that concepts were facilitated in the mouth compared to the hand condition. To demonstrate that the role of the mouth was constitutive for meaning comprehension, we also designed some interference tasks. Two longitudinal studies revealed that the use of a pacifier to impede active mouth movement had a long-lasting effect on abstract word acquisition. A definition task analysis of the conceptual relations produced by six-year-olds revealed that the distinction between concrete and abstract concepts was less clearly marked for children who had used a pacifier beyond age three, even if their definition accuracy was not affected (Barca et al., 2017). In a categorization task performed by eight-year-olds, response times with abstract concepts, but not with concrete and emotional concepts, were slower the longer children had used a pacifier during infancy (Barca et al., 2020).

Another study in which we addressed metacognition and mouth activation with an interference paradigm is based on word difficulty ratings (Villani, Lugli, Liuzza, Nicoletti, & Borghi, under review). Difficulty ratings can be interpreted as metacognitive signals of scarce fluency. Participants rated the difficulty of concrete and abstract words and were concurrently submitted to four interfering conditions: a gum chewing condition, in which participants actively involved the mouth, an interoceptive condition, in which they had to pay attention to their heart beat, an articulatory suppression condition, in which they had to pronounce a syllable, and a softball manipulation condition. We predicted that the softball manipulation condition would particularly

interfere with concrete concepts, whereas the other conditions would interfere more with abstract ones. We will discuss only results relevant to the hypothesis that processing abstract concepts involves the mouth. We found strong support of the hypothesis that the gum condition interfered more with abstract than with concrete concepts (animals and tools) when compared to the ball condition, even if the interference of the interoceptive condition was more marked. Contrary to our hypothesis, the articulatory suppression seemed to increase the difficulty of all verbal stimuli. The null result contrasts with the results obtained by Zannino et al. (in prep.), and is likely due to the fact that the task involves an explicit evaluation and does not take into account online performance.

Evidence for activation of the mouth motor system was also found in other laboratories. Ghio et al. (2013) found that participants rate that abstract concepts activate mouth and hand effectors; the mouth effector was evaluated as particularly relevant for mental state abstract concepts. Dreyer and Pulvermuller (2018) provide fMRI evidence for the activation of the mouth motor system, in particular for abstract concepts of mental states. Since mental state abstract concepts are generally evaluated as particularly abstract, this evidence concurs in demonstrating that, the higher conceptual abstractness, the more the mouth motor system is activated.

Social Deference: Developmental Evidence

In order to rely on others to complement the gaps in our knowledge, we need to trust them and their knowledge. We also need to correctly identify which experts can help us. This is a complex ability that develops gradually.

Relevant in order to understand the role of deference—when, why, and how we refer to experts—are studies on causal understanding. Kominsky et al. (2018) argue that in order to select the right experts we need to have at least some information on causal mechanism, such as to know in an abstract way how a bike might work. The authors introduce the term “mechanism metadata”, i.e., information on information concerning mechanisms of a given system. Metadata do not imply detailed information. They are more abstract and are compatible with fragmentary knowledge that is consistent across individuals with a similar exposure level and is present for every causal system

people encounter. In some experiments they presented seven- to ten-year-olds and adults causally complex objects (e.g., microscope, TV) and found a relationship between causal complexity (including a high number and diversity of components) and the tendency to ask for help. They found that the sense of complexity extends from artifacts to natural objects (body parts), and also provide preliminary evidence that this sense of complexity, although more variable, is present already at age five. Interestingly, children's ability to form and use abstract concepts dramatically increases from ages four to five onward. Even if this study does not focus on abstractness, it shows that children gradually develop the ability to rely on experts and that this reliance on others increases the more casually complex objects are.

More crucial to us is a study testing deference when learning abstract concepts, such as numerical ones. Kominsky et al. (2016) investigate the processes that lead children aged five to six, older than nine and adults to rely on the competence of others. It is useful to select informants who are confident, but confidence might be a signal of ignorance when precise information is unknowable. In the last case the admission of ignorance might not be "mere ignorance" but rather "virtuous ignorance", the admission not to know something that is impossible to know. Children of first, second-third, and fourth-fifth grade were tested in a study of numerical knowledge on abstract concepts (e.g., it is possible to know the number of windows of the White House, but not the number of all the leaves of all the trees in the world), and children of second and fourth grade and adults were tested on specific vs. unknowable predictions about the future (e.g., it is possible to predict that a rainbow seen on October 1, 2224 will have a red stripe on top, but not that the most popular boy name on that date will be George). Children were asked questions and were invited to choose the best experts to help them to answer the questions. Kindergarteners and first graders tended to favor implausibly confident informants, whereas fourth graders and adults did not. In the experiment on future predictions, second graders tended to favor implausibly knowable informants, fourth graders were at chance, and later the performance significantly increased. Importantly, when asked to determine whether items were knowable and not, even four- to five-year-old children were

able to do it, revealing sophisticated epistemological capabilities. However, they were not able to choose implausibly certain informants over virtuously ignorant ones. This might depend on the difficulty to integrate information on the words and on the experts, or on their difficulty in not believing what they are told. The ability to choose the right informants is particularly crucial for the acquisition of abstract concepts, for which knowledge that is not obvious is required.

Meaning is Defined in a Collective Way

So far we have seen that, when our confidence in word knowledge is scarce, we refer to experts. We have introduced the importance of deference - linguistic deference when it refers to meaning. Deference can be explicit when we directly ask information of others, or implicit when we simply absorb information from them.

Importantly, such deference is not automatic; in some cases we may prefer to stick to our own definition than to adopt the one of the community. In other cases conceptual meaning can be defined collectively. Take for example religious concepts: we might want to rely on authoritative sources, such as sacred books or priests. The same occurs for scientific concepts: we might rely on specialist journals, or on scientists. But if we are scientists, then we might try to build/define a notion in a collective way. Consider for example the definition of "abstract concepts". Some authors introduced it. Other authors refined it. Some authors proposed to drop it because it is oversimplified. This negotiation process involves a metacognitive judgment, the evaluation of whether this notion is reliable or presents limitations (Shea, 2019). This process of collective definition always occurs (Baronchelli et al., 2010), but it is more pronounced for complex abstract concepts than for concrete ones because no external referent is present.

When we refer to experts we implicitly recognize that meaning is distributed across different heads. The single members of a community might not be aware of all the nuances of the meaning of single words. This is the so-called division of linguistic labor: "Every linguistic community ... possesses at least some terms whose associated 'criteria' are known only to a subset of the speakers

who acquire the term, and whose use by the other speakers depends upon a structured cooperation between them and the speakers in the relevant subsets." (Putnam, 1975, pp. 145–146).

It is possible that children assume this division of linguistic labor more than adults. Children typically grant parents, teachers, etc., expertise on word meanings they do not have. As for adults, it is possible that in present times deference becomes increasingly more important as we rely more on the Internet and other outside sources in our everyday life. At the same time, for adults it is easier to unmask pretend experts. In a recent study Kominski et al. (2014) revealed a very interesting Misplaced Meaning (MM) effect. The idea is that only a subset of speakers know the distinctive difference between pairs of words, while other people might overestimate their knowledge. They hypothesize that this overestimation is stronger in children. The effect is due to the fact that participants know the concept only at a coarse, more abstract level, but are convinced they also know it in its details. They selected word pairs which were synonyms (e.g. infant-baby), word pairs with well-known differences (e.g. donkey-mule) and word pairs without well-known differences (e.g. cucumber-zucchini). Both children (kindergartners, second, and fourth graders) and adults had a clear MM effect: for example, they estimated that they would name three differences between cucumber and zucchini, but in a subsequent listing task they mentioned only one difference. The MM effect was more marked in kindergarteners, who gave higher estimates and provided fewer differences than older children and adults. The effect was present for distinctive aspects of word meaning, but not for common aspects, excluding the hypothesis that it is owing to broad metalinguistic overconfidence. It is possible that the stronger effect for kindergartners was due to the fact that, because they were aware of the presence of experts, they felt more confident than older children and adults. Consistently, Koening and Harris (2005) have shown that young children rely on knowledge coming from outside sources, and can use in a smart way these networks of deference. Indeed, knowing that we are part of a community in which there are some experts might increase confidence.

Hence, we rely more on others when we feel less confident. At the same time, the awareness that we can rely on others might induce in us a feeling of overconfidence (Rabb et al., 2019). This can happen especially with abstract concepts that we master less than concrete ones. Empirical research should investigate these two concurrent and contrasting phenomena.

Social Metacognition and Abstract Concepts in Use

Abstract concepts have mostly been studied as isolated items; Barsalou et al. (2018) have underlined that it is necessary to study concepts in situated action. In a similar vein, Glenberg (2019) and Falandays and Spivey (2019) argued that, because abstract concepts rely more on social interaction and because their meaning is more variable than that of concrete concepts, we should investigate their use in social interactions. We think that future research on abstractness will need to investigate concept use in real-time dynamic interactions. For example, superordinate concepts might generate more uncertainty when we comprehend them, but in the case of degraded perception we might feel more confident in using a superordinate than a lower level term. It is therefore crucial to investigate the real use of words in dialogue. Focusing on the use of abstract concepts will allow us to better detect the process of meaning search that follows the monitoring processes, and the process of social deference that can be the outcome of the feeling of scarce confidence they generate in us.

Conclusion

Metacognition and social metacognition can play an important function for concepts in general, but especially for abstract ones. Here we have argued that metacognition can play multiple roles for abstract concepts. First, it contributes to their grounding. Second, the monitoring component of metacognition is particularly relevant for them: the higher the degree of abstractness of concepts, the longer the metacognitive process lasts, the less we experience confidence in their meaning and the more we continue searching for it. The monitoring process can lead to two possible outcomes. The first is the use of inner speech, aimed for example to re-explain to ourselves the word meaning. The second is the stronger need for social deference, leading to a form of social

metacognition. We need other people—better if they are authoritative—more the more gaps our knowledge has. We thus prepare ourselves to use language to request their help. Comprehension of abstract concepts leads us to prepare an action, but it generally is a linguistic action, most likely a request. Abstract concepts can thus be redefined as concepts for which the mediation of others is crucial. The more concepts are abstract, the more we need to know. Why in some cases we use the first mechanism, and in others the second, should be investigated by further research. One possibility is that we use the second system, social metacognition, when the simple inner search through inner speech fails. Another possibility is that both mechanisms are concurrently activated. Both in the cases in which we continue searching for the meaning and in which we request the help of others the mouth motor system is activated. In the first case, the mouth might be activated because we use inner speech. In the second case it might be activated because we prepare ourselves to ask questions of other people. Future research should deepen these aspects, adopting methods allowing us to capture use of concepts in real-time interactions.

References

Acheson, D. J., Hamidi, M., Binder, J. R., & Postle, B. R. (2011). A common neural substrate for language production and verbal working memory. *Journal of Cognitive Neuroscience*, *23*, 1358-1367.

Alderson-Day, B., & Fernyhough, C. (2015). Inner speech: development, cognitive functions, phenomenology, and neurobiology. *Psychological Bulletin*, *141*, 931.

Apperly, I. A., & Butterfill, S. A. (2009). Do humans have two systems to track beliefs and belief-like states? *Psychological Review, 116*, 953.

Arbib, M. A., Gasser, B., Barrès,V. (2014). Language is handy but is it embodied? *Neuropsychologia, 55*, 57-70.

Baldo, J. V., Dronkers, N. F., Wilkins, D., Ludy, C., Raskin, P., & Kim, J. (2005). Is problem solving dependent on language? *Brain and Language*, *92*, 240–250.

Barca, L., Mazzuca, C., & Borghi, A. M. (2017). Pacifier overuse and conceptual relations of abstract and emotional concepts. *Frontiers in Psychology*, *8*, 2014.

Barca, L., Mazzuca, C., & Borghi, A. M. (2020). Overusing the pacifier during infancy sets a footprint on abstract words processing. *Journal of Child Language*.

Baronchelli, A., Gong, T., Puglisi, A., & Loreto, V. (2010). Modeling the emergence of universality in color naming patterns. *Proceedings of the National Academy of Sciences*, *107*, 2403-2407.

Barsalou, L. W. (1999). Perceptual symbol systems. *Behavioral and Brain sciences, 22*, 577-660.

Barsalou, L. W., Dutriaux, L., & Scheepers, C. (2018). Moving beyond the distinction between concrete and abstract concepts. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *373*, 20170144.

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

Binder J. R., Desai R. H., Graves W. W., Conant L. L. (2009). Where is the semantic system? A critical review and meta-analysis of 120 functional neuroimaging studies. *Cerebral Cortex* 19, 2767–96.

Borghi, A. M., Binkofski, F., Castelfranchi, C., Cimatti, F., Scorolli, C., & Tummolini, L. (2017). The challenge of abstract concepts. *Psychological Bulletin, 143*, 263.

Borghi, A. M., Barca, L., Binkofski, F., Castelfranchi, C., Pezzulo, G., & Tummolini, L. (2019). Words as social tools: language, sociality and inner grounding in abstract concepts. *Physics of Life Reviews, 29*, 120-153.

Borghi, A. M., Barca, L., Binkofski, F., & Tummolini, L. (2018). Abstract concepts, language and sociality: from acquisition to inner speech. *Philosophical Transactions of the Royal Society B: Biological Sciences, 373*, 20170134.

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

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

Borghi, A. M., Tummolini, L. (in press). Touch me if you can: The intangible but grounded nature of abstract concepts. *Behavioral and Brain Sciences*, commentary to Gilead, Trope & Liberman.

Borghi, A. M., & Zarcone, E. (2016). Grounding abstractness: abstract concepts and the activation of the mouth. *Frontiers in Psychology*, *7*, 1498.

Brenna, B. A. (1995). The metacognitive reading strategies of five early readers. *Journal of Research in Reading*, *18*, 53-62.

Carruthers, P. (2009). How we know our own minds: The relationship between mindreading and metacognition. *Behavioral and Brain sciences*, *32*, 121-138.

Connell, L., Lynott, D., & Banks, B. (2018). Interoception: the forgotten modality in perceptual grounding of abstract and concrete concepts. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 373, 20170143.

Constable, M. D., Kritikos, A., & Bayliss, A. P. (2011). Grasping the concept of personal property. *Cognition, 119*, 430-437.

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

Dove, G. (2018). Language as a disruptive technology: abstract concepts, embodiment and the flexible mind. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *373*, 20170135.

Dove, G. (2019). More than a scaffold: Language is a neuroenhancement. *Cognitive Neuropsychology*, 1-24.

Dreyer, F. R., & Pulvermüller, F. (2018). Abstract semantics in the motor system?–An event-related fMRI study on passive reading of semantic word categories carrying abstract emotional and mental meaning. *Cortex, 100*, 52-70.

Falandays, J. B., & Spivey, M. J. (2019). Abstract meanings may be more dynamic, due to their sociality: Comment on" Words as social tools " by Borghi et al. *Physics of Life Reviews*, *29*, 175-177.

Fini, C., & Borghi, A. M. (2019). Sociality to reach objects and to catch meaning. *Frontiers in Psychology, 10*.

Flavell, J. H. (1979). Metacognition and cognitive monitoring: a new area of cognitive-developmental inquiry. *American Psychologist, 34*, 906-911.

Friston, K. (2010). The free-energy principle: a unified brain theory? *Nature Reviews Neuroscience, 11*, 127-138.

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

Furby, L. (1980). The origins and early development of possessive behavior. *Political Psychology*, 30-42.

Fusaroli, R., Bahrami, B., Olsen, K., Rees, G., Frith, C. D., Roepstorff, A., & Tylén, K. (2012). Coming to terms: an experimental quantification of the coordinative benefits of linguistic interaction. *Psychological Science*, *23*, 931-939.

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

Glenberg, A. M. (2019). Turning social tools into tools for action. Comment on "Words as social tools " by Borghi et al. *Physics of Life Reviews*, *29*, 172-174.

Gottlieb, J., Oudeyer, P. Y., Lopes, M., & Baranes, A. (2013). Information-seeking, curiosity, and attention: computational and neural mechanisms. *Trends in Cognitive Sciences*, *17*, 585-593.

Granito, C., Scorolli, C., & Borghi, A. M. (2015). Naming a lego world. The role of language in the acquisition of abstract concepts. *PloS One*, *10*.

Hacker, D. J., Dunlosky, J., & Graesser, A. C. (Eds.). (2009). *Handbook of Metacognition in education*. Routledge.

Heyes, C. M., & Frith, C. D. (2014). The cultural evolution of mind reading. *Science*, *344*, 1243091.

Holton, D., & Clarke, D. (2006). Scaffolding and metacognition. *International Journal of Mathematical Education in Science and Technology*, *37*, 127-143.

James, W. (1884). What is an emotion? *Mind*, *9*, 188-205.

Koenig, M. A., & Harris, P. L. (2005). Preschoolers mistrust ignorant and inaccurate speakers. *Child Development*, *76*, 1261-1277.

Kominsky, J. F., Langthorne, P., & Keil, F. C. (2016). The better part of not knowing: Virtuous ignorance. *Developmental Psychology*, *52*, 31.

Kominsky, J. F., & Keil, F. C. (2014). Overestimation of knowledge about word meanings: The "misplaced meaning" effect. *Cognitive Science*, *38*, 1604-1633.

Kominsky, J. F., Zamm, A. P., & Keil, F. C. (2018). Knowing when help is needed: A developing sense of causal complexity. *Cognitive Science, 42,* 491-523.

Kuhn, D., & Dean, Jr., D. (2004). Metacognition: A bridge between cognitive psychology and educational practice. *Theory into Practice, 43,* 268-273.

Langacker, R. W. (2009). Investigations in cognitive grammar (Vol. 42). Walter de Gruyter.

Lees, J., & Cikara, M. (2019). Inaccurate group meta-perceptions drive negative out-group attributions in competitive contexts. *Nature Human Behaviour*, 1-8.

Langland-Hassan, P., & Vicente, A. (2018). *Inner Speech: New Voices*. Oxford University Press, USA.

Lidstone, J. S., Meins, E., & Fernyhough, C. (2010). The roles of private speech and inner speech in planning during middle childhood: Evidence from a dual task paradigm. *Journal of Experimental Child Psychology, 107,* 438–451.

Lupyan, G., & Winter, B. (2018). Language is more abstract than you think, or, why aren't languages more iconic? *Philosophical Transactions of the Royal Society B: Biological Sciences, 373,* 20170137.

Mannella, F., Santucci, V. G., Somogyi, E., Jacquey, L., O'Regan, K. J., & Baldassarre, G. (2018). Know your body through intrinsic goals. *Frontiers in Neurorobotics, 12,* 30.

Martinez, M. E. (2006). What is metacognition?. *Phi Delta Kappan, 87,* 696-699.

Mazzuca, C., Lugli, L., Benassi, M., Nicoletti, R., & Borghi, A. M. (2018). Abstract, emotional and concrete concepts and the activation of mouth-hand effectors. *PeerJ, 6,* e5987.

Newcombe, P. I., Campbell, C., Siakaluk, P. D., & Pexman, P. M. (2012). Effects of emotional and sensorimotor knowledge in semantic processing of concrete and abstract nouns. *Frontiers in Human Neuroscience, 6,* 275.

Paivio, A. (1990). *Mental representations: A dual coding approach* (Vol. 9). Oxford University Press.

Pickering, M. J., & Garrod, S. (2013). An integrated theory of language production and comprehension. *Behavioral and Brain Sciences*, *36*, 329-347.

Ponari, M., Norbury, C. F., & Vigliocco, G. (2018). Acquisition of abstract concepts is influenced by emotional valence. *Developmental Science*, *21*, e12549.

Prinz, J. (2002). *Furnishing the Mind*. Cambridge, MA: MIT Press.

Prinz, J. J. (2012). *Beyond Human Nature: How Culture and Experience Shape Our Lives*. Penguin UK.

Proust, J. (2012). Metacognition and mindreading: one or two functions. *Foundations of Metacognition*, 234-251.

Putnam, H. (1975). The meaning of 'meaning'. *Philosophical Papers*, *2*.

Rabb, N., Fernbach, P. M., & Sloman, S. A. (2019). Individual representation in a community of knowledge. *Trends in Cognitive Sciences*.

Schraw, G., & Moshman, D. (1995). Metacognitive theories. *Educational Psychology Review*, *7*, 351-371.

Schwanenflugel, P. J., Akin, C., & Luh, W. M. (1992). Context availability and the recall of abstract and concrete words. *Memory & Cognition*, *20*, 96-104.

Scorolli, C., Borghi, A. M., & Tummolini, L. (2018). Cues of control modulate the ascription of object ownership. *Psychological Research*, *82*, 929-954.

Shea, N. (2012). Reward prediction error signals are meta-representational. *Nous*, 48, 314-341.

Shea, N., Boldt, A., Bang, D., Yeung, N., Heyes, C., & Frith, C. D. (2014). Supra-personal cognitive control and metacognition. *Trends in Cognitive Sciences*, *18*, 186-193.

Shea, N. (2018). Metacognition and abstract concepts. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *373*, 20170133.

Shea, N. (2019). Concept-metacognition. *Mind & Language*.

Siakaluk, P. D., Pexman, P. M., Aguilera, L., Owen, W. J., & Sears, C. R. (2008). Evidence for the activation of sensorimotor information during visual word recognition: The body–object interaction effect. *Cognition*, *106*, 433-443.

Tomasello, M. (2019). *Becoming Human: A Theory of Ontogeny*. Belknap Press.

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

Topolinski, S., & Strack, F. (2009). Motormouth: mere exposure depends on stimulus-specific motor simulations. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *35*, 423.

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

Vygotsky, L. S. (1934, 1986). *Thought and Language (rev. ed.)*. Cambridge, MA: MIT Press.

Zannino, G., Fini, C., Benassi, M., Carlesimo, A. & Borghi, A. M. (submitted). Articulatory suppression delays processing of abstract concepts: the role of inner speech.

Villani, C., Lugli, L., Liuzza, M.T., & Borghi, A. M. (2019). Varieties of abstract concepts and their multiple dimensions. *Language and Cognition*, *11*, 403-430.

Villani, C., Lugli, L., Liuzza, M. T., Nicoletti, R. & Borghi, A. M. (under review). Sensorimotor and Interoceptive dimensions in concrete and abstract concepts.

Yeung, N. & Summerfield, C. (2012). Metacognition in human decision making: confidence and error monitoring. *Philosophical Transactions of the Royal Society B*. 367, 1310–1321.

Wang J., Conder J. A., Blitzer D.N., Shinkareva S. V. (2010). Neural representation of abstract and concrete concepts: a meta-analysis of neuroimaging studies. *Human Brain Mapping*, *31*, 1459–68.

Wellman, H. M., Cross, D. & Watson, J. (2001). Metaanalysis of theory-of-mind development: the truth about false belief. *Child Development, 72*, 655–684.

White, R. H. (1959). Motivation reconsidered: The concept of competence. *Psychological Review, 66*, 297-333.

Williams, J. P., & Atkins, J. G. (2009). The role of metacognition in teaching reading comprehension to primary students. In *Handbook of Metacognition in Education* (pp. 38-56). Routledge.

Figure 1. Functions of metacognition relevant for abstract concepts: Grounding, inner search, and social deference.

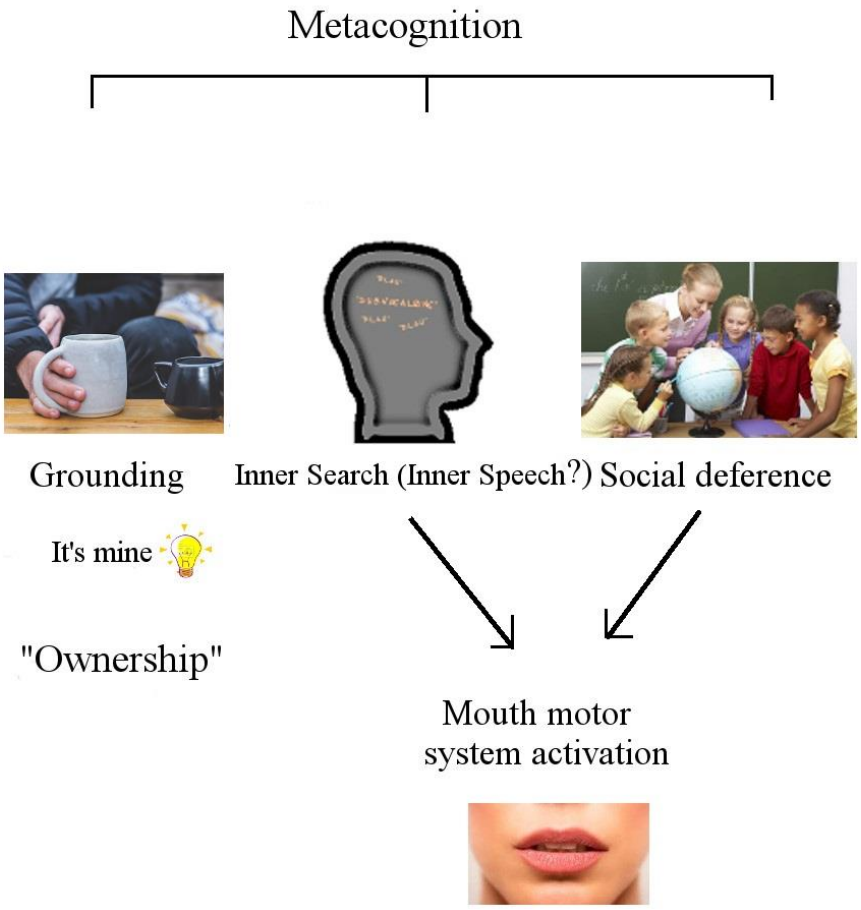

Figure 2. Abstraction and abstractness in dialogue. Abstraction: When we see a degraded stimulus, as speakers we produce fewer prediction errors and feel less uncertain/more confident with superordinate than with basic and subordinate level concepts. In normal conditions, the level of confidence in the speaker instead is clearly higher with subordinate than with basic concepts. The case is different for the listener, for which the degree of confidence might be maximal at a basic level. Abstractness: both the speaker and the listener experience uncertainty/scarce confidence, although this uncertainty is more pronounced in the listener.

		Speaker confidence	Listener confidence
			
	VEHICLE 	++++	++
ABSTRACTION	CAR 	+++	+++
	FIAT 500 	+	+
ABSTRACTNESS	FREEDOM 	++	+

Figure 3. Correlogram. Correlations between the different dimensions rated for 425 abstract concepts (from Villani et al., 2019). In red are positive correlations, in blue negative ones. The intensity of the red and blue colors indicates the strength of the correlation.

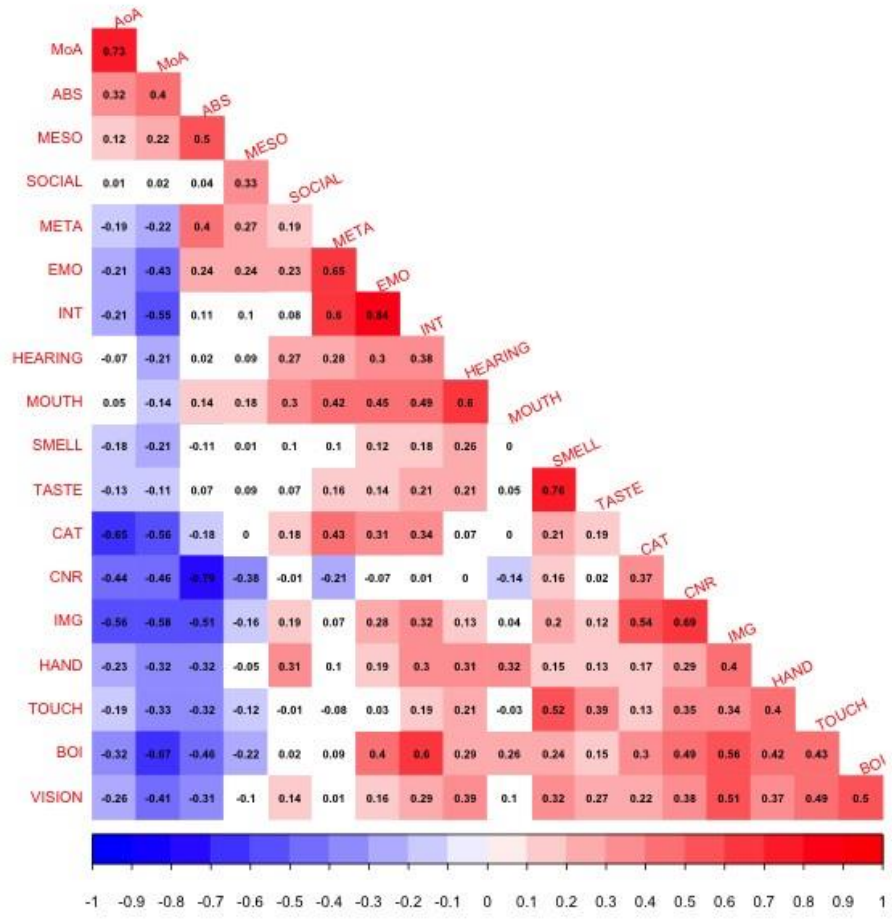

Figure 4 - Evidence on mouth activation. Participants, tasks, and results of each study. ACs = abstract concepts.