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Comment

Access and content of abstract concepts
Comment on "Words as social tools: Language, sociality, and inner grounding in abstract concepts" by Anna M. Borghi et al.

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While the mental representation of abstract concepts (ACs), such as *freedom* or *confidence*, has long been debated, it has only recently come to the fore in the context of grounded and embodied theories of cognition. The Words as social Tools (WAT) theory by Borghi et al. [1] marks an important advance in the development of testable theories of abstract concepts, and by extension, representation of concepts in general. To my knowledge WAT is the first theory to take the role of development in concept representation seriously. Other important aspects of the theory include the importance of social and linguistic information, as well as the role of metacognitive, interoceptive, and extroceptive processes. Importantly, WAT acknowledges differing contributions of these dimensions for different types of ACs, such as emotional, metal-state-related, or social concepts. This commentary deals mainly with tenets of the theory relating to mouth activations, and the role of linguistic and social information.

Mouth activations: At the outset, it is useful to distinguish between the content of concepts, and methods of access to that content. This distinction seems too obvious to require mention at one level, but at the same time tends to be confounded in the case of concrete concepts, where some authors slide back and forth between access channels and content with respect to modality. For example, activation of a region such as the anterior temporal lobe by picture stimuli and auditory words is often declared as showing amodal (or pan-modal, trans-modal, or supra-modal) representations. Activation *by* visual/auditory or verbal/nonverbal stimuli has no bearing on the content of the representations. It does not show, for example, that no visual or auditory information is part of the representations, just that the representational content can be activated by stimuli presented in different modalities, whatever the content may be.

Borghi et al. are careful to distinguish the two, and suggest three ways in which mouth activations can be related to ACs (p. 16). Nonetheless, it is worth emphasizing what is meant when they suggest that mouth activations represent embodiment of ACs, or that they represent "re-enactment of experience of their acquisition." The conceptual content of abstract or concrete concepts cannot be grounded in mouth activations or phonology. The words *freedom* and *justice* both have six phonemes, which, in a neuroimaging study, would lead to a certain amount of activity in areas processing mouth movements, phonology, and covert speech. In an interference paradigm, response times to these words may be increased if covert speech is interfered with. However, the specific difference in the meaning of these two words that is

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not provided by these activations themselves, because the relationship between phonological structure and semantics is largely arbitrary.

As a contrast, consider a concrete concept such as *apple*. We might learn about apples through seeing them, touching them, biting into them, tasting them. The information that is encoded in visual, tactile, or gustatory modalities provides the content of the concept *apple*. By partially re-activating traces of this modality-specific information, we can comprehend the concept at a future time, which constitutes a (partial) re-enactment of the experience. The same does not hold for abstract words, in that activation of mouth movements does not tell us specifically what *freedom* means. It can potentially only be a mechanism of indirect access to conceptual content. One may proposes that mouth and phonological activations ignite other phonological codes for other concepts, setting off a chain of activity that terminates in activation of a complex set of sensatory-motor or emotional information that constitutes the content of what *freedom* means. Mouth activations and phonological codes pertain to modality of access channels, not to the content itself. Importantly, Borghi et al. clarify that activation of mouth motor system in the case of processing words such as *chew* relates to the conceptual content of the word, while in case of ACs it pertains to search and retrieval of the content (p. 4). A re-enactment of experience of the acquisition would need to additionally include extra-linguistic information such as events and social context.

Linguistic Context and Syntactic Bootstrapping: WAT points out the role of linguistic and social context in acquisition of ACs. These two factors can play a very different role in word learning, including learning of ACs. Linguistic context provides a word-to-word mapping, while social context provides a word-to-world mapping. Borghi et al. suggest that ACs can be learned through mechanisms such as syntactic bootstrapping [2]. However, it worth considering just what about a verb's meaning can be learned from syntactic context. Verbs can have meanings at two levels, a template and root level [e.g., [3]]. The template level refers to a general schema that distinguishes between entire classes of verbs. The root level, on the other hand, distinguishes between verbs within the same class. Pinker [4] also distinguishes between root semantic content and semantic perspective provided by the frame, and points out that root content cannot be learned from the subcategorization frames, even for concrete words. Hearing *froze* in all its frames, such as *He froze the milk* and *The milk froze* places the verb in a class, but does not provide its root content (cold solidified liquid). The same considerations apply to ACs. If syntactic frames can only be used to narrow the child's interpretation of the perspective or template level meaning, it places an important limitation on its power. Because the the frame functions as a 'zoom lense', highlighting particular elements of a scene or situation, root meaning necessarily relies on the extra-linguistic context on which the zooming takes place, and cannot be grounded in syntactic context by itself.

Inferences based on specific lexical items, rather than syntactic structure, can also play a role in learning both concrete and abstract concepts. For example, if the child knows what *apple* means, she can infer that *glip* is likely related to eating upon hearing *He gliped the apple*. Syntactic frames also pertain only to verbs, leaving open the question of other major categories of words such as nouns. The lexico-semantic inference can operate across word classes (e.g., knowing the meaning of *ate* helps in inferring that *glip* is likely a food item in *He ate the glip*). Social context, on the other hand, is different from syntactic frames in that it has sensory-motor correlates that can be used to learn the root level meaning, even if they are highly variable and complex. What aspects of linguistic context can be used (e.g., syntactic characteristics of frames, individual lexical items in those frames, or co-occurrence statistics), and what specifically can be learned from them is a continuing and fruitful area of investigation.

Social Knowledge: Borghi et al. point out the importance of social knowledge in acquiring and representing ACs. It is worth remembering that social concepts are necessarily built on top of semantic and episodic content, and should not be treated as some type of primitive building blocks. Social concepts involve people, objects, relations, events, and emotions, and are thus higher order constructs build upon this foundation. It can be misleading to declare brain areas as being "for social processing" without examining their specific role in the levels below, which are themselves complex processes.

Using meta-analyses, recently we examined brain regions involved in emotional concepts, morality judgments, and Theory of Mind [5]. Across these domains, medical prefrontal cortex (mPFC), precuneus and posterior cingulate (prC/pCi), and angular gyrus (AG) were among the regions commonly activated. Divisions of prC/pCi are associated with episodic retrieval and mental imagery [6,7]. AG has been proposed to have a role in processing events and thematic relations, with an overarching function in integrating information across time and across modalities [5,8–10]. Tracking value of rewards and valence, as well as regulation regulation of emotion, is associated with mPFC [11,12], which is critical in social cognition [13,14].

It is notable that the same regions are also involved in concrete concept processing [5,10]. Many concrete concepts have not only emotional content, but also event-based and episodic knowledge associated with them (e.g., *baseball* may evoke events of playing and watching the game in a park), in addition to their reliance on metal imagery and multi-modal integration. These activations are consistent with the role of events and episodic memories in processing ACs, meshing with the importance of social cognition as proposed by WAT.

WAT presents a rich set of mechanisms, hypotheses, and predictions that will be investigated and refined in the coming years, and will advance our understanding of ACs.

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