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**TITOLO DELLA TESI: THE NOTIONS OF FORMAT AND REUSE WITHIN EMBODIED
COGNITION**

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INTRODUCTION

The present dissertation is about what I purpose to call the Opacity Problem of Embodied Cognition (OPEC). Roughly, the idea that ‘embodied cognition’ is an ill-defined expression. I will examine a family of solutions to OPEC, according to which cognition is embodied when it *reuses* body-related representational *formats*. Format-reuse solutions to OPEC, I will argue, do seem to carry with them a set of further opacity problems, and such problems, seem to constrain any theory that targets OPEC by means of these ideas. The discovered constrains hopefully deliver a less opaque notion of Embodied Cognition.

The thesis unfolds as follows.

Chapter 1 both introduces OPEC and presents an underexplored solution to it: the Bodily Format Approach (Goldman 2012, 2014). EC literature is firstly reconstructed, along with a taxonomy of EC positions. OPEC is then put into stage: despite the amount of evidence and the variety of positions, we will try to show, ‘embodied cognition’ seems ill-defined. The third section is dedicated to Bodily Format Approach, according to which EC cases are cases of use and reuse of representations coded in a specific body format. Section four cashes out the debate emerged around Goldman’s view. Objections raised to Bodily Format Approach are then presented together with Goldman’s replies. The chapter ends by siding with Goldman’s replies.

Chapter 2 is critical. Bodily Formats Approach, I will argue, has few niceties, but it has few problem either. And those problems, I will also argue, seem concern the very core notions (b-format and reuse) of such a position. First, it is unclear what b-formats are, according to Bodily Format Approach. A number of possible answers will be presented, but, I will try to show, for each of them there seems to be a problem of individuation. Second, reuse devices may be of different sorts, and it is not fully clear which of them Goldman subscribes – plus, b-format and reuse seems to be two incompatible notions. The second chapter ends with a costs/benefits analysis. And if what we have said about Bodily Format Approach is on the right track, its costs do seem to exceed its benefits.

Chapter 3 drops the body and takes just format to be the explanatory notion of embodiment phenomena. One thing Bodily Format Approach does is to reframe the whole EC discussion into a debate about formats. We call this reframe the Format Shift of Embodied Cognition (FSEC), and we dedicate to it the first section (cf. e.g. Barsalou 1999, Prinz 2004, Mahon and Caramazza 2008, Mahon and Hickok 2016, Machery 2016). The second section is devoted to the distinction typically drawn within FSEC: the notorious “modal vs amodal” divide. Modalist vs Amodalist positions are reconstructed along with the recent debate such views have generated. An interlude on formats is afterwards presented: representations are typically said to possess a format, but what exactly a format is supposed to be? We offer an analysis of the notion as applied to public representations, and we defend a view according to which format features are formal-syntactic features of representations. Fourth and final paragraph tries to apply the earlier format considerations to modal vs amodal distinction, with the aim of showing that, however conceived, formats distinction does not quite help to solve OPEC.

Chapter 4 drops formats and takes on board the Neural Reuse Hypothesis of Embodied Cognition (NREC) (Anderson 2010, Barsalou 2016), the idea that EC cases are cases of sensorimotor neural redeployments. The double goal of the chapter is to present NREC merits and underlie some possible shortcoming. We first present the idea of reuse as applied to artefacts and biological traits: what does it mean for something to get reused, where ‘something’ is either a hand-made item or a naturally selected organ or trait. Neural reuse as an organizational principle of the brain is thus presented and compared with item and trait reuse: we will see what it means for a brain structure to be reused. Neural reuse as applied to EC cases is then put into focus. Again, we will examine what exactly NREC states, and how it relates with neural, artefactual and biological reuses. The fourth section examines the merits of NREC over its competitors: once reuse mechanisms are analyzed down, EC phenomena seems to be way more perspicuous. The fifth and final section is meant to be a bit more sceptical: even though the evidence typically drawn in favour of EC may

be more sharply captured, assuming NREC may have some unexpected implications which an EC defender might not want to go along with¹.

¹ I want to thank my supervisors for having believed in my project from the beginning to the end. My colleagues and friends Marco and Fabrizio, for having generously read and commented parts of the work. Finally, my wife Nicoletta, to whom writing a PhD dissertation can be important, but not too much.

CHAPTER 1

Over the past few decades, the idea that cognition is *embodied* (hereafter EC) has gained growing attention (cf. Mahon 2015). Both scientists and philosophers of mind have increasingly proposed reasons for believing cognition to be embodied. However, what exactly they take EC to mean is not always crystal clear. Despite the use of a common label, scholars notoriously hold different positions (cf. Wilson 2002), which are frequently formulated with not much precision and often contain terms whose meaning is not obvious. The work of Goldman (2012, 2014) does represent a notable exception to such a lack of conceptual precision. Goldman's idea is that cases of EC are cases of b-formats reuse, where 'reuse' refers to the redeployment of brain structures for a new function and 'b-format' picks out a dedicated way to code for body properties. This proposal, however, is not unproblematic (e.g. Gallagher 2018, Kiverstein forthcoming, Shapiro 2014). Some have argued it is too moderate, for it does not capture the revolutionary stance of many EC programs (Shapiro 2014). Others have pointed out it does not provide neither necessary nor sufficient conditions for cognition to be embodied (Kiverstein forthcoming). Others have yet claimed that, reducing EC to b-formats reused, cognitions supposedly embodied turns out to have little to do with the body (Gallagher 2018). Goldman seems to have good reasons to reject the first two objections and neutralize the third one (2014): any cognition that reuse b-formats is embodied, and viceversa, any embodied cognition reuses b-formats. The present chapter is to be conceived as an introduction both to the problem of clarifying the expression "embodied cognition" and the solution that conceives b-formats reuses as EC core defining feature. The chapter runs as follows. We review the EC literature, introducing a new taxonomy of EC positions, based on the interpretation EC defenders give to some expressions they typically use to utter their theses. We then show how, for each thesis, there is a problem of opacity: despite the great deal of empirical and conceptual work, 'EC' seem to still remain a rather vague expression that stand

for elusive commitments. The third section introduces Goldman's approach to EC, whereby cognition is embodied whenever it reuses b-formats. Objections and replies are thereafter presented, unpacking strengths and weaknesses of Goldman's view. We conclude with a word of praise: despite its problems, Goldman's theory deserves more attention than it has been received.

1.1 Varieties of Embodiment

'Embodied cognition' is an increasingly used expression of current philosophical and scientific vocabularies. A growing number of philosophers and scientists of mind tends in fact to argue that cognition is embodied (see e.g. Mahon 2015). Reasons for claiming so typically vary. Some have supported EC by showing that we can design *robots* capable of navigate just providing them with sensory organs and subsumption architectures (Brooks 1991). Others have instead defended it by conceiving our *conceptual* knowledge to be modality specific: the way we use *some* concepts, they hold, would depend on the way our perceptual (Barsalou 1999) and motor (Gallese and Lakoff 2005) systems code for information typically associated with their referents. Others have yet favoured EC by pointing out that many of our *cognitive abilities*, from language processing (Pulvermüller 2005) to vision (O'Regan and Noë 2001), from mind-reading (Gallese and Goldman 1998) to perceptual judgment (Bhalla and Proffitt 1999) are supported by sensorimotor processes of various kinds. Not to mention the role of *metaphor mapping* in conceptual abilities (Lakoff and Johnson 1980), *mirror* properties in action detection (Craighero 2014), *affordances* in language tasks (Glenberg and Kaschak 2002), *fingers* in counting (Andres et al 2007), *gestures* in reasoning and speech production (Alibali et al 2014), etc. etc. – Shapiro 2014 nicely describes the heterogeneous set of EC reasons and claims.

Thus, for example, when you have to judge the slant of a hill from its bottom while wearing a backpack, your judgment would demonstrably change depending on how heavy the backpack is (Bhalla and Proffitt 1999): the heavier the backpack, the steeper the hill will be perceived. Or, if you are required to pull a lever toward yourself to indicate comprehension of a given sentence, you are recognizably slower to react when the sentence refers to an action that involves a transfer away from yourself (Glenberg and Kaschak 2002). Grabbing a cup of tea and seeing somebody grabbing a cup of tea seems to recruit just about the same neural circuitries (Rizzolatti and Sinigaglia 2006). The way you visually experience a bottle crucially depends on the way you implicitly know how your experience would vary as you move around it (O'Regan and Noë 2001). Etc. etc.

Considerations along these – and similar – lines have led people claim that those – and other – cognitive processes are embodied: intelligent skills, visual experiences, perceptual judgments, concept and language processing, reasoning, mind-reading etc., EC supporters argue, are embodied cognitive processes, in the sense that, as the above studies have contributed to prove, intelligent skills, concept processing etc. would variously *depend on body-related subject matters*. For example, judging how steep is a slant is affected by how fatigued my back is; robots skilful navigation is based upon their input-output loops; my visual experience of an apple is constituted by my sensorimotor contingencies; your ability to draw inferences about dogs is grounded in your perceptual symbol system tracking dogs. Thus, what those authors have argued is that cognition is embodied, and they have argued so on the basis of an assorted set of premises.

However, what they take 'embodied' to mean is not always crystal clear. Despite their use of a common label, scholars notoriously defend quite different theses (cf. Wilson 2002), which are regularly formulated at a general level (Wight 2008), and often contain expressions whose meaning is not obvious (cf. Aizawa 2018). In fact, it is sometime noticed, depending on the

interpretation assigned to the terms occurring in each EC formulation, EC positions can range from trivial to non-trivial statements, and from moderate to radical positions (cf. Jacob 2015). What it means to say that the “body plays a crucial role in cognition” depends on what “body”, “crucial role”, “cognition” are taken to refer to by each EC scholar.

As a result, different EC interpretations have produced different EC positions².

1.3.3 *Body varieties*

For some, EC is the idea that the body, conceived as the device endowed with sensory organs and effectors, significantly contributes to the production of intelligent performances: if robots did not have cameras, wheels etc., they would not be able to produce skilful behaviours like navigation or object’s manipulation (Brooks 1999). If we humans did not have eyes, skin, nasal cavities etc., we could not entertain perceptual experiences (O’Regan and Noë 2001) or conceptual processing (Lakoff and Johnson 1999) the way we do. Cases like these motivate the *anatomy* interpretation of EC (cf. Goldman and Vignemont 2009). Anatomical differences make cognitive differences, in the sense that whatever manipulation of anatomy would affect cognitive properties as well: e.g. wearing a more or less heavy backpack would result in visually judging the slant as more or less steep.

Anatomical properties are not the only one that seems to be at stake, however. Body *activity* is part of what scholars take ‘body’ to mean too: eye saccades facilitate problem solving (Ballard et al 1997), facial feedback triggers emotional responses (Niedenthal et al 2005), gestures affect reasoning (Alibali et al 2014). Body activity reading of EC conceives movements and actions to be what of body contributes to cognizing: if we did not move our eyes, make gestures, walk around

² Our EC taxonomy diverges slightly from the one of others (cf. e.g. Adams 2010, Anderson 2003, Shapiro 2011, Wilson 2002, Wilson and Foglia 2015), for we take an ordinary language criterion, so to speak: EC accounts are identified by the way EC scholars have *used* the terms to state them.

upright and forward the way we do, the activity view holds, we would not perceptually experience, use concepts, infer, memorize etc. the way we do.

To some, 'body' does yet mean something different from body anatomy or activity. According to some scholars, the idea that cognition is embodied refers to cases of sensorimotor *brain* activations during non-sensorimotor cognitive tasks. Modality specific triggering in conceptual processing (Barsalou 1999) and premotor activations in action-related verbs processing (Pulvermüller 2005) are paradigmatic examples of EC under this interpretation. 'Body' here is used in a rather peculiar way as to designate something like body-related brain features: neural circuits specifically dedicated to support either perceptual or motor task – which get activated, in the allegedly EC cases, to support either non-perceptual or non-motor tasks. On this view, what contributes to cognition are not much sensory organs and effectors per se, but rather the neural networks that typically receive inputs from sensory organs and send motor outputs to the effectors. Thinking about dogs, processing the word 'kick', seeing someone grabbing a cup of tea etc. would thus being conceived as occurrences of embodied cognitive processes in the sense that, during each such task, the brain networks that receive inputs from sensory organs and send outputs to the effectors get activated. Thinking about dogs triggers the same network that support visual, auditory, tactile etc. interactions with DOG members (Barsalou 1999)³; hearing the word 'kick' strongly activates somatotopic areas of premotor cortex associated with legs movements (Pulvermüller 2005); grabbing a cup of tea and seeing someone grabbing a cup of tea trigger just about the same motor network (Rizzolatti and Sinigaglia 2006); etc.

³ From now on, we will use DOG as a mention of the concept, and 'dog' as a mention of the word (the convention generalizes to any concept and word). We do also switch from concepts to words since EC accounts range both over concepts processing and words understanding.

1.3.4 Contribution varieties

Commitments behind EC do not only rest on the different readings of 'body', however. In fact, EC taxonomy does get further articulated along with the use EC defenders have made of the expression "crucial role". The body, is often said, plays a crucial role in cognition. But, it has been pointed out (Shapiro 2011), different authors use the expression differently (cf. also Wilson and Foglia 2011).

Some people believe the relation holding between body and cognition is one of *constitution*: according to them, the visual experience of a bottle and the processing of the term 'grab' respectively *consist* of sensorimotor contingencies (O'Regan and Noë 2001) and activations of premotor circuitries (Lakoff and Gallese 2005). On this view, visually experiencing a bottle and processing the meaning of 'grab' are *identical* respectively with knowing how our visual stimuli vary as we move around the bottle, and activating premotor circuitries: sensorimotor contingencies and activations are necessary and sufficient for vision and language processes. If this position is correct, then body-related properties would be literally *parts* of our cognitive procedures, in the same sense in which a handle is part of the mug and cutleries are part of the tableware: eye movements or pre-motor activations would be parts of visual experience and action-verb processing respectively – cf. Block 2007 for a critical point on this.

Others have yet assumed the supposed dependence relation of cognition on the body as being one of *causation*: body-related properties, it is often said, play a crucial causal role in cognitive processing. On this view, conceptual abilities, linguistic competences, mind-reading skills etc. causally interact with bodily features. For example, drawing inferences about dogs interferes with brain systems responsible for perceiving dogs (Barsalou 1999) or hearing the sentence 'Meghan

gave you a pen' as opposed to 'You gave Meghan a pen' interferes with systems supporting movements away from myself as opposed to movements toward myself (Glenberg and Kaschak 2002). Here causal relations between sensorimotor systems and non-sensorimotor tasks means that manipulations of the firsts have effects on the seconds: for example, concepts tasks get influenced (either improved or degraded) by perceptual activations, and language performances get influenced (either improved or degraded) by motor triggering.

Others have yet notably taken the body properties to be a *facilitating* factor for cognition. If they are right, what the body does is to *offload*, so to speak, the computational work required to execute a cognitive task (Clark 1997). Gestures in reasoning (Alibali et al 2014), fingers in counting (Andres et al 2007), eye saccades in problem solving (Ballard et al 1997) are cases of such facilitating relation between body and cognition. People who defend this relation maintain that gestures, eyes or fingers movements facilitate the solution of cognitive problems such as explaining how to get from the Tour Eiffel to the Montparnasse Tower, memorizing shapes and colours of some Tetris blocks on a computer screen, or counting integers up to 10. Any such body-related activity, according to this view, would help to get those problem solving done, as far as it would reduce the information load needed to get those tasks done (cf. Machery 2016).

Simulation is yet another notion scholars have been extensively using to express EC commitments: body properties affect cognition in the sense that simulations of perceptions and actions do influence cognition. According to a simulationist, what one means by saying that memory, reasoning, mind-reading, concept and language processing are influenced by body properties is that, during all such tasks, our sensorimotor systems produce a simulation of things or properties memories, reasoning etc. are about. Drawing inferences on dogs is supposed to be done by running a simulation on dogs perceptual symbols (Barsalou 1999), as well as reading the verb 'kick'

induces the simulation of the kicking motor plans – for an exhaustive treatment of the notion of simulation see e.g. Goldman 2006.

1.3.5 Cognitive varieties

EC defenders have also tended to attribute “embodiment” to different kinds of cognitive processes. Somebody typically refers to *low*-level kinds, such as visual perception (O’Regan and Noë 2001) or skilful activities (Brooks 1999), whereas others have in mind *high*-level procedures, such as concepts (Barsalou 1999) or language (Pulvermüller 2005) processing. Typically, authors from the first party believe embodiment to be correctly predicated of high-level cognitions as well, taking them to be nothing over and above low-level cognitions “piled up” during evolutionary time (Hutto and Myin 2017): as systems that support concept and language processing are proved to be continuous with systems that support coping relations with the environment, and EC is correctly predicated of the former systems, so they hold, EC would be correctly predicated of the latter too.

People also divide in wanting either *conscious* or *unconscious* properties to be embodied. According to some authors, it is the *qualitative* aspect of cognition that is somehow related with body-properties of some kind (O’Regan and Noë 2001, Varela et al 1991). Again, implicitly knowing how my visual stimuli of a bottle would vary as a consequence of me moving around it would determine my experience of that bottle as the experience it is. Or the fact that our retina possesses three sorts of cells responding differently to different light frequencies (short, medium, long wavelengths) is what makes our diverse colour experiences those very experiences. The vast majority of EC efforts are nevertheless devoted to *subconscious* cognitions. Body’s contributions, whatever they might be, seem to regard by and large the levels of cognitive computations we are unaware of: we gesticulate while reasoning about spatial properties, our pre-motor neurons get activated even when seeing others grabbing objects, we re-enact perceptions of dogs while

drawing inferences about dogs, etc. and do we carry all such bodily-based cognitive activities in an entirely automatic and unconscious way.

1.3.6 *Embodiment varieties*

Now, the way one combines the above-mentioned readings brings about a set of quite diverse EC positions. EC can be a rather *trivial* thesis (Jacob 2015). Indeed, it seems pretty uncontroversial to say that our body anatomy causally affects our low-level cognition. Of course we have two eyes, a nose set between them, one head that swivels from 120 to 160 degrees on a neck. And, of course, any of these anatomical features causally interact with many of our psychological capacities: each eye can target only a portion of the visual scene; the images each eye produces – given their distance – do not quite correspond each other (at least for those images caused by nearby surfaces); neck swivelling influence one's perceptions, etc. Those are platitudes for folk psychology, and even more so for the scientific viewpoint: nobody would seriously argue that human visual, auditory, tactile or olfactory activities do not causally depend upon the detailed structure of human eyes, ears, skins, nasal cavities etc. Of course, if we had the bat's echolocation system we would have perceived the world differently than we do, as much as opening vs closing our eyes does indeed systematically affect our visual perception (Goldman and Vignemont 2009). Nobody would honestly argue against these trivialities, but nobody would honestly maintain them either.

What seems to be controversial is *whether* and to what *extent* sensorimotor *activations* do matter to *high-level* cognitive tasks. That is to say, whether and to what extent input-output *systems* contribute to reasoning, concept or language processing, mind-reading etc. (cf. e.g. Alsmith and Vignemont 2012, Prinz 2008).

Those who take 'body' to mean non-neural properties have obviously given a negative answer: it is the body itself, so they argue, and not some internal system that controls its parts, that does the contribution. People belonging to this camp have defended a *radical* variant of EC (e.g. Chemero 2009, Hutto and Myin 2013). What they generally maintain is that body anatomy and activity play constitutive roles: robots artificial sensorial organs and effectors are assumed to be parts of their cognitive activities (Brooks 1999), body movements are conceived as necessary and sufficient for visual experiences (O'Regan and Noë 2001), etc. Their radical stance consists in *replacing* body control related properties with body itself related ones, and explaining EC kind of phenomena in a non-computational, non-representational fashion (Shapiro 2011). What these authors claim, however, seems just to apply to low-level cases: body anatomy and activity can meaningfully said to be part of cognition only if 'cognition' refers to perceptual events or skilful activities, for it seems at least weird to say that harm movements or saccades are constitutive part of e.g. language processing. Unless we revise entirely the way we talk, radical variants of EC appear to be restricted to a tiny portion of cognition, that is to say, early stages of perceptual phenomena, excluding the interesting cases of language and conceptualization.

In this respect, scholars who use 'body' to designate body-control brain properties seem to be in a better position: they assume sensorimotor activations to play a crucial role in cognition, in the sense that they take input-output systems to help us reasoning, language and concepts processing, mind-reading etc. Those belonging to this camp have hold a *moderate* EC variant (for example, Barsalou 1999, Pulvermüller 2005): they consider sensorimotor processes to be crucial to cognition without dropping old fashioned architectural assumptions. There are many ways in which our mind-brain systems represent inputs-outputs, moderate EC defenders seems to argue, and these many ways do in fact interestingly interact with the execution of non input-output related processes.

One problem with moderate formulations, however, concerns the *nature* of sensorimotor contribution. Are the so-called modal circuits causally involved in concept processing? Or are they also constitutively so? For instance, does the evidence that our modal areas trigger during DOG related conceptual tasks provide reasons to believe DOG to be causally related to – as opposed to constitutively related to – modal areas? According to moderates, sensorimotor activations matter to higher cognition, but the extent to which they matter is not precisely specified. One reason for that can be that distinguishing causal from constitutional relations just by relying on the empirical evidence turns out to be quite a difficult task (cf. Shapiro 2011). For example, it is not easy to assess whether motor cortex activations during action's verbs processing prove such verbs processing to be constituted by such activations, for the evidence is compatible with motor activations being both prior to and subsequent to non-motor ones (cf. Mahon and Caramazza 2008) – and the constitutive thesis gets proved by the motor system being active at least in synchrony with the non-motor one. Besides, moderates face a scope-related problem: do sensorimotor circuitries matter to *all* high-level tokens? Or rather, whatever its nature is, their contribution applies only to some portion of them? DOG and 'kick' tasks respectively trigger sensorial and motor areas: but what about JUSTICE, ENTROPY, 'beauty' or 'quantifier'? Moderate supporters divide between those who restrict embodiment to a subset of concepts or terms (Barsalou 1999), and those who seem to apply it to higher domains as well (Lakoff and Gallese 2005).

1.4 The Opacity Problem of Embodied Cognition

Thus, despite the great deal of work devoted to its clarification (Anderson 2003, Clark 2008, Shapiro 2011, Wilson and Foglia 2015, Wilson 2002), EC seems remaining a pretty elusive and yet not fully understood notion (cf. Shapiro 2014).

On the one hand, there is a problem of linguistic *idiosyncrasy*: each author uses the *same* label in a slightly different way. As said, ‘embodiment’ could refer both to body related neural properties and extraneural body ones, each making diverse sorts of contributions in a variety of cognitive tasks and domains. However, EC supporters do not seem to be interested in accompany their statements with an explicit stance on the specific EC reading they commit to (Goldman and de Vignemont 2009). On the contrary, they tend to be rather ambiguous over most of the above-mentioned issues. They typically do not point to specific *domains*, sometimes taking evidence from one cognitive token, e.g. processing ‘kick’, and applying it to a broader kind, e.g. language understanding. Moreover, even when they specify the domain over which embodiment is supposed to range, they tend not to be very precise about the *amount* of embodiment it can be legitimately predicated – for example, whether processing ‘kick’ is more embodied, so to speak, than processing ‘democracy’, or whether mind-reading someone doing math tasks is less embodied than mind-reading him grabbing a cup of tea. As a result, the expression ‘embodied cognition’ amounts to a variety of substantially different proposals, most of the time uncritically treated as if they were a unitary, intuitive, perspicuous enough thesis.

The opposite idiosyncrasy problem seems to bother EC literature as well. Scholars tend in fact to use *different* labels to defend *similar* theses. The talk of “grounded” (Barsalou 1999) and “enacted” (O’Regan and Noë 2001) cognition nicely exemplifies this tendency, for grounding and enaction generally goes along with weak and strong EC theses respectively. Grounded cognition

mostly refers to cases of moderate EC, in the sense that cognition is supposed to be grounded when perceptual or motor systems contribute to concept or language processing: for example, DOG is supposed to be grounded when perceptual systems are active during inferential tasks involving DOG, or the meaning of 'kick' is supposed to be grounded when motor systems of a subject are active while he hear 'kick'. Likewise, enactive cognition cases overlap with what we called radical EC cases (Hutto and Myin 2017). That is, cognition is considered enacted whenever non-neural body features play constitutive roles in lower-level tasks: for example, vision is said to be enacted since eye structures and movements are considered to be parts of visual processes (O'Regan and Noë 2001) or colour experiences (Varela et al 1991). Scholars with diverse lexical inclinations tend to use different terms while committing themselves to essentially analogous theses.

On the other hand, there seem to be a problem of *clarity*. Even when it is conveniently tracked down, each EC variant does not seem to provide well enough *specified* statements that rigorously define which position is defended.

Moderate accounts typically attribute to inputs-outputs representations crucial roles in high-level cognitive functions, but they do often keep a relatively ambiguous stance toward the *kind* of cruciality involved: sometimes the relation at stake seems to be one of causation (Barsalou 1999), in the sense that modal circuitries seem to be necessary for conceptual tasks – e.g. drawing inferences about dogs. At other times, the relation seems instead to be one of constitution: somebody seems in fact to consider motor activations to be both necessary and sufficient for language tasks – e.g. processing 'grasp' (Gallese and Lakoff 2005).

Moderates also swing between those who hold a facilitating sort of contribution and those who submit other kinds of constrain relations. For instance, to some, motor activations help

comprehension tasks involving sentences like 'Meghan gave you a pen', as opposed to sentences like 'you gave Meghan a pen' (Glenberg and Kaschak 2002). Others (Lakoff and Johnson 1999) have instead argued that spatial concepts like UP, DOWN, BACK and FRONT are somehow shaped by the way we represent objects relative to our body: upper, downer etc.

None of the above relations, it is been pointed out, are satisfactorily understood (Shapiro 2014). How can we possibly decide whether modal brain areas influence our conceptual tasks concerning dogs rather constituting a part of them? And if they just influence them, which kind of influence is it? Is it of a causal, facilitating, or shaping sort? Alternatively, if it is a piece of it, what kind of piece? Could motor activations in action verb tasks determine the nature of those very tasks?

The fact that there is quite a lively debate about those issues with fairly little advancement (cf. e.g. Adams and Aizawa 2008, Shapiro 2011) creates the impression that the notions EC has been defined upon are still underilluminated. One reason for that might be that the *divide* between causal and constitutive relations is not quite easy to identify (Shapiro 2011). Does reading a recipe count as a constituent part of such process or is it a contributor to it? And what of measuring ingredients or getting to the supermarket to buy the aubergines you have forgot? Unclear cases of constitutive vs causal kind of relations seem to apply to the body's role in cognition as well: are perhaps eyes part of the visual processes? Or they just causally contribute to it by providing optic information? And what about rods and cones? Aren't they both part of the human eye and cause of visual processing? Insofar as those boarder-line questions do lack clear answers such notions seems to be of quite little help for the sake of clarifying EC.

Another reason for the apparent EC stagnation is that notions like body shaping or special contribution sometimes give the impression of implying *trivial* theses (e.g. Adams and Aizawa 2008). Surely, cognition is sensitive to body-related properties: changes in blood glucose have for

example effects on attentive tasks, and sleep deprivation may impact our capacity of demonstrating Peano's axioms. This seems vacuously true. However, if EC has to be interesting, one may argue, body features must do more than bearing causal relations with higher cognition.

As a result, there seems to be a disproportion between the quantity of experimental data collected on EC related phenomena and the quality of conceptual analyses devoted to them (see e.g. Goldinger et al 2016). If the above considerations are on the right track, *embodiment* does in fact remain an unclear property of – or a relation entertained by – some cognitive tokens. Despite the impressive array of studies on EC-like phenomena, scholars keep on claiming that cognition C is embodied E – or cognition C bears a relation E with body B – without clarifying what does it mean for C to be E – or for C to bear the relation E with B. All it seems we have, at the present state of the art, is an assortment of diverse empirical premises, on the basis of which a multitude of scholars has been defending a set of relatively unclear conceptual conclusions. But, one could remark, how is it *possible* to *hold* EC in the absence of a clear and consistently applied account of it? Even assuming the limits of empirical underdetermination, it seems that the evidence provided in favour of EC counts as such depending on how EC gets actually formulated. And if it remains unclear what exactly is argued when one claims that “cognition is embodied” plus the expression has not a fixed meaning, one could then conclude, it looks likewise difficult to understand which reasons exactly should legitimately confirm or disconfirm embodied cognition.

Indeed, getting clear about what property P – or relation R – makes cognitive token C embodied E seems necessary for evaluating whether or not cognitive token C does enjoy property P – or entertain relation R. In fact, if C does enjoy P – or does entertain R – it can then be legitimately considered E – otherwise it cannot. The problem of clarifying the cogence of EC arguments would then become the problem of making *explicit* EC. That is, defining the conditions under which a given cognitive token C has to be considered embodied E seems to be required for someone to

understand whether that token C is, as a matter of fact, E – or not. Sticking otherwise with unclear EC commitments, as someone has suspected (Goldinger et al 2016), may have the unhappy outcome of stagnation, with EC not undergoing that much of a scientific and philosophical development.

Call that problem the Opacity Problem of Embodied Cognition (hereafter OPEC)⁴.

1.5 Goldman's solution

1.3.1. Clarity & fruitfulness

There seems to be at least one exception of such a lack of conceptual precision (Goldman and de Vignemont 2009, Goldman 2012, 2014). Indeed, unlike many EC theoretical enterprises, the work at hand does explicitly want to target OPEC. On that account, EC is in fact in dire need of some good old fashioned conceptual analysis: a tidy formula that would define EC in terms of a conceptually *clear* and empirically *fruitful* notion (cf. Goldman 2012). Whatever 'embodied' means each time, it would be better reduced to a clearer and consistently applied concept, which picks out a natural property (or a relation) providing some sort of precise empirical prediction. For example, it has to make it clear when exactly reasoning, language processing, etc. are – or not – embodied, in a way that is both non trivially true and predictable by the data on reasoning, language processing, etc.

In this sense, the work of Goldman – and de Vignemont⁵ – is supposed to offer a solution to OPEC. It aims at providing a definition of what is for a given cognitive process C to be embodied E. Indeed, the clearer an EC thesis can get, it is argued, the easier one could establish whether the

⁴ Caveat: OPEC has to apply only to specific *variants* of EC. The present work is thus devoted to detailed EC accounts, rather than to EC conceived as a general framework. Whether OPEC is problematic or not would then depend on the fine details of each EC thesis taken into account (i.e. once terms and relations are precisified). I am grateful to a reviewer for his comment on this.

⁵ As this account got recently defended by Goldman alone, we will attribute the paternity to him.

experimental findings prove C to be E – or not. Goldman's (2012, 2014) explicitly appeals to a definitory strategy: necessary and sufficient conditions for C to be E has to be founded. Something of the form 'C is E if and only if ___' where '___' is filled in by a perspicuous condition. Any reasoning or linguistic process that possesses a given body related property (or relation) is a case of embodied reasoning or linguistic process, and conversely all reasoning or linguistic process which instantiates that property (or relation), according to Goldman's account, are embodied reasoning or linguistic processes.

This is the *conceptual* side of the story: there is a rather ill understood notion –i.e. embodied cognition – which has to be reduced to a possibly more explanatory one – i.e. having a better defined natural property or bearing a better defined natural relation. And the reduction has to capture the intuitions lying behind EC – i.e. the idea of body contribution's to cognition – typically drawn from the abovementioned studies. In other words, Goldman wants to interpret EC evidence in a way that is non-trivial, clear and explanatory enough.

On the other hand, his account is supposed to be of *empirical* import as well. Whether evidence confirms, for example, action verbs processing to be embodied, would depend on whether action verbs processing instantiates the *right* "embodied" property (or relation). So, according to the present view, the issue of whether action verbs processing has to be considered embodied would become the issue of whether that very processing does satisfy the set of embodied conditions provided by this account. The empirical import consists in the fact that the embodied conditions provided by Goldman are supposed to be empirically *testable*: action verbs processing would be considered a token of embodiment when (and only when) experimental findings show it instantiates the right embodiment condition and such a condition is empirically testable. Following

Goldman's criterion would make it is easy to test whether action verbs processing is embodied, for it would be easy to test whether his criterion is met⁶.

1.3.2 *The Bodily Format Approach*

What is the condition then? Goldman first describes what the condition is *not*. According to him, the EC defining features have *not* to be found in body anatomy nor activity readings (§1.1.1), for body *per se* attributes seem to be neither necessary nor sufficient to capture what is going on in embodiment examples (Goldman 2012, see also Goldman and de Vignemont 2009). First, they are not necessary, because being caused or constituted by extra-neural body attributes is hardly an essential property of many embodiment cases: if it were so, the set of EC phenomena would have been *limited* to perceptions or action commands. It is difficult to see how linguistic or conceptual processing, e.g. attending the word 'kick', can be caused or even constituted by our body anatomy or activity, e.g. the structure of our legs or the way we move them. And higher level linguistic or conceptual tasks represent a primarily interest for many EC models (§1.1.4). But body *per se* definitions seem not to provide sufficient conditions for embodiment neither, for being caused or constituted by body *per se* properties does not seem enough to capture all embodiment effects: if it were so, it is been hold, every perceptual operation would end up being trivially embodied, as long as every perceptual process seem to be partially caused or constituted by the structure of our sensory organs (§1.1.4). And that, so it is argued, would be quite an unhappy result, for we want embodiment to be an interesting feature of e.g. vision (O'Regan and Noë 2001) or visual categorization (Bhalla and Proffitt 1999).

For those reasons, the solution to EC definitory problem favoured by Goldman is *moderate* in character (§1.1.4). That is, he believes bodily *representations* to be the defining features of EC

⁶ More on Goldman niceties in Ch 2, § 1.

phenomena – more on bodily representations soon. What makes a cognition C embodied E, he claims, is the fact that C operates over bodily representations B. In other words, to possess bodily representations is both a necessary and sufficient condition for C to be E: all and only a cognitive process C operating over a bodily representation B can be taken as embodied E.

Not any moderate solution fits the bill, however. Representations can be bodily in virtue of their *contents*. That is to say, they can have our own body subject matters as their intentional objects: mind-brain systems can take our own body (anatomy/activity) to be in certain ways, having it as their representational content, and it is the fact that they refer to such own body subject matters that makes those representations bodily. For instance, I can represent my legs to be in a certain position or to move in a certain direction by seeing them lying on the floor or gliding forward, and it is in virtue of having those contents that those representations can said to be “bodily”. Now, as Goldman says, a bodily content solution does not accommodate EC phenomena, for it does not provide neither necessary nor sufficient conditions. On the one hand, there are many – indeed the most interesting – EC processes which clearly do not refer to our own body: hill’s slant perceptual judgment is about the hill’s slant, tea-cup grubbing action detection is about tea-cup grubbing action, finger counting is about numbers etc. If being about our own body has to be necessary for a piece of cognition to be considered embodied, then most of the compelling EC cases would be ruled out, since most of those cases are not cases of cognition directed to our own body.

The sufficient side seems to be problematic as well: there seems to be non-EC cases which nonetheless take bodily matters as their representational contents: looking at the position of my leg or sending movements to my arm could be two such examples, for attributing embodiment to those bodily oriented cognitive activities looks like an empty re-description of them. None in the EC community would say that looking at our feet or moving our arms are embodied processes.

A way more promising solution to OPEC, according to Goldman, has to take representations in bodily *formats* as the defining features of EC. According to that view:

cognition is embodied if and only if it *re-uses representations in bodily format*

(Goldman 2012, 2014). Since the notion Goldman wants to reduce embodiment to – left hand side of the biconditional – is a complex one, in order to understand his solution, and whether it is actually a promising one, one has to understand what representations in bodily format are and what reuse mechanics consists of.

Let's begin with the first notion. Representation can be considered as bodily also in virtue of its format. Take the following example: when I move my leg forward, I can represent its movements perceptually, e.g. by seeing them, but I can also represent them interoceptively, e.g. by sensing the movement from the inside as it were. Both representations have leg movements as their content: they take my leg as moving in a certain way, e.g. gliding forward. And so, they have the same truth conditions: they are true if the leg does move that way otherwise are false. However, they represent in two formats: a visual format vs an interoceptive one. There is a sense in which both representations refer to the same body activity: leg's movements. And there is a sense in which they code in two different ways: say an "external" way and an "internal" one. Now, on Goldman's view, each such representation code for leg's movements in a different format, and only the second representation codes in a bodily related format – that is, a bodily format (BF).

More precisely, a BF is meant to be a mental representation with 1) a proprietary *code* 2) typically used by a set of *inner sense* systems, such as the interoceptive system or the motor system 3) to represent body-related subject matters, such as limb positions or movements (Goldman 2014, p. 100). Interoceptive systems paradigmatically exemplify b-formatted representations with *descriptive* content – leg in position S – while motor systems operate on b-formats with

prescriptive ones – leg: move forward (ibid). BF are thus defined upon the way interoceptive and motor systems code for body related properties, in the sense that the body related information those systems elaborate are assumed to be conveyed in BF. According to Goldman, what the interoceptive and the motor systems typically do is to represent a set of body related subject matters couched in a specific BF.

Thus, under Goldman definition, any cognitive process C turns out to be embodied E when it operates over representations in BF. All and only the processes which operate over BF representations should be called “embodied”. This does not seem yet satisfying, however. If we did stop here, EC cases would coincide with interoceptive and motoric cases: if C is E when it operates on BF, and BF are just interoceptive/motoric, then EC applies to interoception/motion: On this account, EC would coincide with interoceiving limb position/movements. But again, the more interesting EC examples are not interoception nor motor command: visual categorization, concept processing, action’s detection neither equate to interoceptive sort of operations nor to prescriptive motor commands.

So, the *simple* format definition has the double unpleasant outcome of consider interoception and action phenomena as instances of EC (sufficient side), while ruling out non-interoception and non-action phenomena as non EC phenomena (necessary side).

The second aspect of Goldman’s moderate definition is precisely supposed to obviate this unpleasantness. Indeed, the interesting aspect of EC story, he quite happily recognizes, does not rest on the *primary* function of BF representations. Rather, it resides on the way those systems get reused to execute different cognitive tasks (cf. 2012, 2014). Anderson (2007, 2010, see also 2014) has been defending a theory of those exploiting mechanisms which Goldman relies upon.

According to Anderson, there is a solid evidence for neural redeployment, which is the idea that, under evolutionary time (and even ontogeny), neural structures established to support *one* function get redeployed to support *another* function⁷. An extensive review of recent fMRI studies (cf. 2007, 2010) shows that many brain regions (even small ones) are likely to be activated in a variety of different tasks over multiple domains. There is no region-function one to one mapping. For example, the so called “Broca’s area” does not only get involved in language processing tasks but seems to support also action and imagery related functions – among others. And the same organizational principle applies to diverse regions, regardless of where they are localized and which functions they got selected for.

Neural reuse view (cf. also Dehaene and Cohen 2007, Gallese 2008, Hurley 2008) gives thus Goldman reasons to think that systems delivering BF representations do not support just interoceptive tasks or motoric functions, but they are rather likely to get massively reused in a variety of non-interoceptive non motoric tasks. Under evolutionary time (or even ontogeny), systems selected to process BF representations get redeployed to realize a variety of higher level cognitive tasks. Neural reuse nicely suits Goldman’s purposes, for it allows him to attribute embodiment to higher cognition while maintaining BF as the EC defining feature. Thus, Goldman’s solution to OPEC takes the following form:

cognitive token *c* is embodied if and only if *c* uses or reuses representations in BF

where the “use” condition ranges over some sort of *primitive* embodiment, capturing sensorimotor cases like interoceptions and motor commands, whereas the “reuse” condition does range over cases of *derivative* embodiment, modelling the more interesting EC phenomena such as language understanding.

⁷ For a more extensive and detailed treatment of neural reuse, see Chapter 4.

According to Goldman, OPEC would then be solved in the following way. Wearing a heavy backpack would affect my judgment of the slope steepness because circuitries originally selected to interoceive my back got redeployed to judge the slope; hearing the word 'kick' strongly activates the pre-motor circuit related to leg's control because BF representations originally deployed to send commands to the leg got redeployed to process the word 'kick'; and so on for any EC effect. As a consequence of Goldman's account, interoceiving the states of my back is primitively embodied while visually judging the slant of the slope is derivatively so – of course, if the first cognitive token uses BFs while the second reuses them.

This seems a pretty satisfactory solution to OPEC. From low level sensorimotor processes up to inferential and linguistic tasks, any embodied cognitive token seems to have, under BF approach, a conceptually clear way for being identified. If visual experiences, perceptual judgments, concept processing, mind-reading, language understanding etc. deploy or redeploy BF representations, then they have to be considered embodied visual experiences, embodied visual judgments, etc. Otherwise they have not. And viceversa, any embodied cognitive processes, being it primitive or not, have to operate over BFs, either using or reusing them. So, for example, if we find out that, when we make elementary arithmetic tasks we do recruit BF representations originally used to control fingers' movements, then this task counts as an embodied activity under Goldman's characterization. On the contrary, if some scholar would discover that we do not recruit BFs during visual judgment task then, by Goldman lights, we could not count it as embodied.

On the other hand, Goldman's method seems epistemologically efficient as well. The only thing one has to do in order to establish whether or not a cognitive token instantiates embodiment is to check whether recruits BF representations. If it does, then it counts as an embodied cognitive token, otherwise it does not. Thus, checking out whether we reuse BFs when we judge how steep

is a slope is all and only we have to do to establish whether the visual judgment is embodied, under Goldman's view. And the *check*, after all, seems easy enough to carry out.

1.4 Objections and replies

Yet, despite all that, the BF approach has not convinced everybody. Even if some have endorsed it (Gallese and Sinigaglia 2011) and others have defended it (Adams forthcoming), Goldman's account has raised a number of perplexities. Indeed, somebody has argued it is too moderate, for it does not quite capture the revolutionary stance of many EC programs (e.g. Kiverstein forthcoming). Somebody else has targeted its definitory strategy, pointing out that it does not provide neither necessary nor sufficient conditions for cognition to be embodied (Shapiro 2014). Other have yet claimed that, reducing EC to b-format reuses, supposedly embodied tasks seem have little to do with bodies (Gallagher 2015).

1.4.1. The anti-moderation challenge

Let's see the first concern. If Goldman's characterization were correct, EC would not represent that big of a challenge to the standard conceptions of cognition. As he explicitly recognizes (Goldman 2012, p. 72), there is nothing in his idea of embodiment that requires a revolution within cognitive science orthodoxy really. BF approach is in fact consistent with cognition being computational procedures over representational structures (ibid). Indeed, if Goldman is right, EC is just a subset of algorithmic operations over cognitive representations of a peculiar sort: what is embodied of mind-reading somebody grabbing a cup of tea, for example, has to do with our brain computing over BFs originally used for grabbing tasks.

The orthodoxy, scholars have objected (Kiverstein forthcoming, Shapiro 2014), could not account for EC, since whatever it means, EC is the idea to conceive the body itself – and not brain computations over representations – to be the crucial contributor to our cognition. Goldman himself has admitted not to take the body itself as the crucial contributor in EC cases, however. And this is the reason why, according to some criticism, BF view is indeed limited and distortive of EC story.

It is *limited* because it does not apply to paradigmatic EC examples (Shapiro 2014): robot navigation skills (Brooks 1991), coordination dynamics (Kelso 1995), categorical perception in simulated agents (Beer 2003), enactive world-making (Varela et al 1991) are well recognized EC cases which hardly concern BF's codes. Any model that does not account for those phenomena, so the complain goes, cannot be an adequate model of EC, for EC typically applies to those phenomena. In other words, BF is too an incomplete approach to EC, since it does not apply to these anatomy/activity contributions to cognition, and those anatomy/activity contributions are what essentially characterize EC (cf. Kiverstein forthcoming).

Besides, and for analogous reasons, Goldman's move is accused to be *distortive*, in the sense that, taking Goldman's ideas at face value, the body itself turns out not to play any substantive role in cognition (cf. Gallagher 2015). The distortion is supposed to be twofold. On the one hand, if Goldman is right, the relation between input-output systems and central cognition seems to be just one of *causation* (Adams forthcoming). BF seems in fact to screen off, so to speak, both perceptual stimuli and motor responses, receiving inputs from our (internal) sensors and sending outputs to effectors: what BF representations do, the critic goes, is to transduce in an "inner sense" way certain stimuli, e.g. from our back, over which our cognitive computations are carried out, e.g. in visual judgment. *But* EC requires more than just body causation. Indeed, it is the very modular, "sandwich-like" architecture (Hurley 1998) which is considered to be inadequate by

radical EC defenders: if body's crucial role in cognition has proved something, they typically hold, is that the idea that fodorian *trichotomy* is false (Jacob 2015). There is no boundary between vision and cognition when it comes to categorical tasks about dogs, as well as there is no boundary between cognition and action when it comes to 'kick' processing, in the sense that there are no transductions between input-output systems and cognition during these tasks' performances. In other words, Goldman account of EC is distortive, so radicals EC claim, since BF representations bear causal relations with perceptual and motoric systems, and they want cognition to be *constituted* by these systems (Kiverstein forthcoming).

But Goldman move is distortive in at least another sense. Such a view seems in fact consistent with our brain been in a vat (Shapiro 2014). Using and reusing BFs seems perfectly consistent with being envatted brains. Even if we were envatted brains it seems we could still judge the slant of an hallucinated hill, by operating over representations selected to code for the states and properties of our back. Nothing seems to prevent us from getting BF representations activated during that task while being immobile or unable to use our body (if having a body at all).

By Goldman's lights, embodiment turns out to be just *neural* event: as long as they redeploy BF representations, action verb understanding of an envatted brain can just be as embodied as action verb understanding of an open-air brain. Having that as a consequence, however, suffices to cast doubts on the adequacy of Goldman's proposal, for again, if anything would capture the essence of EC, that is the idea of body itself (anatomy or activity) being *necessary* for cognition, and body itself does not give any essential contribution, on Goldman's account (Shapiro 2014)⁸.

Both these alleged limitations and distortions of Goldman's position follow from its moderation. Moderation does not seem to be problematic in itself, however: there are many interesting

⁸ More on that body irrelevancy objection and Goldman's reply in Ch 2.

empirical results on body contributions to cognition that can be – and have to be – clarified *within* computational/representational assumptions (Goldman 2012). Moreover, there is no need to defend moderation, as: 1) scientific moderation is not a vice in itself, and 2) there is no reason why EC phenomena cannot be captured in computational and representational terms. Non computational/representational readings of EC related phenomena (§1.1.4), does not evidently score better. Radical defenders obviously think it does (Kiverstein forthcoming, Gallagher 2015), but it seems they often take it for granted, rather than providing explicit arguments for it (cf. Adams forthcoming). For example, they typically *assume* robots’ organs (Brooks 1991) or sensorimotor contingencies (O’Regan and Noë 2001) to prove that anatomical features or movements play constitutive roles in skilful activities or visual experiences, respectively, even though, it is been said, it is not obviously so (cf. Block 2007).

And even if it were, it is not entirely clear how one can generalize from low-level to high-level processes within a non-representational context. Most EC radical accounts seem to identify cognition with behaviour (cf. Aizawa 2015), but it is not obvious how one could “scale up” from behaviour to cognition (§1.1.4), on the one hand, and whether identifying cognition with behaviour is a good move, on the other. Goldman’s proposal on EC is admittedly *not* an all-embracing one: if EC amounts to BF reused, EC certainly turns out to be less radical than EC fan would wish for. And nevertheless, Goldman’s account does not quite seem to be motivated by an ecumenical spirit. For example, it does not seem interested in what roboticists or dynamic system theorists (Brooks 1991, Kelso 1995) call ‘EC’. Rather, solving OPEC for a class of solid behavioural and brain studies is what interests him. For example, BF’s view nicely fits with visual-motor recalibration in geographical slant perception (Bhalla and Proffitt 1999), premotor activations in mind-reading tasks (Rizzolatti and Sinigaglia 2006), left-handed vs right-handed differences in preferences and attitudes (Casasanto 2014), motor cortex activity in action-related verbs

(Pulvermuller 2005), fingers in counting (Andes et al 2007) – among other studies. Goldman’s goal is to provide a sharp way to deliver a sharper characterization and prediction to account for these and similar studies. In that sense, it is *not* distortive: it only takes ‘body’ to mean BF representations – instead of body anatomy/activity – and it bets on this interpretation to capture a diverse pool of evidence from the one anti-representational scholars rely upon.

Rather than distorting EC evidence, Goldman’s view wants to *distil* what seems of empirical value, while, at the same time, it provides a new way to *explain* it. Our back processes are proved to influence hill’s slant visual judgments *because* the systems that control our back get reused to visually judge the hill’s slant; brain areas that control leg’s movements get activated when we hear the word ‘kick’ *because* the systems selected to code for legs’ movements get reused to process the word ‘kick’; and so on, for any piece of behavioural or brain evidence that shows how body-related features affect non-bodily related cognitive tasks.

Indeed, Goldman’s view is *reformist*: it is a compromise between the idea of the body itself as being involved in our cognizing on the one hand, and the idea of the body as not playing any role in cognition on the other: according to Goldman, sensorimotor brain areas do get involved in processing non-sensorimotor tasks, where ‘sensorimotor areas’ is cashed out in term of BF representations, whereas the involving relation gets captured by the mechanisms of neural redeployment. Perhaps this reformism is *brain-centric*: it may take embodiment to be a property of just neural states⁹. However, unlike what detractors of BF view have pointed out, such a reformism can reconcile brain-centrism with embodiment, via BFs. One could in fact believe the body to play a substantive role in cognition and maintain that this substantive role is covered by BF representations in the brain: my leg substantially contributes to ‘kick’ processing for my leg’s

⁹ Although Goldman hints at contents of BFs as functions of what they refer to: a change in extra-neural properties would result in a change of BFs representation contents either, thus envatted BF representations would not have the same contents of a non-envatted BF representation (2014, p. 104). We will have more on this in the next chapter.

BFs are reused during ‘kick’ processing, and so on. Apart from those “ism” talk – brain-centrism, reformism, radicalism etc. – the important thing here is about what the *evidence* in cognitive psychology and neuroscience *tells* us of EC effects and phenomena. And the evidence seems consistent with Goldman’s definition, in the sense that maintaining that sensorimotor areas are activated during non-sensorimotor tasks is compatible with holding that BF systems are reused in non-sensorimotor tasks. It might not be a revolutionary or consensus-gathering stance. But after all, making a scientific revolution or gathering consensus is not exactly what the present account is looking after – that is, again, target OPEC and possibly solve it.

1.4.2 *The definition challenge*

There has been at least another family of complains. Goldman’s view wants to provide a set of necessary and sufficient conditions for embodied phenomena. As any definitory enterprise, BFs view invites then a hunt for counterexamples. One may in fact well argue that there are cases of embodiment without BFs redeployment, and conversely, cases of BFs redeployment without embodiment. According to somebody (Shapiro 2014, pp. 85-88), this is exactly what happens. Let us begin with the necessity side.

BF representations may *unnecessary* for embodiment since there may be cases of EC without the instantiation of BF representations. There may be cases where a cognitive system does not use or reuse BFs and still we would say it possess EC. According to Shapiro (2014), *robots* may well be such systems, for robots do not have brains, and therefore, they could not process representations in BF either, since BFs seem *identical* with somatosensory and sensorimotor neural networks. But, so Shapiro argues, one could nonetheless attribute EC to artificial creatures: for example, if the robot represents its body states by means of a general format, say visual and motoric, and we later on discover that this format gets reused in inferential processes, it seems we can attribute embodiment to these processes, although there seem to be nothing fitting the

description of BF reuse (ibid. p. 85). If this is right, Goldman's view does not provide necessary conditions, as a piece of cognition could be conceived embodied without reusing BF representations.

The robot case does not seem to be a counterexample for Goldman, however. On Goldman's view, BFs are in fact supposed to be *multiply realizable* properties, in the sense that BFs are not identical with physical features of brain circuitries. For that reason, it is not in principle a problem to envisage robots embodiment – like any other non-brainy creature EC – since BFs can in principle be processed by different physical structures and robots can indeed possess the right structure. So, as there can be robots not endowed with formats dedicated to interoceive their body states, there can well be robots provided with dedicated motor codes, or interoceptive codes, which might also be redeployed during inferential tasks, or visual categorization tasks. Thus, BFs are not physical events of human brains. According to Goldman, primates, birds and, of course, mobile robots can use BFs to represent their bodily states and reuse them in higher tasks of different sorts. In other words, any system S can possess embodied cognitive token $c_1, c_2 \dots c_n$, because any S can possess (use/reuse) formats dedicated to represent its body (Goldman 2014, p. 104).

Indeed, Goldman has just focused on *human* brain systems, and therefore on human brain embodiment. However, as explicitly pointed out (ibid. pp. 104-105), there seems to be nothing in his definition that prevents other physical systems from processing BFs, and thus possessing EC: as I can reuse BFs to perform visual judgment tasks, so can – and plausibly do – primates, birds or mobile robots (ibid). If a system is not provided with BF representations, it does not instantiate embodied cognition either, being it a mobile robot, a primate or a human being. It follows from the definition: the demarcation criterion between EC and non EC, according to Goldman's account of EC, is in terms of either using or reusing BFs.

Of course there is the (logical/physical) possibility of non-BF endowed creatures. But that possibility does not have dramatic consequences on the way one has to draw the divide between EC and non-EC: systems that reuses BFs during vision, language processing etc. tasks would instantiate embodied vision, etc. either.

Perhaps so, but what about the *sufficiency* threat? BF representations may well not be enough for EC, as it may well be that all cognition reuses (even just one) BF, but implausible that all cognition is actually embodied (Shapiro 2014, p. 86). If BFs reuse is sufficient for EC, Shapiro has pointed out, then reusing just a *single* string of BF is sufficient for a cognitive process – being it visual, linguistic or other – to count as embodied. But, one may say, it seems likely that most – if not all – cognitive processes reuse even just tiny bits of BFs. That is, the reuse of a BFs string can plausibly occur in *any* single cognitive event, from vision to counting: the more one looks at BFs reuse, the more one realizes how pervasive it can be in any given cognitive task. But if that is the case, one may think, then a rampant BFs reuse risks to *trivialize* embodiment attributions: all cognitive tokens would in fact count as embodied cognitive tokens, making EC attributions an empty act (ibid, p. 87).

But sufficient conditions may fail another reason (ibid. p. 90), in the sense that they may not be fine-grained enough to discriminate between cases in which BFs reuses *preserve* their original functions – conservative reuses – and cases where BFs reuses do not preserve their original functions – non-conservative reuses¹⁰. Representations in BF, according to Goldman, got selected to represent bodily matters in certain “inner sense” ways, and they get reused, in embodied cases, to realize non-bodily related functions. Now, according to the present objection, the problem with Goldman would be that his sufficient conditions do not help to distinguish cases of conservative

¹⁰ Conservative vs non-conservative is one (among other) possible distinction one could draw on reuse. For an expansion of the critic cf. Ch 2; for a broader analysis of functional relations cf. Ch 4.

reuses from cases of non-conservative reuses. The argument goes along these lines: if the reuse of motor system is enough for action verbs processing to be embodied, action verbs processing is embodied regardless of whether the system gets reused for its original function or not. More generally, if BFs redeployment suffices for a cognition C to be embodied E, then C might turn out to be E *despite* of the fact that C reuses BFs conservatively – because of their body-related original functions – or non-conservatively – because of functions entirely unrelated with representing bodily subject matters. In other words, Goldman's sufficient conditions would be too *generous*: they may deliver as embodied, cognitive processes which have little to do with body (representation), and therefore they may apply 'EC' to body *unrelated* processes.

Sufficiency objections have not convinced Goldman, however. On the one hand, leaving the conceptual *possibility* for *all* cognition to be embodied does not quite seem to be a problem for a theory of embodied cognition: any definition of what is for cognition to be embodied should leave conceptual room for either options, that is, for any cognitive token to be either embodied or disembodied. After all, whether every process (or even no process) is embodied is an empirical issue, which would actually depend on whether BFs get reused in every (or no) process (Goldman 2014, pp. 105-106). If so, then allowing for the possibility of every cognitive token – or no cognitive token – to be either embodied or disembodied does not seem to be a problem for Goldman's account of EC. In other words, the fact that a single string of BFs is likely to be reused to carry out any cognitive function is not itself problematic for BFs reuse approach, since: 1) EC definition should leave conceptually open whether any piece of cognition is embodied, and 2) whether a single string of BFs gets actually reused to carry out every cognitive process is a fact of

the matter which has to be empirically confirmed (or not)¹¹. And BFs approach, according to Goldman, seems to satisfy both requisites.

The second sufficiency concern does not *seem* problematic either. There seem to be no need to strengthen BFs definition in the direction suggested, it has been pointed out, for *any* case of BFs *redployment* is said being almost invariably a case of what we have called *conservative* redeployment (Goldman 2014, p. 106). Thus, according to Goldman, if the interoceptive system gets reused in a visual judgment task it does preserve its original function of interoceiving back's states, and if the motor system gets reused to support action words processing it does preserve its original function to control limbs movements, and so on, for any case of BFs representational systems' redeployment in any sort of high level task.

Intuitively, Goldman's reply makes good sense: the part of the motor cortex that controls legs' movements gets reused to support 'kick' processing tasks because controlling legs' movements and reading the word kick are analogous functions (e.g. leg's motor commands); and if the interoceptive system gets reused for our hill's steepness judgments it does so because interoceiving our back's states and judging how steep an hill is are similar functions (e.g. simulating back's states). The conservative reuse reply, according to Goldman, does apply to any case of EC redeployment. If so, then sufficient conditions are by no means too generous: they would deliver as embodied cognitive tokens that have to do with the body and thus, they would apply embodiment only to bodily-related cognitive tokens.

¹¹ BF account conceives embodiment as a dichotomous property: either a process reuses BFs or it does not. However, EC may well come in degree (BFs more or less reused). How many BFs get actually reused in cognitive process C, as opposed to cognitive process C1? More on this in Ch 2.

1.4.3 Goldman's revenge

Roughly, this is how the discussion around BF approach to EC has gone so far. Anti-moderation and definitory problems have challenged Goldman's solution to OPEC but Goldman's solution seems have the resources to resist both challenges. Of course, one could counter-reply to Goldman. For example, one could argue, it is not obvious how BF representations can be multiply realizable if, as it seems, they are defined over interoceptive and sensorimotor circuitries of human brain. Otherwise, one could also maintain, it is not necessarily true that BFs reuse cases are almost invariably cases of BFs conservative reuse, as long as there is plenty of non-conservative reuse cases both in biological and artifactual redeployments¹².

Even if one is not convinced by Goldman, however, there are reasons why she may want to consider his view *carefully*. Indeed, we have seen the ways in which "embodiment" and "embodied cognition" have been differently cashed out (§1), with the result having EC debate not progressing much in one sense or the other. Like it or not, BF view does introduce two notions exactly to make it progressing: again, the concept of BF, on the one hand, and the notion of reuse, on the other. And like it or not, such a novelty has not yet received a systematic treatment: it seems nobody except from Goldman himself has so far devoted that much of a theoretical attention to these notions, and *explicitly* applied them to solve OPEC. The idea of consider bodily related representational formats plus redeployment mechanisms operating over them as EC core defining features seems a novelty. Additionally, only few scholars have noticed and discussed Goldman's account, and thus some issues might have been left uncovered or under-analyzed so far. Anti-moderation challenges and definitory complaints might for example not be the *only* problematic aspects of Goldman formulation. Perhaps these objections could be better characterized and further strengthened in not yet explored ways.

¹² Both replies anticipate and trace considerations we will be dealing with along the whole thesis.

Be that as it may, the *novelty* of Goldman's view seems worthwhile investigating. In particular, it seems worthwhile 1) looking deeper into the ideas of *body format* and *reuse*, and 2) *checking* whether introducing them does help to resolve OPEC.

The idea of format is certainly not a brand new one. Philosophers and cognitive scientists have extensively use it for a great deal of goals (cf. Jackendoff 1992). What is new, however, is to exploit it for the sake of explaining EC kind of data. There is quite a lively discussion on how to understand representational formats, on the one side (more in Ch 3), and there is also quite a controversy on how to account for EC effects, on the other (§1), but surprisingly few scholars have explicitly taken the first debate to clarify the second. Goldman is one exception: we might store body-related information in a specific representational format, Goldman suggests, and storing information in that format may explain why we visually judge hills' steepness, or we make inferences about dogs the way we do.

The idea of reuse as an organizational principle of the brain (Anderson 2010) is not entirely a brand new one either. Scholars have been exploiting it for different goals (cf. Deheane 2005). However, when it comes to understand embodiment effects, not so many have taken the idea on board (Gallese 2008, Hurley 2008), and almost nobody has put it into work to the end of giving a solution to OPEC. Again, Goldman seems an exception: we might redeploy perceptual circuitries in DOG-related inferential tasks, he suggests, and redeployment mechanism would actually explain the perceptual activations during DOG-related inferential tasks – (more in Ch 4).

In other words, the originality of Goldman's view consists in the following aspect: he combines these two notions in order to work out a possible solution to OPEC. Maybe we are not convinced by that solution, for some of the above illustrated reasons, or for reasons of different sorts (more

in Ch 2). But given the pressure of OPEC, we may want to try and go along with Goldman for a *little* while, and see whether *BFs re-use* is conceptually clearer and empirically more fruitful than *EC*.

1.5 Conclusive remarks

The present chapter wants to do four things. First, it introduces a new taxonomy of embodiment positions, based on how expressions like ‘body’, ‘crucial role’ and ‘cognition’ have been employed by EC supporters: depending on how these terms are interpreted plus the way those interpretations are combined, we end up having different EC commitments. Section two brings in what we have called the “Opacity Problem of Embodied Cognition”: roughly, the idea that embodied cognition is an ill-defined notion, in the sense that we do not have yet a clear and consistently applied account of what makes a given cognitive token embodied. OPEC seems quite urgent, or so we argue. In fact, if it turns out to be difficult to pinpoint, for each EC variant, the exact property or relation that makes cognition embodied, it seems difficult to say whether cognition is embodied or not either. Section three presents a recently proposed solution to OPEC, according to which cognition is embodied when it reuses bodily-related representational formats. We have shown its motivational issues (conceptual clarity empirical fruitfulness), what the solution does not say (i.e. body anatomy/activity, body content theses), and finally, what the reuse of BF representations actually means for Goldman (i.e. reuse: reuse of brain structure into new function; BFs: bodily-related codes). Section four tries to summarize the debate emerged around Goldman’s solution: the main objections are presented along with the respective replies, unpacking strength and weakness of BFs reused account of EC, and showing how, despite its possible limitations, Goldman’s solution may deserve an accurate inspection.

CHAPTER 2

The Body-Format Approach to Embodied Cognition seems to have quite a few niceties, for it seems both conceptually clearer and empirically more promising than most accounts of embodiment. However, I will argue, there seems to be some problems with its key notions. First, it is not obvious a) what a body-format is supposed to be, and so b) what gets reused in the alleged embodiment cases. Second, the idea of reuse is not innocent. On the one hand, reuse mechanisms seems to come in different kinds, and depending on whether BF's get reused one way or the other, there may be undesired consequences for the whole theory. On the other hand, the way b-formats are identified by Goldman might conflict with the very idea of neural reuse. The chapter deals with such identity concerns. Different candidates are provided and explored. Indeed, if the notion of b-format reused turns out to be unclear, Goldman's proposal seems to fail its core mission – solving OPEC. Indeed, if we do not get what should happen if BF's get reused, we can hardly sort out when cognition is embodied under Goldman's approach. The chapter runs as follows. I first show some niceties of Body Format Approach: I defend Goldman from his critics and argue that most of his replies are on the right track. I then rise the issue of BF's individuation: Goldman's identity criteria for BF's seem unstable, as they swing along diverse and inconsistent parameters. Furthermore, how one should understand the notion of reuse is problematic too. I list a number of concerns, and I try to show that, once we assume BF's reuse to explain EC data, we might not get that many satisfactory outcomes. I conclude with a costs-benefits analysis, maintaining that costs do seem to exceed benefits.

2.1 Niceties of BFA

The Body Format Approach to Embodied Cognition (henceforth BFA) is been challenged for different reasons (cf. Ch 1). Scholars have criticized its moderation (Gallagher 2018, Kiverstein forthcoming, Shapiro 2014): BFA, it is pointed out, does not assign enough explanatory power to the body, for what contributes to cognition, according to BFA, are body *representations*, and embodied cognition, it is noticed, is the idea that it is the body *itself* that contributes to cognition. Other authors have disputed BFA definitory strategy, since BFA would not provide neither necessary nor sufficient conditions for embodiment, since there are EC cases without BFs reuse, and non-EC cases with BFs reuse (Shapiro 2014).

As discussed (§1.5), Goldman rejects both families of criticisms. On the one hand, moderation is taken to be a healthy methodological feature. According to him, there are solid reasons to keep the notion of representation in the identification and explanation of most cognitive phenomena. Moreover, Goldman does reject both the necessity thread – there is no EC without BF representation reuse – and the sufficiency one – any process that reuses BFs is ipso facto an instantiation EC.

Indeed, BFA has stimulated a new discussion on EC with two camps stuck in their respective positions. There are reasons to believe BFA not to be satisfactory, and reasons to think it as the right way to go. None of those argumentations seem have gathered much more consensus to prevail over the other. This first section summarizes the debate, showing how reasons pro prevail over reasons contra¹³.

¹³ Some of the following considerations may reiterate few points we have already encountered in the previous chapter. These reiterations are meant to be instrumental to the argument of the present chapter.

2.1.1. *Is moderation a problem?*

Take the case of language. BFA is the following thesis: language processing L is embodied if and only if L reuses BF representations. For example, reading the word 'kick' is embodied if and only if such a process reuses BF representations. That is to say, if the internal way we represent our leg moving is redeployed to process that word, then that cognitive processing is embodied. And conversely, if processing the word 'kick' is embodied, then the internal way we represent our leg moving is redeployed during such a cognitive task (cf. Goldman 2014, p. 102).

Now, radical EC supporters argue, one consequence of BFA is body irrelevance, in the sense that if, BFA is true, legs' features in the 'kick' processing case are irrelevant, even though 'kick' processing turns out to be embodied under BFA. But body irrelevance, according to radical EC fans, is a very costly consequence, for again, if EC means anything, that is the idea of *body* contribution to cognition. It is simply false, so they say, that BF representations of legs do all the linguistic work in the 'kick' processing example, since *legs* themselves do some work too: it is in virtue of having the legs we have that linguistic processing of 'kick' have its "embodied" characteristic. The mistake consists in attributing both metaphysical and epistemological importance to representations (being them BFatted or not), as representations are both metaphysically and epistemologically *superfluous*: there is no need to postulate them in order to individuate or account for body contributions to cognition (Gallagher 2018). So, the objection says, BFA is doubly mistaken, because a) it assumes such unnecessary entities and b) it does not attribute sufficient explanatory power to the body, but rather to representations *of* the body. Call a) the anti-moderation (anti-representation) challenge; and call b) the body-irrelevancy complain. Let's start with the anti-moderation challenge.

We have seen (§1.5) why moderation is not something one has to argue for very much, in the sense that defending a non-representational variant of EC, one may hold, does not seem to be quite a promising move (Goldman 2012, 2014). First, it is unclear how to understand the remark that the *body makes cognitive work*: in what sense legs would make linguistic work or backs perform inferential tasks? Indeed, what makes radical EC positions *less* promising than their moderate counterparts, is the opacity of their commitments (Goldman 2014, p. 92). For one thing, radical EC fans maintain that the body plays a crucial role in cognition: sensorimotor contingencies, bodily affects, movements and posture, we are told, all shape cognitive phenomena in a non-representational fashion. Nevertheless, what such a *shaping* relation is supposed to be, is often left unanalysed: do legs cover causal roles in language task? Or should we take them as proper part of it? Indeed, OPEC does apply to most radical EC accounts: is not fully clear which role the body itself is supposed to cover in higher cognitive tasks, and it is not obvious how one could possibly resolve OPEC within an anti-representational framework (§1.2). Consequently, it is hard to say whether the data *confirm* radical accounts: if it is unclear what the embodied relation between legs and linguistic process is supposed to be, it will be unclear whether data confirm the relation to occur too.

In *this* respect, BFA appears to have an advantage over radical approaches to EC: we sort of get what it means to reuse BF leg's representations to process 'kick', and so, we get what should happen for data to confirm BF legs' reuse in this task: if the internal way we represent our legs moving gets reused during processing 'kick', then processing 'kick' is actually embodied under BFA, otherwise it is not. And the same condition applies to any task for which there is some evidence of embodiment. In other words, BFA has a card left to play with radical complains: while BFA targets – and possibly resolves – OPEC, anti-moderation criticisms just seem to rhetorically protest about the use of representational accounts, leaving us with little clues on how to explain EC effects with

anatomical features alone. On the contrary, BFA does provide a set of conditions for EC (conceptual clarity) which in turn make clearer and more testable predictions (empirical fruitfulness): whether or not fingers counting, perceptual judgments, episodic memories, inferential or action-detection tasks are tokens of embodied cognition would depend on whether they redeploy representations in BF. If the answer is positive then all these tokens are embodied under BFA, and it seems pretty undemanding to assess it. And anti-moderate campaigns seem not undemanding in this sense (§1.2).

This is a *first* nicety of BFA: Goldman overcomes tricky “constitution versus causal dependency” discussions (cf. Adams and Aizawa 2008, Rupert 2009), which have become a bit sterile (cf. Shapiro 2014). Alongside, he provides clear criteria for embodiment: either I reuse BFs when I hear the verb ‘kick’ or I do not, and it seems easy enough to check whether or not data proves it to be the case.

2.1.2. *Body irrelevancy?*

But what about objections about body irrelevancy? Does BFA imply the idea of our bodies being unnecessary for cognition? And if so, is that really problematic? It seems the argument for body irrelevancy has two premises. First: the idea that BFA *implies* body irrelevancy. On this premise, envatted brains could possess BFs, in the sense that having representations in BF does not require to have a body: we could well be brains in a vat reusing BFs for e.g. linguistic or conceptual tasks. The second premise is the idea that body irrelevancy is false, given the evidence: what the empirical studies do show is that having a body is necessary to cognize.

Goldman rejects the first premise. According to him, BFA does not imply body irrelevancy, in the sense that BFA is *inconsistent* with our brains being in a vat. The *contents* BF representations, we are in fact told, are taken to be functions of what they refer to: the internal way we represent our

legs' movement would not be such if it did not refer to our legs' movement, but say e.g. our backs' position¹⁴. Thus, BFs have to be externalistically identified: two internally identical systems immersed in two diverse environments do not have the same BF representation. If that is the case, Goldman seem to argue, envatted brains could not have BFs, because envatted brains do not have the same wide contents of outside brains (cf. Goldman 2014, p. 104). In other words, BFs of my leg would take anatomical, kinematic etc. characteristics of my leg as contents: they internally represent my leg's anatomy or kinematics to be in certain ways. So, they would not be the BF representations they are if we did not have leg's anatomy or kinematics we do. According to BFA, it is in virtue of having the legs we have, moving them the way we do etc. that we possess BF representations, and it is in virtue of the fact that we seem to reuse those BF representations while hearing action word like 'kick' that our linguistic processing of 'kick' seems to exhibit embodiment under BFA. Any difference in legs' condition would hence make a difference in BFs *of* legs, and any difference in legs BFs would in turn make a difference in legs BFs *reuse*. In other words, if BFs of legs get redeployed while hearing verbs like 'kick', having legs with certain features is necessary for having 'kick' hearing embodied under BFA. And since envatted brains do not have legs at all, they could not ipso facto 1) have BFs representations of legs and 2) reuse BFs in action words tasks¹⁵.

Even if the first premise of the body irrelevance argument turns out to be true, however, one can still refuse the second one. BFA may be consistent with brains in vat, one could hold, but *brains in vat* might well be *consistent* with *EC findings*. In this sense, demonstrating that BFA implies body

¹⁴ This externalist account of BFs seems inconsistent with their previous functional individuation (§1.4), so that, one may well argue, BFA oscillates between accepting and refuting functionalism. More on BFA ambiguities later. Thanks to Simone Gozzano for a useful comment on this point.

¹⁵ Radical EC theorists may not be convinced by Goldman semantic reply, for semantic irrelevance is not enough for them. Bodily actions, they typically maintain, do count as genuinely cognitive, and the body being necessary for BFs still keeps cognition locked inside (cf. e.g. Mark Rowlands). I discussed this radical point elsewhere (Ch 1). Thanks to Daniel Weiskopf for a comment on this.

irrelevance would not reduce BFA ad absurdum, as long as BFA could indeed be true in light of the EC evidence. In fact, one could rightfully ask whether evidence on body-related contributions to cognition proves the *need* of anatomical properties or activities for cognition. Do pre-motor activations during ‘kick’ processing show legs to be necessary for it? Radical EC defenders typically answer positively: brain activations are often said not to be enough for cognitive phenomena. It is rather unclear, however, how those findings would support such a strong commitment in the first place.

On the one hand, the pool of evidence BFA is supposed to give an explanation of (Ch 1, § 1.1.4), are body-related *activations* in high level cognitive performances. For example, BFA wants to model sensorimotor interferences in visual judgment tasks (Bhalla and Proffitt 1999). Of course those tasks involve anatomical parts, like backs or eyes. But what these findings are typically taken to show, pertains the *systems* that control such anatomical parts rather than the parts themselves. For example, data on visual-motor recalibration in geographical slant perception does not seem to show that our back gets involved in visual categorization tasks, but it would rather show the contributions of back’s control systems to the tasks. On that evidence, backs, legs or eyes would affect visual, memory, linguistic tasks *via* backs’, legs’, or eyes’ control systems. And BFA takes seriously this evidence. It is unclear how one draws from weak premises on body-related activations, strong conclusions on the body essentiality to cognition – but cf. Gallagher 2018.

On the other hand, once we take the “sensorimotor system” reading of the data, it seems difficult to resist representational explanations of some kind. In fact, it is not obvious how to account for visual judgments, episodic memories, reasoning and language comprehension without postulating representational properties. One thing is to say that a light-seeking robot does not operate over semantically evaluable internal structures, quite another is to say that our lexical competence about ‘kick’, does not need representations at some level of the explanation. Any minimally

conceptual task, it is pretty widely recognized, seems to require, for its production, some sort of symbol system, being it modal (Barsalou 1999), or amodal (Mahon and Caramazza 2008). So, for example, the way we process 'kick' would somehow depend on the way we represent its meaning, the way we remember our last kick would somehow depend on our representations of that action stored in the memory buffer etc. In that respect, it is hard to defend a non-representational variant of EC with regard to language processing, episodic memories, or any sort of higher order process – but see Hutto and Myin (2017).

Now, if the above argumentations are correct, BFA has the sources to neutralize the body irrelevance challenge. First, body irrelevance does not follow from BFA, in the sense that having and reusing BFs is incompatible with being brains in vats. Second, body irrelevance – not attributing enough explanatory power to bodies – does not follow from the evidence on EC effects, which is consistent with BFA. For one thing, EC effects do not seem to imply anti-representational EC stances: motor activations in cognitive tasks seem to ask for a representational account. And BFA seems just the representational account EC-related data are asking for: we activate premotor areas related to legs movements during 'kick' processing since the way we represent our legs' movements get reused in 'kick' processing. These data would confirm BFA's moderation rather than its radical competitors.

2.2 Definitory complains

So, BFA has quite a few advantages: it targets OPEC, providing a definition of what EC is meant to be, and it does so by distilling what the evidence on body related activations in complex tasks seem to show. We have seen why such features seem to be nice and how the niceties mainly belong to BFA moderation.

BFA have raised a second class of concerns, however (§1.4). These concerns are about BFA definitory solution. According to Shapiro (2014), the reuse of BF representations is supposed to be neither necessary nor sufficient for a cognitive token to be embodied, since there can be cases of EC without the reuse of BFs representations, and there can be cases of BF representations reuse without EC. *Non-brainy* systems are supposed to be counterexamples of the first kind: according to Shapiro (ibid, p. 85), mobile robots could not possess BFs, for they do not have properties of our sensorimotor networks, but can still instantiate EC, for they could process general visuo-motor formats for complex cognitive tasks. On the other hand, BF representations *non-conservative* reuses can be conceived as counterexamples of the second kind. We may reuse our sensorimotor circuits in higher order tasks not because these circuits original function is body-related, but for other reasons, perhaps because of some efficiently based considerations. However, this can hardly be a case of embodiment, Shapiro has pointed out, for the function of coding for body matters is hardly relevant for the cognitive tasks – this is another way to argue for the thesis that BFA implies body irrelevancy.

Now, we have seen (§1.4) how both definitory concerns are, on Goldman's lights, *misguided*. For one thing, BFs are not supposed to be properties of some brain networks, but rather, functional descriptions of them (Goldman 2014, p. 106): any structure that fits the right functional description would ipso facto realize BF representations, and so, nothing would prevent a mobile

robot – as well as other non-brainy systems – to instantiate them, as long as they fit the descriptions. Furthermore, almost any case of BFs reuse is a case of BFs *conservative* reuse, according to Goldman (ibid). That is: BFs reused in ‘kick’ processing task preserve their functions of representing our legs, BFs reused in slant visual categorization task preserve their functions of representing the internal states of our backs, etc. In other words, when paradigmatical BF representational systems get reused in higher order tasks, they typically preserve their original body-related functions.

One problem that seems to cross both radical and definitory complains to BFA can perhaps be framed as follows. Body per se is said to be irrelevant for BFA, partly because BF representations are taken as *neural* events (brain-centrism), but also because BFs are likely to get redeployed for entirely non-body functions (non-conservative reuse). Contrariwise, BFA refuses body irrelevance objections, partly because it conceives BFs not to be neural events (anti-brain centrism), partly because it considers BFs reuses as conservative of their body functions (conservative reuse). One direction one could go to explain the disagreement at stake is to look into the *nature* of BF representations on the one hand, and check out the fine *mechanisms* of redeployment in embodiment cases on the other. BFA and its critics might have different assumptions on what makes something a BF representation or what exactly happens when BF representations get reused. And having different assumptions on these crucial notions is likely to provide disagreements on BFA. For example, if one takes BFs to be purely physical events of our brain circuits, then EC would be a property of the human brain, under BFA. On the contrary, if one takes BFs to be functional properties that happen to be realized by some human brain (among other systems) circuitries, then EC would be a property of any system which happens to realize the right functional profile.

Thus: how are BFs identified? Are BFs individuated in virtue of their body-related contents? Or is it just their vehicle that matters? For example, what makes our motor systems to code in BF is the fact that they send commands to our limbs? Or is all about the brain networks they employ regardless of what they code for? Besides, one should question the level at which BFs are individuated? If BFs are not features of the human brain, are them algorithmic or psychological features? And if BFs are computational features (as it seems), how come that body-related contents seem to matter for a representation to count as a BF representation?

The way one replies to the above identity questions seems to affect her replies to questions on BFs redeployment mechanisms either. For example, if BFs are taken to be computational properties shared by a given set of neural circuitries, then BFs redeployment would be the redeployment of computational properties. Otherwise, if BFs are content-involving representations, that is, if they are partly identified by the body-related subject matters, then cases of BFs redeployment in complex cognitive tasks are cases of body-related conservative redeployment.

Hence, what is a BF representation? And what happens when a BF gets reused?

2.3 Puzzles for BF representations

Let us begin with the first question. Call it the problem of individuation for BFs. This is the problem of providing the conditions under which something should count as a BF representation. Preliminary to it, however, is the problem of understanding what formats in general are: that is, what makes a representation to code in a given format, and what do we mean by saying that a

representation stores information in a given format. Indeed, the question of what is a format and how we might identify it seems preparatory to the identity problems for BFs.

2.3.1 *What is a format?*¹⁶

There is an increasingly widespread use of the term ‘format’ within cognitive science (cf. Machery 2016). Some formats are claimed to be *modality* specific – i.e. visual, auditory, format, etc. (Barsalou 1999) – while others are typically considered to be *amodal* – i.e. language-like (cf. Mahon and Caramazza 2008). Not to mention *sensorimotor* (Pacherie 2018), *visuo-spatial* (Barner et al 2016), *map-like* (Rescorla 2009), *mixed* (Shepherd 2018) – among others – formats. Despite the common use of the expression however, there is no consensus about what formats are and how we should make sense of them (cf. Haimovici 2018).

On the one hand, different authors seem to use different criteria to specify cognitive formats – e.g. kinds of inputs, homomorphic relations, neural bases. On the other hand, each criteria provided so far seems to be problematic (ibid). What holds together the ‘format’ talks seems an intuition about representations. Icons and sentences can express the same content in diverse ways. For example, a road sign with a schematic picture of two children holding their hands seems to vehicle the very same information of the sentence ‘Beware, children crossing!’ And the same thing can be said for languages – being them natural or artificial: binary notation expresses integers differently from the way decimal notation does, English and Italian can convey the same propositional contents despite their phonographic or syntactic differences, one and the same hour can be coded analogically and digitally, a doctoral dissertation can be stored in DOC and PDF, etc.

In other words, behind the ‘format’ talk there is the intuition that *one* content could be stored, conveyed and transmitted in *different* ways (cf. Crane 2016, p. 95). Format properties of

¹⁶ The following considerations are meant to introduce identity considerations on *body* formats. For a more worked out investigation on the idea of format, see Ch 3 §3.3.

representations – being internal or public representations – do seem to be properties of the vehicle, rather than proprieties of the content¹⁷. What makes two representations being of different formats seems it has to do with the way they store, convey and transmit content, rather than with the content itself. What makes a picture of a cat and the word ‘cat’ being of different formats has to do with the way they encode the content *cat*, rather than the content itself. So, it seems that formats amount to *non-semantic* properties of representations, for one can keep the content and vary formats (e.g. the picture of a cat vs ‘cat’), and conversely, one can keep the format and vary contents (e.g. ‘cat’ vs ‘dog’) ¹⁸. Besides, format features do not seem to coincide with physical features either, for one can dissociate physical features of a representations from format ones. For example, the English sentence ‘Beware, children crossing’ can be written, spoken, stored on radio waves, carved in stone etc. (one format/many realizers). And viceversa, ink and metal can implement both the pictorial road sign with two children holding hands and the discursive road sign ‘Beware, children crossing’ (one realizer, different formats). In other words, the same information can be stored in different formats, and these formats can be realized by different media.

Now, most cognitive scientists believe that the brain contains formats of its own. Whereas English consists of symbols of various shapes and rules for their compositions, the brain employs codes in a neural syntax (Wajnerman Paz 2018). It is unclear though where intuitions would carry us once we move from clear cases of public representations to *not* so clear cases of neural representations. Does firing rate of a circuit count as a neural format? Or is it the firing synchrony among different circuits that does the job? Should we conceive somatotopically organized activations as some sort of icons instantiated by neural populations? And how do we want to

¹⁷ Format and vehicle talks sometime overlap and sometime do not. Those who speak of formats may want to capture something different from what the vehicle talk does typically to refer to. More on that in Ch 3.

¹⁸ Not every non-semantic feature of representations is a format feature, however. For example, ‘cat’ and ‘cat’ differ in non-semantic features, but it seems wrong to say that they differ in format.

identify brain codes and syntax anyway? What renders something a neural format? The fact that those questions seem to be unsettled leaves the notion of neural format underspecified (Machery 2016, Martin 2016).

Furthermore, if the idea of *neural* format is still a muddled one, one may wonder how the idea of *body* format can already be clear. After all, if applying the notion of representational format to neural populations seems to be problematic, how could the notion of body related representational format be fully perspicuous? Identity problems for BFs do represent a case of the identity problems for neural formats. If that is correct, showing that there is a way to identify BFs would also prove that there is a way to identify neural formats; and conversely, identity problems for BFs would provide reasons to have suspects on neural formats too.

2.3.2 BFs (*extensional*) definition

Now, BF representations have been defined *extensionally* (Goldman 2012, 2014; see also Goldman and de Vignemont 2009): somatosensory, interoceptive, motor – among other – systems, have been taken to operate on representations in BF, in the sense that, according to BFA, BFs are essentially the representations over which somatosensory, interoceptive, motor systems paradigmatically operate¹⁹.

Take the case of proprioception. What distinguishes seeing the position of one's leg from proprioceiving it, is the fact that, despite they both represent the leg's position, the latter does so in a sort of "inner" sense way, while the former presents it by means of an "outer" sense, so to speak (cf. Goldman 2014, p. 100). And the same applies, according to BFA, to motor circuitries: hearing one's leg movements does in fact differ in at least one way from actually delivering the motor command to it, as the first process, but not the second, represents one's leg movements

¹⁹ It is perhaps worth underline that formats in general, and BFs in particular, are *properties* of the *representations*, rather than features of the processes that operate over the representations.

from an “internal standpoint” as opposed to an external one (ibid, p. 100). Now, if Goldman is right, both cases are cases where one and the same content gets stored in two different formats. And both cases are cases where the first systems represent contents in an “inner sense” way – i.e. in BF – while the second ones represent contents in an outer sense way – i.e. in non-BF, perhaps in a modality specific format. Thus, as the binary and decimal systems can represent the same natural number, PDF and DOC can code the same text, and ‘Beware, children crossing!’ can be stored by a sentence or by an iconic sign, on BFA, some brain systems do represent body positions and movements from the inside (BF) whereas other systems represent them from the outside (non-BF).

Interoceptive and motor systems are supposed to be the paradigmatic examples of BF representations, in the sense that BFs are supposedly the data structures over which the interoceptive and the motor systems paradigmatically operate. Binary and decimal systems do have symbols and combinatorial principles to represent natural numbers, English and Italian do have lexical primitives and grammatical rules to represent their propositional contents, and so it is supposed to happen, for example, with interoceptive and visual systems, in the sense that interoceptive and visual systems would store the information about our limbs’ positions by means of two different vocabularies and syntaxes (Goldman 2012).

2.3.3 Overlapping puzzles

One might wonder whether the extensional definition of BFs is satisfactory. There is one immediate objection to it. It seems clear how intuitions behind the definition of BF representations stand at the personal level, i.e. what it means for a limb’s movement to be represented proprioceptively as opposed to visually. Two diverse formats: proprioception and vision. One content: limb’s movement. How do such inner sense vs outer sense intuitions apply at

the subpersonal level, however, seems not as obvious as BFA maintains. It is not obvious, for example, that our motor system have dedicated formats to store information about our limb's position. And even if it does, it is not evident that such proprietary codes are actually responsible for the inner sense way we represent our limbs moving. Sometimes Goldman *seems* to swing between attributing formats/contents to a personal level, and taking the distinction to be a matter of subpersonal systems. (cf. 2012, pp. 3-4). Yet, one may legitimately ask, how is it possible to think that the format/content distinction applies both to personal and subpersonal levels?

The existence of cells populations located in monkeys motor cortex and coding for precise actions, such as holding or grasping (Rizzolatti and Sinigaglia 2006), would be a reason to believe that motor systems do process proprietary formats (Goldman 2014, p. 101). Still, one may reply, the so called "motor vocabulary" is a dedicated *neural* activation, and BF representations, as Goldman himself says, are *not* neural events: one thing is the way in which the information gets stored, i.e. its format, another thing is the physical system that realizes the information, i.e. its medium. Indeed, we have seen how Goldman recognizes the distinction, as he does conceive BFs to be multiply realizable (ibid, p. 107; cf. Ch 1, §1.4). But this seems incompatible with taking motor *cortex* vocabulary as paradigm of BFs. Thus, either motor activations in the monkey brain are not a case of dedicated BFs, or BFs are just features of brainy systems – of monkeys, humans fishes? – which in turn is inconsistent with their multiple realizability (cf. Shapiro 2014)²⁰.

Moreover, one might suspect, assuming interoceptive and motor systems to operate over BF representations could consist in a sort of *overlapping* mistake, for it seems that nothing in the interoceptive or motor systems matches with the inner sense way in which we represent our body postures and movements to be. It is hard to see how the inner sense way in which we represent

²⁰ One way out for BFA could be to show how those selective neural activations are in fact computationally describable. The burden of the proof is on BFA, however (more on that below).

our movements could possibly be identified with some abstract properties of our motor systems. Thinking otherwise, seems like overlapping the personal level of description – i.e. the inner sense way we represent our movements – with the subpersonal one – i.e. the interoceptive and motor systems. But it seems either the format/content divide is cashed out in terms of personal phenomena like vision or interoception, or it is done on the base of subpersonal – e.g. visual or interoceptive – systems. BFA, it seems, both takes BF representations as theoretical entities, dedicated codes of specific cognitive systems, and phenomenological entities, dedicated inner sense ways in which we consciously represent our body subject matters. But maintaining both criteria, so we argue, seems to be an overlapping mistake.

3.3.4 *Computational puzzles*

Perhaps what Goldman wants to say is the following: format properties of motor and interoceptive systems are computational properties of those systems. Better, BFs are the *formal features of representations* to which the interoceptive or motor computations are sensible. There is an algorithmic level at which those systems can be modelled, BFA may claim, and this is the level where we find BFs.

On this reading, there is nothing at the personal level that fits the BF description, since the way we BF represent our legs' movements is a formally describable set of dedicated data over which our motor system compute to send the commands. Computational-representational descriptions of this sort should individuate BFs: BFs are dedicated and formally describable structures which get paradigmatically computed by the interoceptive or motor systems, and which eventually give rise, at a higher level of description, to the "inner sense" way we represent our body. Moreover, on this reading, BFs are, as Goldman wishes, multiply realizable: any system that computes the right set of

structures – being it interoceptive, motor, or even non brainy systems – would ipso facto operate over BF representations.

There are few reasons to bear suspects about this argumentative line, however. One could in fact wonder whether the mind/brain systems Goldman identifies BFs with do share *any* computational properties. Is there evidence about that? Are there any motoric or interoceptive codes, or even sub-codes, in the brain? The BFA defender answers positively. Perceptual systems, it is pointed out (Goldman 2012), seems to have distinctive formats (Barsalou 1999, Prinz 2004), and modal formats can even possess subformats (cf. Milner and Goodale 2006). Besides, vision-to-language transfer costs is typically taken as an indicator that visual and language systems operate over different formats (cf. Jackendoff 1992).

In this regard, Goldman's account of BF representational systems would not be exceptional, in the sense that motor activations would store and transfer data structures in a dedicated way, and so would happen for other BF systems as well. Nonetheless, it is not so clear how this could be an entirely satisfactory answer.

For one thing, what Goldman seems to talk about is body-related *task selectivity of some regions*. Sets of cell populations in the premotor cortex would selectively fire in grasping tasks as opposed to holding ones (Rizzolatti and Sinigaglia 2006). Neural cells in so called "interoceptive system" (Craig 2002) would be selectively activated in pain tasks of many kinds and associated specifically with tickle, temperature, itch and other body related stimuli. And so on for any BF system. However, one might object, body-related task selectivity does *not* seem to be a computational-relevant property: one thing is to say that a given brain region gets selectively activated in precise body-related tasks, another is to say that there are proprietary structures computed by such a region during those tasks.

The first thesis does not seem to imply the second. In fact, there can very well be regions dedicated to specific body related performances *without* there being any interesting computational-representational features each of those regions enjoy. Take for example the case of motor cortex. From the fact that the motor cortex somatotopically responds to precise legs' movements, it does not seem to follow that, during legs' movements, the motor cortex operates over dedicated codes. Goldman seems to infer the second idea from the first one. But there seems to be little argumentation for that. If BF representations amount to body-related tasks selection of certain brain regions, then, one could insist, why should we use the first notion (BFs) rather than the second one (body-related tasks selection)? Does the talk of BFs representations make some sort of difference in prediction? – more on this in §2.4.

2.3.5 *Semantic puzzles*

On the other hand, even assuming algorithmic procedures over data structures dedicated to bodily-related tasks, one could still wonder whether and to what extent body-related *contents* of these data structures play in those procedures.

As we have discussed, Goldman seems to take an externalist stance here: BFs are externally identified, in the sense that the contents of BFs representations are supposed to be the functions of what they causally interact with (2014, p. 105). So, BFs of my leg movements take my leg movements as content, they represent my leg's movements, and such content, on BFA, would contribute to BFs identity, they would not be the BFs they are if they did not refer to my leg's movements.

Now, content externalism seems incompatible with a computational view on BFs. On the one hand, we are told, BF representations are partly identified by what they refer to: body-related subject matters. On the other hand, we are also told, BFs are format features of representations

that cognitive systems operate upon, and formats features of representations seems to be non-semantic features: what makes a picture different from a sentence is not much what it represents, but rather the way it does. So, *BFs* are *non-semantic* features of representations. The computational account earlier discussed would also confirm that conclusion. Computational procedures do seem to be “blind” with respect to contents: what they allegedly “see” are just the formal properties of the representations²¹. Thus, if *BFs* are formal features of representations computed by interoceptive and motor systems, then what of *BFs* seems to matter is not their body contents, but rather, the transitions interoceptive and motor systems are allowed to make. Interoceptive and motor systems would be insensitive with respect to what *BFs* are taken to represent, for *BFs* would just be formal features of representations, and interoceptive/motor systems would just be sensitive to such formal features.

If this is correct, then the way I represent my legs’ movements by means of *BFs* has *little* to do with the movements of my legs, as much as the way in which a picture of a cat represents a cat has little to do with cats: it seems like nothing in *BFs* – and in neuronal patterns that realize them – makes *BFs* representing my leg’s movements rather than the position of my hand, in much the same way in which there seems to be nothing in the word ‘cat’ – or in the ink that realizes it – which makes ‘cat’ representing a cat rather than any other entity or property²².

This may not be an happy result for Goldman though, since, as an account of EC, BFA has to deny that body matters are irrelevant for cognitive operations. Indeed, Goldman seems has to face the following dilemma: either *BFs* are format features (computational sensitive) of representations, or they are body-related. One could not have both. If *BFs* are functions of what they are taken to

²¹ I assume here a formal-syntactic view of computations individuation, in line with Egan (1992), Paternoster (2003), and Piccinini (2008). For a different view, cf. Rescorla (2012), Sprevak (2010).

²² Content ascriptions to these vehicles are typically taken to be extrinsic, i.e. they depend on an environmental context (cf. Dennett 1987, Egan 1992). If that is correct, then *BF* representations are about bodily-related subject matters only once we interpret *BFs* as referring to these matters.

represent (body matters), then they cannot be format (computational sensitive) features, because format properties are not functions of what they are taken to represent. In other words, if BFA considers BFs to be body-related properties, it is unclear in which sense BFs are considered to be format as opposed to content properties. Conversely, if BFs are format (algorithms sensitive) properties of representations, then what they are taken to refer to (body-related subject matters) is irrelevant, since format properties of representations are non-content involving properties. That is to say, if BFs are format properties of representations interoceptive, motor and other systems process, then whether BFs code for legs' movements, light intensities, numerosity or any feature at all seems not very much relevant.

Either ways might not please BFA. On the one hand, going for the first option (BFs as body-related) would amount to give up the notion of format altogether. And giving up format seems too costly for BFA, since it is a central notion for BFA, and BFA seems a promising account of EC because it postulates body formats. On the other hand, going for the second option (BFs as formal/algorithm-related) would save the format, but it would also imply the irrelevancy of body for BFs (thus, the irrelevance of body for embodied cognition). And the body irrelevancy, as we already discussed, is something that BFA may not want to go along with.

2.4 Puzzles for reuse

But suppose there is a satisfactory – both conceptually and empirically – account of what BF representations essentially are and how we should identify them, such that cognitive neuroscientist could confirm whether and to what extent BFs get processed in any given task. Even so, one could maintain, BFA might *still* have problems with the notion of *reuse*. Recall that, according to BFA, the interesting cases of embodied cognition are cases in which BF

representations get reused. The next two sections are thus dedicated to the reuse condition. More precisely, we will be concerned with a) the issue of conservative vs non-conservative reuse – that is, whether BFs original functions get preserved in BFs redeployments (EC); and b) the question of whether assuming that brain regions are massively reused is compatible with defining BF representations on the base of regions' functions.

2.4.1 *Conservation puzzles*²³

Here is one way to cash out the first problem. Consider the following scenarios of artefacts' redeployment. We typically receive presents in wrapping paper. Some of us take such paper and reuse it for new presents. This seems to be a case in which a given physical structure gets used and reused for the very same function: that is, a piece of paper originally designed for wrapping presents gets reused precisely to wrap another present. Call it *conservative* reuse. Conservative reuse amounts to functional *identity* between use and reuse: the function of wrapping paper seems the same both in the case of received present and in the given one.

Consider now the example of plastic bottles. Plastic bottles are typically designed for containing water or other liquids. Sometimes, however, interior designers reuse plastic bottles to contain plants. Vertical gardens in fancy studios are one place where to find those containing-plants bottles. Now, such a creative design solution is a case where structure gets reused to carry out similar to the one it was originally designed for: a plastic bottle originally designed for containing water or liquids in general gets redeployed to contain plants and even gardens. Call it *semi-conservative* reuse. Semi-conservative reuse amounts to functional *similarity* between use and reuse cases. The function of containing water and of containing plants are similar: they are both

²³ The following puzzles do specifically affect BFA. For a wider treatment of reuse mechanisms, see Ch 4.

contain-functions, in the sense that contain-water function and contain-plant functions are both contain-functions.

Thirdly, take for example the case of a tablet redeployed as a chopping board. What seems to happen in this case is that an item originally designed to carry a functions, get reused to cover another function, entirely unrelated to the original one: one thing is to write emails quite another is to chop onions or champignons. Call it *non-conservative* reuse. Non-conservative reuse amounts to functional *detachment* between use and reuse cases. One and the same structure has two very different functional profiles. Indeed, what makes something a proper tablet – display, RAM, memory, battery, etc. – is quite different from what makes it a good chopping board – the hardness of its surfaces, its water-resistance, etc.²⁴.

Now, one might wonder what happens when those intuition pumps on artefacts redeployment are applied to BF representations: is BF reuse as conceived by BFA analogous to the plastic bottle case? Or is it rather of a non-conservative kind? One might indeed wonder whether embodiment, as Goldman's conceives it, amounts to cases where BFs original functions – representing bodily conditions – are conserved or non-conserved when redeployed in complex cognitive tasks.

As said (cf. Ch 1 §1.4), Goldman seems to buy the first option. According to BFA, when redeployed in language understanding or in visual categorization tasks, representations in BF *conserve* their original functions of representing the body (2014, p. 4). BFs would carry the same function both in use and reuse conditions. For example, when reused to process 'kick' BFs conserve their original functions of sending motor signals to our legs, or when reused to judge the slant of a hill, BFs still conserve their original functions of representing the states of our back. Thus, on BFA, BFs reuse in EC cases is analogous to wrapping paper case of reuse: as the wrapping function is conserved in

²⁴ Note that conservative is conceived as a *graded* property of reuse: apart from cases of fully conservative/non-conservative cases, reuses can be (and are) of a *more or less* conservative kind.

the reuse case (e.g. giving the present), the legs' control functions are conserved in the reuse case (e.g. process 'kick').

However, things might *not* be that straightforward. In fact, Goldman's position is ambiguous. While discussing the mechanics of BFs redeployment he points out that, in all the interesting embodiment cases, BFs get reused "for representing things *other* than one's own bodily parts or states" (2012, p. 4, his emphasis). Thus, when redeployed in linguistic or categorization tasks, Goldman declares, BFs represent non-body properties and states of affairs: for example, when they got reused in visual categorization tasks, BFs would represent visual information. If so, one may argue, BF representations' reuse in higher order tasks could be like plastic bottles reuse in vertical gardens, or even like tablets reuse in the kitchen. Just like plastic bottles in vertical gardens do not contain water and tablets taken as chopping board do not broadcast videos, BFs in visual categorization tasks do not represent the states of our back. In other words, there may not be functional identities between BFs uses and reuses in the interesting cases of embodiment.

The issue is then whether BFs redeployment resembles plastic bottles containing plants – semi-conservative – or it is rather akin to tablets sustaining onions – non-conservative. In the first case, BFs reuse would be functionally similar to BFs use, whereas in the second one the two vehicles would be functionally detached.

Goldman's move could be to follow the *semi-conservative line*. After all, the function of representing my legs' movements from the inside seems to be similar to the function of reading the action verb 'kick', in much the same way as containing water or liquids and containing plants or soil are functionally similar. What seems to be semi-conserved here is the function of representing *motor commands* to my legs: both legs' movements and 'kick' reading tasks represent the motor commands to my legs, with the commands being just inhibited in the 'kick'

reading case, while they are actually sent in the case of legs' movements. Semi-conservative machinery may be there in other EC cases. Take, for example, the case of BFs reused in social cognition (cf. Goldman and de Vignemont 2009), where the same neural populations is taken to fire both while I grab a cup and when I observe someone else grabbing that cup (Rizzolatti and Sinigaglia 2006). This seems another candidate of semi-conservative BFs reuse: my grabbing a cup seems functionally similar to my observing someone else grabbing a cup, since both task seem to share the general function of programming a *grab-movement*. BF representations' redeployments of this EC sort, Goldman may then conclude, could be semi-conservative: the function of representing bodily states of affairs is maintained throughout BFs redeployments in all such non-bodily related tasks.

But what if BFs get redeployed for entirely different functions? That is: what if BF reuses are analogous to tablet reuses? Recall, when somebody reuses a tablet as a chopping board, there is nothing in its original function that is of much interest. The choice is not motivated by the fact that the device can e.g. broadcast videos! What makes it a good choice depends rather on the hardness of its surfaces or on its relatively modest weight²⁵. By the same token, BFs reuses could be cases of non-conservative reuses. The role of BFs in language processing or perceptual categorization tasks could in fact well be detached from their original functions of representing body matters. What makes BF reuses in language/concept tasks a good – both evolutionarily or ontogenetically speaking – could very well be a *non-body* related property. For instance, the reason why BF representations get redeployed in higher cognitive tasks may just be the fact that they are available: I may reuse the tablet to chop onions because it could be the only available item in the kitchen, and BF representations may got reused in language/concept tasks because they are the only available representations within the neural context.

²⁵ The relevance of structural properties in redeployment mechanisms will be scrutinized in Ch 4.

Now, it is not obvious whether BFs reuses are conservative or semi-conservative. Indeed, they might also be non-conservative. If they are conservative or semi-conservative, then the body counts in non-bodily tasks (contra body irrelevance). For example, if the function of representing my legs' movements gets preserved in 'kick' task, then there is a sense in which my legs count in that linguistic task. On the other hand, non-conservative BFs reuses seem to imply body irrelevance. If BFs do not conserve their original functions to code for my back's states when reused in hill's slant judgment, then there seems to be nothing interesting about my back's states that gets reused in hill that gets reused in hill's slant judgment.

Rather, what might be relevant is how *efficient* (or non-efficient) BFs reuse is for the task at hand. As a chopping board, a tablet does not seem quite efficient, perhaps because of its fragility: sharp knives are likely risk to break its surface. On the contrary, BFs reuse in a visual judgment task may turn out to be efficient: judging the hill as more or less steep depending on how heavy our backpack is, might turn out to be an efficient solution. However, and this is the point here, they may not be efficient because of their property of representing back states. Body-functions would not count. Other BF features, such as availability, would²⁶.

So, Goldman's view seems *unstable*. On the one side, he seems committed with (semi) conservative reuses, while he says that BFs get almost invariably reused because of their functions of representing body matters (Goldman 2014, p. 107). On the other side, BFA can be read as to maintain a non-conservative line either, as BFs are said to be reused for representing things other than bodily matters (Goldman 2012, p. 4). If that is the case, one could ask him to choose between the two options. Either he defends the first one, providing reasons to believe that, when reused in cognitive tasks, BFs continue to have their old – or similar enough to old – body-related representational functions. Or, he has to follow the second line, and buy body irrelevance. BFs

²⁶ Efficiency considerations will be extensively discussed in Ch 4, §4.4.

reuse would be like the tablet reuse, as in both cases old and new functions are detached, and so, when reused in higher cognitive tasks, BFs stop having body-related representational functions²⁷.

2.4.2 Architectural puzzles

But there is another issue on the reuse condition. We have seen how BFs are *defined* over a set of systems, and how those systems are supposed to be selective for body-related inputs: interoceptive, somatosensory, motor, etc. systems are *dedicated* to body stimuli, and BFs are defined over those systems. Now, this definition of BFs seems to be in tension with the idea of neural reuse (Anderson 2010, 2014). That is to say, it seems at least *prima facie* contradictory to hold a) *BFs are defined over brain systems dedicated to body-related tasks*, and b) *any brain system gets massively reused in many different cognitive tasks*. Let's unpack that.

We have seen how BFs are identified with a number of systems, which are said to primarily represent bodily-related states of affairs (Goldman 2012, 2014). For example, the lamina I spinothalamocortical interoceptive system (Craig 2002), does represent “highly resolved sensations [...] from (and about) about the body” (Goldman 2012, p. 8) and such lamina I spinothalamocortical interoceptive representations would paradigmatically identify BFs. Also, systems like lamina I, according to Goldman, are considered to be dedicated: that is to say, they are evolutionarily designed to work on a specific class of inputs. In other words, the interoceptive system is domain-specific. It contains representations of distinct, highly resolved sensations (ibid), being it tuned to physical information about our own bodies, such as “different types of pains, tickle, temperature, itch, muscular and visceral sensations, sensual touch” (ibid). It is this dedicated, domain-specific property of the lamina I spinothalamocortical interoceptive system

²⁷ Daniel Weiskopf has argued that 1) when reused, vehicles shift their functions, 2) functions shift implies vehicles change, thus 3) vehicles used $\neq$ vehicles reused. I am unsure about 2). Why functional differences would imply structural differences? When I reuse a tablet as a chopping board its very structure does not seem to change, despite the clear differences in functions, and this seems to be true of cognitive vehicles either. The point will hopefully become clearer in Ch 4.

which makes it, according to Goldman, a prototypical example of BF's representational system. More generally, on BFA, it is to have a body-related task dedication which makes a circuit coding in BF, and some circuitries, like lamina I, do have such a property, according to BFA²⁸.

One might wonder whether this BF's extensional definition is compatible with the very architectural notion of neural reuse (Anderson 2010). The idea of neural reuse does in fact conceive individual brain regions to be functionally diverse: according to Anderson, each region gets triggered during multiple tasks in different task categories. For example, Broca's area is not only active during language processing tasks, but also in action-related and imagery-related ones, such as movement preparation, action sequencing, action recognition, imagery (ibid, p. 245). Besides, functional diversity seems to be directly proportional with phylogenetic oldness: the older a brain region is supposed to be, the more likely it would be reused in many tasks (ibid, p. 258). Accordingly, neural reuse predicts that regions typically active in sensorimotor tasks would get more likely activated in a variety of other tasks, such as language, reasoning or decision making tasks. (ibid). Rather than assuming a modular architecture where each brain structure has a dedicated function, neural reuse is the idea that each brain structure gets massively redeployed in very many cognitive domains (cf. also Anderson 2016)²⁹.

But this idea seems to conflict with BF's definition. It seems they cannot be both true at the same time. For if there actually are systems dedicated to inner bodily representations, then neural reuse seems to be false: it is not the case that *each* brain structure is reused in many tasks if there are body-dedicated structures³⁰. Again, take the paradigm case of interoception: if lamina I spinothalamocortical brain region does represent a specific class of inputs – pain, tickle,

²⁸ Terminological point: by 'dedication' here I mean 'dedication *solely* to a specific set of tasks'. Goldman needs dedication in this sense. Thanks to Daniel Weiskopf for having stressed this point.

²⁹ Details on how neural reuse hypothesis conceives structure-function mapping will be discussed in Ch 4.

³⁰ Possible objection: are not there functional priorities of brain structures? Possible rejoinder: yes, but functional priorities is not equivalent to task-dedication, and BFA need task-dedication. More on functional priorities in Ch 4.

temperature – it is not functionally differentiated. What such a region does is to represent sets of specific physical stimuli coming from our body, and it does not respond to other sets of physical stimuli, such as optic inputs coming from the environment.

Domain specificity seems incompatible with *functional diversity*: either a region is domain specific or it is functionally diverse. And if BFs are dedicated-to-the-body systems, then either there are no BFs or they are not functionally diversified. Besides, functional specificity of BF systems seems even more incompatible with neural reuse, since BF systems are supposed to be phylogenetically *old* systems and neural reuse hypothesis would predicts them to be massively redeployed. Thus, if lamina I is both a dedicated and phylogenetically old system, then neural reuse is wrong in saying that the older a region is, the more likely it gets reused.

The point seems to hold in the other direction as well. If the idea of neural reuse is true, then BFs could not be defined over systems dedicated to the body, for the simple reason that there would *not be* dedicated brain systems. Neural reuse predicts each brain element to be redeployed in multiple tasks across a variety of domains, which seems in turn to entail that one could not reasonably attribute a one single function to one single structure. For example, if a certain brain region gets equally activated in interoceptive and visual judgment tasks then attributing interoceptive functions as opposed to visual judgment ones to it seems an error. There could not be an *interoceptive* system as opposed to a visual *judgment* one, on neural reuse view, since that region is functionally diversified. It does support both interoception and visual judgment functions, and to call it “interoceptive”, as opposed to “visual judgment” system, seems just an inexact way of speaking.

Now, if what we said on neural reuse is correct, then *defining BFs* on the base of what the “interoceptive”, “somatosensory” or “motor” *circuits supposedly do*, seems *problematic*. On the

one hand, as already discussed, neural reuse entails functional diversification and functional diversification prevents one to attribute just one function to any given structure. Roughly, one brain circuit that gets activated during interoceptive and visual tasks is just as interoceptive as it is visual – unless one is able to prioritize one functional attribution over another³¹.

On the other hand, if neural reuse hypothesis is correct and BFs are identified on the basis of what certain structures do, BFs have *different* functions depending on which task such structures are involved in. For example, if lamina I system gets reused both during interoceptive and visual judgment tasks, and BFs get identified by what that circuit does, then BFs have “interoceptive” rather than “visual judgment” functions depending on whether they are involved in one task rather than the other. But then, BF representations seem functionally diversified structures – which again is problematic for BFA, for the above discussed reasons.

To conclude. It seems that BFA has to choose between keeping neural reuse and defining BFs as body-specific. Indeed, if Goldman wants to keep neural reuse on board while extensionally defining BFs on the base of what certain brain systems supposedly do, it would be forced to choose between dropping a bodily specific functional individuation of BFs and defining BFs as functionally diverse in kinds. Either options would lead BFA to redefine what BFs essentially are – and thus, what embodiment is on BFA. In the first case, it would give up the body *specificity condition*: BFs would not be bodily dedicated, in the sense that, for example, lamina system would not be selectively activated in interoceptive tasks – being also active during visual categorization tasks. Going along the second line would instead imply BFs as functionally *scattered*: as lamina system would not have any precise function but rather a variety of functions, BFs defined over such a system would not have any precise identity either, but a variety of functions. One might

³¹ Phylogenesis may do it, but prioritizing functions on a phylogenetic base is not unproblematic. Cf. Ch 4, §4.3.

thus wonder whether the very notion of BF is of much interest. In any event, it seems fair to say that neural reuse leaves BFs definition unsatisfactory.

2.5 Costs and benefits

As any theory, BFA has costs and benefits. There are reasons to consider it as quite a promising position. But there are also reasons to bear few suspects about the explanatory power of Goldman's proposal. A costs-benefits analysis might then be worth as to decide whether the firsts exceed the seconds – or the other way around. And thus, whether BFA is a convenient theory of EC to buy – or *not*.

2.5.1 BFA benefits

Let's start with benefits. As already said, the motivational issue behind BFA is to provide a *conceptually clearer and empirically more fruitful* account of "embodiment". BFA reduces embodiment to BF uses/reuses. Such reduction, according to Goldman, would clarify what it means for a cognitive process to be embodied (to reuse BFs), allowing one to assess whether that cognitive process is embodied (whether it reuses BFs). In other words, BFA addresses OPEC (§1.2). EC is an ill-defined notion which, on BFA, would be clarified by the idea of BFs reuse.

Consequently, and precisely because of its clarity, the notion of BF redeployment seems also epistemologically sharper than EC. Insofar as it clarifies embodiment, the idea of BF redeployment would also possess a better predictive power of EC. So, if BFA is right, it would be easier to check whether motor activations in action verb reading tasks (Pulvermüller 2005), or visual-motor interferences in slant perception (Bhalla and Proffitt 1999) are actually cases of BFs redeployment – compared to check whether they are cases of embodiment – since it would be easier to check

whether BFs would actually be redeployed during those tasks – compared to check whether those studies would actually confirm embodiment!

We regard conceptual clarity and empirical fruitfulness to be rare and nice features of Goldman's account: rare because 'embodiment' and derivatives expressions are often used but seldom critically analysed. And nice since gaining in clarity and prediction is after all what a reductive enterprise is supposed to do.

Moderation seems another benefit. Despite popular criticisms (Chemero 2009, Hutto and Myin 2013), it is not obvious how one should not postulate mental representations at some level of the psychological explanation, unless she is satisfied with capturing adaptive behaviours or low level-perceptual operations. Interesting EC phenomena are typically of high-level sort, e.g. body-contribution to linguistic or conceptual tasks, and postulating BFs does exactly want to meet the challenge of representation-hungry EC considerations. Furthermore, BFA's moderation has an *extra*-feature: it distinguishes between representations that are bodily in virtue of their contents – about the body – and representations that are bodily in virtue of their formats – present the body in a dedicated way. Representations have long been said to have vehicles and contents, and BFA does exploit this inveterate distinction to the end of clarifying what EC data would show: evidence on bodily contributions in complex tasks would show that bodily formats get reused in such tasks. This is important because BFA moderation shifts the explanatory burden from body-contents to body-formats.

Reframing the "embodiment" talk into a "format" talk could then be counted as another theoretical merit of BFA. The notion of format seems in fact to be *naturalistically* more treatable than the notion of content. The way in which information are stored in our mind/brain systems might be more easily graspable in scientific terms than the way in which mind/brain systems

possess aboutness. The issue of whether and how the mind come to represent is famously thorny (Cf. Crane 2016): aboutness is hardly naturalizable. But formatness seems less so. This is why the hard problem of content (Hutto and Myin 2017) does not affect BFA. BFA on action verb tasks is not the idea that ‘kick’ processing is about leg’s movements, but rather that ‘kick’ is stored *in* our motor system. And the way in which our motor systems store information seems an empirically treatable case.

Last but not least, *neural reuse* hypothesis (Anderson 2010). Neural reuse seems to imply BFA: if neural reuse is true, BFA is true either. The converse does not hold, for BFA is narrower in scope than neural reuse – neural reuse conceives *all* structures to be reused, whereas BFA quantifies just over some circuitries (BFs). Neural reuse says that *any* brain structure gets massively redeployed, that is, it gets reused in many cognitive functions. What BFA claims instead is that a *subset* of structures gets reused in many functions. The exact logical relation holding between the two theories may vary depending on how one treats their details. However, if it is the case that neural reuse is larger in scope than BFA, then neural reuse implies BFA – while it is not the case that BFA implies neural reuse.

Now, neural reuse seems to be a pretty well-justified position about brain architecture (Anderson 2007, 2010, 2014): there is a number of solid reasons to believe that our brain regions are functionally diversified and hyper-connected, so much so that each brain element seems to be used and reused for multiple functional purposes. If so, then BFA has also solid reasons to believe that our body-related brain regions gets massively reused for multiple cognitive functions (EC in BFA sense), for body-related regions are just a subset of all brain regions.

Besides, by assuming neural reuse, it seems BFA has also been capable of *selecting, unifying* and (hopefully) better explaining the heterogeneous neurophysiological and behavioural evidence

typically invoked in favour of EC. BFA does *select* evidence, for not any EC data would demonstrate embodiment under BFA: for example, evidence typically drawn from situated robotics (e.g. Brooks 1991) would not demonstrate EC under BFA, since there seems no BFs – indeed, no representation! – reused in situated robots, and so no embodiment. On the other side, as Goldman has pointed, the idea of BFs reuse would *unify* many embodiment effects: for example, motor activity in language processing tasks (Pulvermüller 2005, Glenberg and Kashack 2002), mirror mechanisms in social cognition (Rizzolatti and Sinigaglia 2006), fingers motor activations in counting (Andres et al 2007), visual-motor geographical recalibration during hill perception (Bhalla and Proffitt 1999) seems could all be described as cases of bodily oriented systems redeployments in non-bodily related tasks. “Embodiment” would stand for “BFs reuse” in the sense that various neuroscientific and behavioural data typically invoked to demonstrate embodiment about a given task could be *united* under the banner of BFA. Eventually, such a reductionist enterprise would turn out to be an explanatory advancement. For example, conceiving motor activations in language comprehension tasks as BFs reuses, in contrast with embodiment, would explain those activations without assuming opaque relations between body properties and cognition (§1.2): compared to postulating various bodily-related properties contributions, the move of assuming BFs reuses would help in better explain motor activations in language tasks, for the idea of BFs reuse seems sidestep tricky issues about which bodily properties are involved and what contributions do they provide, while at the same time giving an informative account of what produce activations in the first place. Beyond clarity, fruitfulness and moderation, the appealing to reuse seems another nicety of BFA, as reuse seems explanatorily sharper compared to the notion of bodily-related contributions³².

³² How sharp the neural reuse account of EC can be, will be hopefully clearer later on in Ch 4.

2.5.2 BFA costs

BFA is also costly. And its costs seems to derive from both the *key notions* of BFA.

2.5.2.1 Metaphysical costs

As I hope the above analyses have shown, it is not fully clear what '*BF*' refers to. There are few conceptual problems regarding the notion. One problem seems of a *metaphysical* sort. BFA adopts a systems-based individuation's criterion for BFs. However, the way those systems are identified appears rather underspecified. First, 'system' talk is ambiguous between a *structural* and a *functional* reading. What BFA calls 'interoceptive' does for example seem to designate a pattern of activations localized in the spinothalamocortical region (i.e. structural reading), and an inner sense way to represent body-related states (i.e. functional reading). As a result, '*BF*' would also be ambiguous, referring both to neural properties of certain brain circuitries, for example activations in the spinothalamocortical area, and cognitive properties of some functional kind, for example highly resolved sensations of body states including pains, tickle, itch, etc. (Goldman 2012, p. 4).

The ambiguity seems to depend on two notions being overlapped: that is to say, the idea of *format*, and the idea of *realizer*. We have seen why we should better distinguish these notions (§2.3.1) – and we will have more on that later on (§3.3). But BFA seems to conflate them. BFs are supposed to be format properties of body-related representational systems, *and* realizer properties of those systems, i.e. brain structures that would implement BFs. Put it differently, BFA seems to conflate the idea of coding in a dedicated way – i.e. inner sense vs outer sense – with the idea of implementing in a specific system – motoric, interoceptive etc. It is this conflation, so we claim, that generates a metaphysical ambiguity on BFs.

On the other hand, ambiguity seems to rest on the second concept of BFA either. If BF representations are metaphysically underspecified, one might legitimately ask, how the idea of BFs *reused* could possibly be metaphysically perspicuous? Two options appear on the table. BFs could be considered as *format* properties. If that were the case, then what would get reused in the alleged EC cases were the format features by which we code for bodily matters in an “inner sense” way. For example, if a BF is the internal mode in which I code for my legs’ movements, then if I redeploy such BF while attending to the word ‘kick’ I still end up coding in an inner sense mode for my legs’ movements. Formats seem not the *kind* of properties that can possibly be reused, however. Only realizer properties can³³. This is because the unity of redeployment cannot clearly be abstract properties, such as formats or functions. It is hard to understand what would it means to say ‘the function of containing liquids gets redeployed to contain soil’. And likewise, saying that the inner “sense way” of storing bodily information gets redeployed to execute, for example, language tasks, seems like making a *categorical* mistake.

This is perhaps why BFs have also been interpreted by BFA as *structural* features. In this sense, it seems clear what would it mean for a BF to get reused: it would mean, for example, that the motor brain region gets reused in a linguistic task. So far so good. We have seen, however, how reuse could come in different sorts – conservative, semi-conservative, non-conservative – and depending on which sort of reuse BFs undergo, BFA would turn out to have quite different outcomes. If BFs do conserve/semi-conserve their original body-functions in EC reuse cases, then body-functions would count on BFA. On the contrary, if BFs reuses do not conserve their original functions, then body matters would be irrelevant for BFA. Taking BFs to be brain structures is not enough to disambiguate these issues on BFs brain structures reuse. But taking BFs to be brain structures, we have seen, has the undesirable consequence of overlapping formats with realizers,

³³ The unity of reuse is a crucial point, and it will be extensively investigated in Ch 4, §§ 1, 3, 4.

on the one hand, and leaving format as an explanatory vacuous concept, on the other. In any event, BFA does not have illuminated such metaphysical issues very much.

2.5.2.2 *Semantic costs*

A second problem for BFA is of a *semantic* sort. Whether BFs are identified at the neural level as opposed to the cognitive one, and regardless of the kind of reuse BFA subscribes, one thing seems uncontroversial of them: format properties are non-semantic properties of representations, and thus, if BFs are format features, BFs are non-semantic either. In other words, whether BFs are defined over brain circuitries or they do coincide with cognitive systems, what characterizes them as formats is actually not much *what* they represent, but rather the *mode* they do. For example, what of a motor area renders it to code in BF is not much that it refers to limbs' movements as opposed to action verbs. Instead, it is the specific mode it stores whatever information it happens to be: neural firing rates, populations behaviours, sets of computational procedures may all be candidates of BFs, since they are all formal properties of our neural/cognitive system. However, there is a sense in which BFs are semantically characterized. After all, what makes the spinothalamocortical system to code in BF seems it has at least partly do with the fact that it typically represents body-related states of affairs. That is why BFs has the *B*-property. They are partially identified by the contents they characteristically bear: a system that does not typically bear bodily contents would not operate on BFs (Goldman 2012; cf. Goldman and de Vignemont 2009).

Thus, BFA seems a semantically unstable position, for it seems to oscillate between a content-involving account and a non-content involving account of BFs. And these accounts do in turn conflict with each other. If BFs are representational formats, like images or sentences, they seem not to carry their contents essentially: one could ascribe whatever content to neural activations

(or computational procedures) but, per se, those activations (or procedures) are not about bodily affairs more than they are about non-bodily ones. In fact, syntactically identified BFs may just be about anything, in the sense that the way motor cortex gets activated seems has nothing to do with my limbs' movements. On the other hand, if BFs representations are content-involving, then they are *not* format properties anymore: if, for example, representing limbs movements is what makes a system to code in a motor BF, then it does not matter whether such movements are represented in an inner as opposed to an outer sense way.

BFs seems to be both format – inner sense – and content – bodily-related – properties. That is to say, a BF representation seems both a) a body-related *way to* represent and b) a representation of certain classes of bodily related stimuli. However, it is hard to see how those features of our mind-brain system could possibly be so characterized: either BFs are syntactic features of brain circuitries or they are semantic features of them. And BFA does leave such conflict open³⁴.

2.5.2.3 Epistemological costs

Lastly, there is an *epistemological* issue. Remind the main motivation behind BFA is to solve OPEC. BFA is taken to be explanatorily sharper than its EC competitors. If our analyses are correct, though, this sharpness is disputable. The idea that, by assuming BF reuse, we should explain behavioural or brain data on body-related contributions to cognition better than we do by holding EC, is no longer obvious.

Firstly, for metaphysical reasons. If BFs redeployment are not that much precisely identifiable mechanisms, then it is hard to assess what exactly happens when BFs get redeployed in complex cognition, for it is hard to appreciate what exactly counts as BFs redeployments in the first place. If BFs redeployments amount to *neural activations* of some brain area during complex cognitive

³⁴ Maybe BFs are bodily related but non-semantically individuated features. BFA has to tell us, however, how could it be so. We will have more content vs format considerations in Ch 3, §3.4.

tasks, then BFA seems to be just a *re-description* of the available EC evidence, rather than an explanation of it. Does the assumption of motoric BFs redeployment in action verb tasks make some differences in predictions from postulating motor activations in those very tasks? If it does, BFA does not seem it has clarified how.

On the other hand, if BFs redeployments amounts to putting into new functions 'inner sense' formats, then BFA seems explanatorily *obscure*: how could the notion of functionally co-opted 'inner sense' format explain EC effects if it is unclear what the 'inner sense' formats are and what the cooptation consists of? Does assuming the *reuse of motor 'inner sense' formats* in visual judgment tasks make any explanatory difference from assuming *motor activations* in such tasks? Again, it does not seem so. Maintaining that action verb processing tasks reuse BF motor representations does not seem to be explanatorily more powerful than maintaining that there are motor activations during action verb processing tasks.

But replacing 'embodiment' with 'BF reuse' may be epistemologically pricey for a *semantic* reason. Recall, BFA swings between a semantic and a syntactic variant. On the syntactic view, *bodily affairs are irrelevant*: BFs are a set of syntactically identified formats. On the semantic view, *body properties do matter*: BFs depend on being them about body affairs. The swing is not epistemologically harmless. Where should we look when we want to know whether BFs get redeployed for example in a linguistic task? Do we have to check just brain syntactic properties? Or should we also look into extra-neural features? Are there specific patterns of brain activation that constitute evidence of BFs redeployments in such a task? And do the kinematics features of legs' movements count in BFs reuses anyway?

The answer seems it would depend on the semantics of BFA. Since the semantics of BFA is ambiguous, however, the epistemology of BFA seems unstable as well. If it is not clear whether

BFs are internally or externally identified, it would also be unclear whether BFs redeployment should be investigated just internally or also externally. Swinging between an internalist and an externalist semantics does make BFA swinging between internalist and externalist BFs epistemology. What has to occur for a BFs to be reused in a language comprehension task is ambiguous, and so what counts as a corroboration of BFs reused in that task could not be but unambiguous too. Unless BFA can disambiguate these puzzles, it cannot confirm BFs reuses in any complex task too. And indeed, such empirical under-determination would not allow, at the end of the day, BFA to solve OPEC.

2.6 Conclusive remarks

BFA was introduced to solve OPEC. Despite its merits, however, it does not seem it has quite succeeded. Goldman himself has recognized how little is said about the criteria of individuation of formats (2012, p. 8), maintaining that, on this regard, BFA does not advance much (cf. also Goldman and de Vignemont 2009). The present chapter has targeted precisely that lacuna. At the core of BFA stand the two notions of BF representation and of neural reuse, but the way BFA treats those notions seems *ambiguous* and *inconsistent*. Ambiguous, since 'BF' points to different things – structures vs functions, formats vs contents – and 'reuse' can be of different sorts – conservative, semi-conservative, non-conservative. Inconsistent, because BFA cannot define BFs over functionally specified body related brain systems and take each brain system to be functionally diversified. So, despite its beneficial characteristics – e.g. moderation, neural reuse in EC – BFA seems has suffered for the very reasons it was introduced for: conceptual *clarity*, empirical *fruitfulness*. 'BF redeployment' does not seem well enough specified, for the above mentioned reasons. Rather than being a conceptually clearer and empirically more fertile account than its competitors, BFA seems has substitute an obscure notion – EC – with an even more obscure one – BFs reuse. It seems we could not be satisfied with BFA until we will not be able to sort out a) how BFs should be identified, and thus, b) what counts as a BF redeployment. For the time being, OPEC is here to stay.

CHAPTER 3

The Bodily Format Approach to Embodied Cognition (Goldman 2014) may not sufficiently cope with OPEC (cf. Ch. 2). One thing it does, however, is to reframe the talk on EC into a talk on formats: cognition is supposed to be embodied in the sense that bodily formats get somehow involved in cognition. Scholars have recently tended to converge on this shift: despite they disagree on how to read the evidence, both EC defenders (e.g. Glenberg 2015) and EC critics (e.g. Mahon 2015b) do seem to concord on the fact that what evidence mostly speak of are the representational formats, rather than the contents, of cognition (cf. Mahon and Hickok 2016). The present chapter deals with such a format shift in the discussion over EC. Formats discussion, I will argue, seems to import a similar set of problems risen with b-formats discussion, in the sense that the problems with body-formats view (Ch 2) seem constrain formats reframe of EC either. The chapter runs as follows. I firstly introduce the recent trend of format discussion over EC, i.e. the idea that embodiment of cognition would depend on whether cognition gets stored in a “sensorimotor” format. An interlude on formats is thereafter provided, showing what a representational format is supposed to be, and so, what the discussion over sensorimotor format involvements in cognition seem to be committed to. Finally, I see whether the debate on sensorimotor formats, as opposed to bodily ones, does help to solve the Opacity Problem and I hold that the problems for bodily formats do apply to sensorimotor formats too.

3.1 The Format Shift on Embodied Cognition

Consider the following scenario. If you are asked to recall your bank pin-code, you may take a little while, and perhaps struggle a bit in doing so, for you may have been busy in performing an entirely different task. However, if someone asks you to imagine yourself in front of a withdrawing machine along with your hands spread on the keyboard while digit the pin-code, you are likely to recall the series of number immediately: the simulation of your fingers' movements *somehow* facilitates the task of retrieving the series of numbers. I take this as to be a typical case of "embodiment effect": a body-related property affects a cognitive task, in the sense that a difference in body-related properties would produce a difference in cognitive outcome. In the present case, the simulation of one's fingers' movements would affect the retrieval of her pin-code.

Embodiment effects are commonplace phenomena within embodied cognition literature (cf. Ch 1). Indeed, a plethora of – empirically controlled – embodiment effects has been discovered and extensively studied. For example, when you have to judge the slant of a hill from its bottom your judgment would demonstrably change depending on how heavy the backpack you are wearing is (Bhalla and Proffitt 1999). Or, hearing the word 'lick', as opposed to the word 'kick', more strongly activates somatotopic areas of premotor cortex associated with tongue movements, as opposed to the areas associated with leg movements (e.g. Pulvermüller 2005, 2013). Also, drawing inferences about dogs, for example answering the question "do dogs have fingers?", would activate the perceptual systems by means of which we receive dogs-inputs (Barsalou 1999)³⁵. Embodiment effects are taken to be epistemologically solid (Shapiro 2011, 2014). There are good reasons to believe that variations on body-related variables – i.e. motor activations, perceptual

³⁵ It is perhaps worth mentioning how these and others embodiment effects are so considered only by EC supporters. Ch 1 (§§1-2) discusses the cogency of these considerations.

activations – do produce some cognitive-related – e.g. linguistic, conceptual – changes as well. As already said, however, things are not very much clear cut when it comes to *explain* embodiment effects (cf. Ch 1): how to better account for embodiment effects is yet a controversial issue (cf. Barsalou 2016, Mahon and Hickok 2016). Indeed, OPEC seems yet to be resolved.

There are different ways to solve – or perhaps dissolve – OPEC (some of which have been reviewed in Ch. 1, §1.1.1). A recently frequented move is to conceive embodiment effects as a matter of representational formats (cf. e.g. Glenberg 2015, Machery 2016, Mahon 2015b, Mahon and Hickok 2016, Martin 2016). According to this view, we would retrieve our digit-code faster as we imagine ourselves while moving our fingers on the keyboard because that digit-code gets stored in the *same* format used to send signals to our fingers: for example the sequence 45243 would get stored in the same format used to type 45243 on the keyboard, and the fact that those information get stored in the same format would explain such an embodiment effect. Likewise, what would explain the fact that the word ‘kick’ activates pre-motor circuits associated with legs movement is the fact that both the concept KICK and the signal sent to our legs do share the same format: the way our brain stores information to process kick and to send signal to our legs are identical in format, and such a format identity would explain pre-motor cortex activation during the word ‘kick’ processing. Speaking more generally, a growing number of scholars claims that, *for any embodiment effect E, where a body related property B allegedly affects a cognitive process C, E has to be explained by postulating B and C to be encoded in an identical format I.*

I will call such account the Format Shift in Embodied Cognition (hence, FSEC).

First of all, FSEC has to be contrasted with the *content-involving* account of EC. That is, the idea that body related contributions to higher cognitive tasks are essentially a matter of shared contents (cf. e.g. Barsalou 2016). On this account, what better explains, for example, perceptual

activations during concepts-related tasks would be the fact that concept and percept share the same contents: thinking about a dog and seeing a dog would essentially be states having the same (dog) content, and this would in turn predict such embodiment effect, for having the same contents would be the reason why perceptual areas are active during conceptual tasks. Content-involving account predicts that DOG is a sort of distilled representation resulting from perceptual representations of dogs, and any conceptual task involving DOG would ipso facto be (at least partly) an instantiation of those distilled perceptual representations: we tend to answer ‘no’ to the question ‘do dogs have fingers?’ by processing “perceptual symbols” of encountered dogs (cf. Barsalou 1999, 2008, see also Prinz 2004).

Content-involving view commits to the following thesis: *for any embodiment effect E where a body-related property B allegedly contributes to a cognitive process C, E is explained assuming C and B as having same (or a similar) contents.*

Thus, FSEC takes then format properties to capture embodiment. *Not* every thesis on format coincides with FSEC, however. A number of long-standing debates have taken formats to capture cognitive phenomena. For example, the debate on whether there is a *language of thought* (Fodor 1975, Dennett 1987) is concerned with whether our thinking – imagery or other cognitive processes – get stored in a language-like, rather than an image-like (Pylyshyn 2002, Kosslyn et al. 2006) or a map-like format (Camp 2007, Rescorla 2009). According to the language of thought hypothesis, by postulating a language-like format one can explain some features of our thought – typically, systematicity and productivity – better than by assuming some image-like or a map-like representational formats. According to pictorialists, however, if we assume imagery tasks to be carried out by means of image-like cognitive format, we would be in a better position to explain why the time taken to scan an image is a function of distances traversed (cf. Kosslyn 1973; see Pylyshyn 2002 for a different view). Discussions on whether there are specifically grammatical

representations (Chomsky 1980, Devitt 2006), whether reasoning is formal or model-based (Braine and O'Brien 1998, Johnson-Laird 2006), and what is the structure and development of math cognition (Carey 2009, Deheane 2011), are all in the business of understanding the representational formats by means of which we would actually use language, reason, make decisions, memorize, imagine, do math or visualize the way we do. Thus, according to the format theorists, for any given cognitive task T, assuming a specific format F, as opposed to a different format F', would best explain T.

Now, what distinguishes FSEC from these general format-based accounts are the phenomena over which formats are supposed to range. FSEC is a thesis on embodiment effects: as the language of thought debate takes systematicity and productivity of thought to be what has to be explained by postulating linguistic vs non-linguistic formats, or the imagery debate considers reaction times during mental rotation tasks to be what has to be modeled by postulating iconic vs non-iconic ones, and so on for any formatted position, FSEC takes sensorimotor formats, as opposed to non-sensorimotor ones, to best explain why body related properties contribute to non body related tasks. According to FSEC, what would best explain, for example, premotor cortex activations in 'kick' processing is the fact that kick is stored in a sensorimotor format – rather than another, non sensorimotor one. And the same would be true of any embodiment effect token.

3.2 Modal vs Amodal formats

Thus, both FSEC and other views take a set of cognitive phenomena to be a matter of representational formats, while dividing both on the phenomena to be explained and the formats doing the explanatory work. FSEC itself is neutral on the kind of formats explaining embodiment. It just says that the correct way to capture bodily related contributions to non-bodily tasks has to

assume formats transactions between them. According to FSEC, we retrieve the number 45243 faster as we imagine ourselves typing that very number because our brain stores the number 45243 in a format that is compatible with the one used to type it. FSEC comes into parties, depending on the kind of formats postulated to explain these and others EC effects. FSEC notoriously divides into (at least) two groups.

3.2.1 *Modal view of Embodiment Effects*

On the one side, some scholars have taken EC data on body related contributions to non body related tasks as a reason to believe that those tasks are carried out operating over sensorimotor formats (cf. e.g. Barsalou 1999, 2008, Glenberg 2015a, b, Mahon 2015a, b, Mahon and Hickock 2016, Prinz 2004). On this view, the digit code 45243 gets stored in a motoric format, DOG gets coded in a perceptual format, KICK is carried in a motoric format, etc. for any cognitive token allegedly producing an embodiment effect. Assuming a sensorimotor storage for each such information, according to these authors, would explain why we have a variety of embodiment effects in the first place. We retrieve the number 45243 faster as we imagine ourselves typing that very sequence since we store the number in the same format used to type it, we activate perceptual circuitries while performing a concept task that involve the word 'dog' as we store DOG in the same format used to see, hear etc. category members of dogs.

More generally, *for any embodiment effect E where a body related property B affects a cognitive task C, the present view would explain E by assuming B and C to be conveyed in a shared sensorimotor format.* We will call it the Modal view of Embodiment effects (MEE), for sensorimotor formats are typically defined in terms of the *modes* in which our sensorimotor systems represent their contents.

According to MEE, when we perceive objects in the world and act upon them, we do so by means of various modes. Thus, I may *see* my dog running but not *hear* it, and conversely, I may hear my dog barking but not see it. In the first case, I represent my dog through (or in) the visual mode, while in the second case I represent it through (or in) the auditory one. We may also command our legs to move while not seeing them moving, or (perhaps in hallucinations) we may see our legs' movements without sending motor commands to them: in the first case, we represent our legs' movements through (or in) a motoric mode while in the second case we represent them through (or in) a perceptual mode. All those cases are supposedly be cases where an object – i.e. a dog – or an action – i.e. a leg's movement – are represented by diverse – i.e. perceptual or motoric – modes, and these two modes are what sensorimotor formats are defined upon.

Now, according to MEE, sensorimotor formats are not just involved during perceptual and motoric tasks, such as perceiving a dog or moving a leg, but they do contribute to conceptual and linguistic processing too: answer questions concerning my dog or read the word 'kick' would require sensorimotor formats. It is in fact the occurrence of these modality specific formats that would explain why, according to MEE, brain circuitries typically associated with perception or action get activated in conceptual or linguistic tasks: the way we see dogs, we hear them barking, we smell them, etc. contribute to draw inferences about dogs, as the way I represent my leg movements contribute to process action related expressions such as 'kick'. The same sensorimotor formats that captures the visual aspects of dogs or the kinematic aspects of kicking come into play again when answering whether dogs have fingers or when processing action verb like 'kick', and it is the involvement of those sensorimotor formats that explain these and other embodiment effects. Thus, we retrieve the number 45243 faster as we imagine ourselves typing that very sequence on the keyboard for we do encode that very sequence in the same sensorimotor formats used to type

it on the keyboard, and the fact that both tasks operate over the same sensorimotor formats would explain that reaction time.

According to MEE, the evidence that higher cognitive tasks get influenced (improved or degraded) by sensorimotor activations would prove that those performances are carried out in sensorimotor formats. If retrieving my pin-code is facilitated by motor simulation of me typing my pin-code, MEE defenders hold, then my pin-code gets stored in the same format in which I send the commands to my fingers for typing it. Or, if a disruption in my pre-motor cortex did make me take longer in processing the action word 'kick' then, MEE does also argue, KICK would get stored in the same format I use to send motor commands to my legs.

Indeed, MEE seems the theoretical counterpart in the EC literature of the mental imagery hypothesis: they both seem in fact to postulate image-like formats in order to explain a set of cognitive properties. Indeed, they divide on the properties they want to account for. Typically, the imagery hypothesis wants to explain the reaction times in mental rotation tasks, while MEE wants to model sensorimotor contributions to cognition. If MEE is correct, EC effects in complex cognitive processes would be explained assuming image-like formats over which those processes operate. Drawing DOG-related inferences or hearing action verb like 'kick' would be a matter of manipulating representations with analogical features. As maps represent the territory analogically, so that greater distances in maps represent greater distances in the territory, the same would happen for sensorimotor formats, in the sense that, according to MEE, differences in the way modal formats represent my dog correlate with differences in stimuli from my dog, or the motoric formats by which I represent my legs' movements vary as a function of my legs' movements. Thus, MEE takes sensorimotor formats to be somehow homomorphic with their representational contents, and such an homomorphic relation seems to explain, on MEE, the

variety of embodiment effects³⁶. The fact that perceptual formats analogically represent dogs-related properties or that motoric formats represent legs-related properties would explain why dogs-related and kick-related tasks involve sensorimotor formats³⁷.

3.2.2 *Amodal view of Embodiment Effects*

FSEC has a second (and widely defended) variant. According to some scholars, embodiment effects could be (and indeed are) better explained by postulating representations with non-sensorimotor formats (cf. Chatterjee 2010, Dove 2009, Machery 2016, Mahon and Caramazza 2008, Mahon 2015b, Weiskopf 2007). On this view, DOG-related inferences or action verbs processing tasks are carried out by means of cognitive processing operating over non-sensorimotor formats: if we have to answer the question about whether dogs have long ears, or if we have to attend to an action verb like ‘kick’ or ‘lick’, our cognitive system does operate on representational formats that are said to be “abstract” or “symbolic”.

Indeed, assuming abstract and symbolic storage for each such information (which typically get realized by associative circuits) would both explain the sensorimotor activations phenomena and accommodate a series of dissociations between sensorimotor activity and cognitive operations. We have, for example, visual cortex activations during DOG-related inferential tasks because modal representations in which DOG gets actually stored are systematically connected with perceptual representations by means of which we represent dogs visually – and the same explanatory pattern would hold for motor cortex activations during action verbs processing. Thus, on this account, embodiment effects would be the result of a fast informational *spread* from amodal formats to modality specific formats (Mahon and Caramazza 2008). The present model

³⁶ By ‘homomorphism’ I mean a structure-preserving function from elements in one domain into elements in another domain.

³⁷ Analogicity-based considerations have been typically used also to solve the so called “symbol grounding problem” (Harnad 1990, Searle 1980; cf. also Barsalou 1999, Glenberg 1997), the problem of how symbols get their meaning. We do not discuss the problem here, for it concerns contents-properties rather than formats ones. More on that later.

does also explain why differences in sensorimotor systems do not always result in differences in cognitive operations. Damages in modality specific systems have been found not to affect high level cognitive tasks: for example, both congenitally blind people and apraxic patients have been shown to process the meaning of visually loaded words – e.g. ‘dog’ – or motorically loaded ones – e.g. ‘kick’ – respectively, just like control subjects (e.g. Bedny et al 2012; cf. Mahon and Hickok 2016 for a review). The idea that, say, DOG gets represented in a non-perceptual format or KICK gets conveyed by means of non-motoric formats would explain why blind and apraxic subjects do process ‘dog’ or ‘kick’ as non-blind and non-apraxic ones.

I call the Amodal view of Embodiment Effects (AEE) the thesis according to which *for any EC effect E where a sensorimotor activation S seem to affects a cognitive task C, E is explained by assuming C to be stored in a non-sensorimotor format N* (with sensorimotor activity being a matter of informational dynamics rather than of representational format³⁸). It is “amodal”, for its explanatory relevant notions are abstract formats, defined independently from what our modal systems do³⁹.

AEE seems to bring to embodied cognition literature ideas from the language of thought hypothesis: both AEE and the language of thought hypothesis seem to assume language-like formats in order to explain a set of cognitive properties. Indeed, they divide on the properties they want to explain: language of thought hypothesis typically wants to model the systematicity or productivity of thought, while AEE aims at capturing the traffic between perception, cognition and action – what we called embodiment effects. If AEE is correct, embodiment effects on complex cognitive processes would be explained by postulating language-like representational formats over

³⁸ The idea of drawing from a premise on sensorimotor activations a conclusion on sensorimotor formats has not convinced for a number of reasons (cf. Mahon and Hickok 2016, Barsalou 2016).

³⁹ N.B. AEE is a non-EC explanation of EC effects. Typically, AEE defenders are in fact critics rather than defenders of EC.

which those processes operate. So, for example, drawing DOG-related inferences or processing action verbs like 'kick' is a matter of manipulating language-like symbols that have nothing to do with perceptual properties of dogs or kinematics properties of a kick. There is nothing in the words 'dog' or 'kick' that resembles what we typically refer to with those words, and there is nothing in the language-like symbols forms DOG or KICK we allegedly process in those tasks that resembles sensorimotor properties of dogs or kicking.

Hence, according to AEE, amodal symbols which are used to represent DOG or to process 'kick' are essentially different from the modality specific symbols that we typically use to perceive for example visual properties of dogs or to send motoric commands to our legs. The two systems operate over *different* representational *forms* and follow diverse organizational *principles*. However, albeit cognitive amodal symbols do entertain arbitrary relations with their referents, AEE claims, they would also entertain *systematic relations* with sensorimotor activity (perhaps Hebbian connections), and these systematic relations, according to AEE, would perfectly accommodate embodiment effects. So, visual activations during DOG-related inferences, or motor activations in KICK-related linguistic tasks, can be explained 1) assuming DOG-related, or KICK-related amodal symbols, and 2) assuming these symbols as systematically connected with sensorimotor activity. On AEE, DOG-related symbols entertain systematic connections with the sensory modes in which we see, hear etc. members of the category DOG and KICK-related symbols do bear systematic links with motor modes in which we send motor commands to our legs, and so on for any supposedly embodiment effect.

3.3 Interlude on formats

FSEC has thus two competing explanations of embodiment effects: they both take representational formats as the explanatory relevant notions, while they disagree on the kind of formats doing the explanatory work. On MEE, modal formats best explain embodiment effects, while on AEE, amodal formats are better suited. It seems FSEC debate is not advancing much, with MEE and AEE stuck in their interpretations of the data. In doing so, FSEC seems to propose once again the problem of how those data, after all, can actually be explained (that is OPEC, cf. Ch 1). One way to go is to see what the notion of format in FSEC amounts to, i.e. what are the ontological commitments of MEE and AEE, which entities do those theories quantify over. The present paragraph is to be understood as a sort of interlude on the concept of representational format.

Representations are typically said to have both a content and a vehicle. Take again (cf. Ch 2) the sentence:

1) 'Beware, children crossing!'

1) has a specific content, which could be expressed in terms of the proposition *Beware, children crossing*⁴⁰: the content of 1) is the proposition *Beware, children crossing*. Natural languages such as English can typically express a potentially infinite set of diverse contents by combining a finite set of lexical entries in accordance with their grammatical rules: 'Children are not crossing', 'Children and reindeers are crossing', 'If children are crossing then motor vehicles must slowdown' etc. Despite their peculiar semantic properties (more on this later), linguistic expressions are not the only way we know to store and transmit contents, however. Pictures, diagrams, maps and other items can do the job too.

⁴⁰ Contents have been also identified with sets of possible worlds or states of affairs. What contents are is irrelevant, however, for what matters here is the relatively non controversial idea that representations do possess contents, and the idea that contents can be – and have typically been – cashed out in terms of propositions, among other ways.

Consider the following picture:

2)



There is a sense in which the road sign possesses the same content, i.e. express the same proposition, of 1): the way colours and lines are organized seems to depict exactly the proposition *Beware, children crossing*. This is why we are supposed to drive carefully when we encounter it on the road: we want to respect the traffic laws and we know that, if we must beware of children crossing, we are supposed to drive carefully. On the other hand 1) and 2) do store contents in different ways: while 1) does it by means of English words, the way 2) expresses the proposition *Beware, children crossing* is by means of organized coloured spots. What distinguishes the sentence 'Beware, children crossing' from its pictorial counterpart is the vehicle of the content, i.e. the way the content is conveyed: 1) typically exemplifies a discursive vehicle, whereas 2) is a paradigmatic case of an iconic one. The specific way in which 1) stores and conveys the content expressed by the proposition *Beware, children crossing* is what makes it the – discursive – vehicle it is, whereas the specific way in which 2) stores and transmits the same content is what makes it the – iconic – vehicle it is.

A number of scholars have pointed to public representations to make the vehicle/content distinction clear (e.g. Fodor 1975, Kosslyn 1981; cf. also Camp 2007, Rescorla 2009, Burge 2010, Kulvicki 2015). The fact that sentences and pictures (just to take the paradigmatic cases) can convey the same contents, and viceversa, how different contents can respectively be encoded

either by pictures or sentences, seems provides an intuitively solid reasons to doubly dissociate the notions of representational content and vehicle. What of that distinction seems have mattered more is the way in which different vehicles do carry contents, in the sense of both 1) the set of primitives each vehicle is composed of and 2) the way such primitives compose to carry their particular representational contents.

So, fully discursive vehicles are typically said to be *different* from fully iconic vehicles in, at least, two ways (cf. e.g. Quilty-Dunn, forthcoming)⁴¹. First one: parts of iconic vehicles do seem to typically correspond to parts of what they do represent, while this is hardly true of discursive vehicles. For example, parts of the icon in 2) seems to represent parts of its content, while that does not seem to apply for the sentence in 1): the letter ‘w’ does not represent anything whereas any spot in 2) seems to have a representational import. Second, holism: unlike discursive vehicles, icons represent holistically, in the sense that parts of icons store various properties at once, and so, unlike linguistic items, icons do not have canonical decomposition (Fodor 2009). Parts of 2) representing kid’s head do also represent her head’s shape, and there seems to be no discrete part in 2) that uniquely picks particular individuals or properties, unlike what happens in 1), where ‘children’ or ‘crossing’ range over specific individuals or properties⁴².

As a result, there is a number of ways in which public representations seem to specifically encode their contents, and these encoding modes are typically taken to be the *vehicular* properties of such public representations. So, for example, icons and sentences seem to encode their contents by following different *rules*, which in turn operate over different sets of *primitives* representational symbols. Indeed, for any for any public representation P, there seems to be a set

⁴¹ “Fully” since vehicles seem to form a continuum between iconic – e.g. photographs – and discursive – e.g. sentences, depending on whether they instantiate paradigmatically iconic properties or paradigmatically discursive properties.

⁴² Of course, those principles are debatable (cf. Camp 2009) and non-exhaustive: a number of other features typically possessed by discursive vehicles (arbitrariness, abstractness, digitality), and there are other properties (analogicity, density, concreteness) typically possessed by icons.

of primitive structures *S* and a set combinations *C* by means of which *P* represents its content, such that *S* and *C* define the *vehicular property V* of *P*, being *P* fully iconic – e.g. photograph – fully discursive – e.g. sentence – or hybrid – e.g. map.

Now, the notion of representational *format* seems to be *closely* related with what we said about the notion of representational vehicle. In most contexts the two terms have been used synonymously as to designate the property of a representation to encode its contents in a specific way. So, one could say, icons possess formats different from sentences, for icons and sentences encode contents in different ways, as much as say that encoding content in different ways is what makes icons and sentences diverse vehicles. If that is correct, it could not be the case that two representations possess the same vehicle without having the same format, and viceversa, there are no cases where two representations share format but do not share vehicle. Thus, for a representation to have a certain vehicle would *ipso facto* mean for it to have the same format: it would be weird to say that 1) and 2) possess two distinct vehicles while having one and the same format. But then, one could question, why should we have two expressions if they designate the very same notion?

One reason to distinguish representational formats from vehicles may be the following. Vehicles have either been interpreted as being *physical bearers* of representational contents – i.e. physical properties – or *formal-organizational* properties of some kind – i.e. non-physical properties (Fodor 2009, Crane 2016).

On the first reading, the vehicular properties of 1) would be sequences of pixels on the screen while the vehicular properties of the representation in 2) would be pieces of metal road signs are made of. On this reading, ‘vehicle’ would then be a synonym of ‘physical realizer’. For any

representation R, there is a *physical property P* that implement R, and P is what ‘vehicle’ means under this reading.

On the other hand, vehicles could be interpreted as being *non-physical features*: 1) conveys the content of ‘Beware, children crossing’ in a *certain way*, this way is what makes 1) a discursive vehicle, and the way 1) conveys its content is independent from its realizer: ‘Beware, children crossing’ could be implemented by marks of ink on a piece of cellulose or sequences of sound waves through the air, and none of these physical realizers seem to capture the very way in which 1) encodes its content. On this second reading, the notion of vehicle would thus be similar to the idea of *mode of presentation*: for any representational content C, there is a way in which C gets stored, and E is *independently* identified from its physical *realizer P*, and E is what ‘vehicle’ would actually mean under that second interpretation – more on what we mean by ‘a way in which C get stored’ shortly.

Now, one reason why one may want to introduce formats could be to *distinguish between physical and formal properties of a vehicle*: format properties would in fact be formal properties of representational vehicles. Thus, format properties of 1) would be formal properties of the discursive representation embedded in it – linguistic primitives plus their rules of combinations – whereas format properties of 2) would be formal properties of its iconic representation – pictorial primitives plus their rules of combinations. More generally, *for any public representation R, there is a vehicle V and a content C, and format properties F are formal-organizational properties – i.e. primitives plus principles of combination – of V.*

There is may be a second reason why one would like to distinguish between formats and vehicles. Beside the physical-formal reading, vehicles can also oscillate between a *syntactic* and a *semantic* interpretation. Take for example 1). Fully discursive vehicles such as sentences seem to follow

specific semantic principles: for instance, in the case of 1), there seems to be a function that *arbitrarily* maps vehicular parts into values – i.e. conventional mapping. There seems to be nothing in the word ‘children’ that makes it referring to a specific set of objects or properties rather than another. And in fact, for that very conventional mapping, ‘bambini’ or ‘garçon’ do just the same referential work. Diverse vehicles would have diverse semantic rules – e.g. iconicity, holism, etc. – so much so that vehicles can be partly identified by those very semantic rules. Representational vehicle can also be syntactically individuated, though. Consider again 1). A number of syntactic rules govern the way in which primitive symbols grammatically combine together: for example, syntactic rules of English grammar that combine vehicular parts into wholes do not distinguish between ‘children’ and ‘CHILDREN’, for such rules are just sensible to parts’ values rather than parts themselves. In other words, *the way in which a vehicle V encodes its content C could be syntactically identified, in the sense that, for any vehicular property V, there are syntactical features S, and S are what ‘vehicle’ means on this reading.*

So, a second reason for introducing the notion of representational format is to capture exactly this reading of representational vehicles. That is, it is to distinguish between semantic and syntactic properties of vehicles. If this is so, format properties have just to be conceived as syntactic properties of representational vehicles, as opposed to semantic properties of them. On that reading, format properties of fully discursive representations such as 1) would then be purely syntactic – i.e. non-semantic – properties of them, and likewise, format properties of fully iconic representations such as 2) would be purely syntactic – i.e. non-semantic – properties of them. In other words, it seems that a) there are (at least) two different ways in which 1) and 2) store their contents, b) both ways have purely syntactic properties, and c) these purely syntactic properties are the formats of 1) and 2). For example, a) there is a way in which 2) combines different values along different dense magnitudes (e.g. color, distance, direction) in order to store its content, b)

this way is intrinsically non-content involving – that is to say, it does not possess content essentially – and c) such a purely syntactic mode of presentation is what we should call the ‘format’ of 2).

Now, if what has been said so far is on the right line, format properties are both non-physical properties – i.e. abstract features – and non-semantic properties – i.e. syntactic features – of public representations (cf. also Ch 2 §2.1.1). After all, even the ordinary use of the term ‘format’ seems to be consistent with this characterization: analogical vs digital format, PDF vs DOC format seem in fact designate both non-physical and non-semantic properties, in the sense that, for example, it seems there is nothing in a clock’s physical properties that makes it encoding hours in an analogical rather than a digital format, or, there seems to be nothing in the content of the present chapter that makes it encoding in a PDF rather than a DOC representational format. Both analogical vs digital or PDF vs DOC distinctions seem to be non-controversially distinctions in format, and both formats distinctions seem to non-controversially capture non-physical and non-semantic features. Consequently, it seems that, *for any public representation R with content C there is a way in which C is realized (the vehicle V of R), and for any V there are non-physical and non-semantic features of V (the format F of R).*

3.4 Identity puzzles for FSEC

The vehicle vs content distinction does not exclusively apply to public representations, however. Cognitive states – qua representational – have also been viewed in term of what they represent and the way they do. Thus, when I think that my bank pin code is 45243, I am thinking about a particular thing or state of affair, namely that my pin code is 45243, and such a particular thing or state of affair is the content of my thought. On the other hand, there are different ways in which I

may cognitively represent that series of numbers. For example, I could think of 45243 by entertaining a visual percept of such sequence in my mind, perhaps having an image-like representation of those numbers, but I could also think of this state of affair by means of language-like symbols: that is, by entertaining a set of abstract and arbitrary items in my mind.

As said, those who apply vehicle/content divide to cognitive phenomena, typically invoke formats to explain such phenomena (Kosslyn et al 2006, Pylyshyn 2002; Shepherd 2018, Quilty-Dunn forthcoming). In our example, they might claim that my thoughts about 45243 get stored in a perceptual (iconic) format, or they could take my thought's format is conceptual (discursive). More relevantly here, scholars tend to claim that EC effects concerning 45243 would either get explained by assuming *modal (iconic-like) formats*, or they would be accounted for by postulating formats that are essentially *amodal (discursive-like) in kind*.

The present section wants to investigate what does exactly mean for *embodiment effects* to be explained by modal, rather than amodal, *cognitive formats*, given what we said on iconic vs discursive *public* formats: that is to say, we will try to see whether format properties in public representations can be used to account for EC effects – as modal rather than amodal formats – and so, whether such “format shift” does solve the opacity of EC. Puzzles *similar* to the ones raised for b-formats (cf. Ch 2, §2.2.2) seem to apply to modal/amodal formats as well. Let's see which puzzles actually concern FSEC, and how similar they are to the ones we have discussed with regard to the B-Formats Approach.

Recall that, according to MEE, postulating modal formats would best explain embodiment effects, while according to AEE, the best way to account for embodiments is to assume formats which are amodal in kind: we do recover our pin code faster as we imagine ourselves typing it because our cognitive systems convey the string of numbers in motoric formats (MEE) as opposed to

representing it in symbolic formats (AEE). Also, recall that the reason why modal vs amodal representational formats would respectively best explain embodiment effects is that they are either realized in specific (sensorimotor vs associative) *circuitries*, or they bear characteristic (structural vs arbitrary) *relations* with regard to their representational contents (Haimovici 2018). This are the available options: DOG-related conceptual tasks interfere with perceptual systems, either a) because brain areas generally associated with perception get (immediately or later in the process) involved in those tasks, or b) because DOG-related concepts do (or do not) entertain some resemblance's relations with dog-related stimuli.

If these are the explanatory options available, then one might also ask how one could possibly know which of them is right. That is, *first*: what are the truth-conditions of these options, what should happen for MEE, as opposed to AEE, to be true. And *second*, which of those options is actually true: whether EC effects are better explained by postulating modal formats, as opposed to amodal ones. In other words, one may ask what it means to store in a modal vs amodal format. The question of what should happen for MEE, rather than AEE, to be true, seems depend on the way in which modal formats, as opposed to amodal ones, are characterized respectively by MEE and AEE. Understanding what exactly 'format' means when MEE talks about "modal formats", as opposed to how we should read the notion of format when AEE talks about "amodal formats", may indeed help us understanding what has to happen if MEE, rather than AEE, are correct, given the evidence on EC. Call this set of puzzles, the identity problems for FSEC.

3.4.1 *The neural based criterion*

The identity problems for FSEC could be stated as follows. Scholars typically consider either modal or amodal formats to be explanatorily powerful units, while leaving *underspecified* what modal and amodal formats exactly amount to (cf. Machery 2016). On a widespread reading,

modal/amodal distinction is a matter of *neural organization*: brain circuits typically associated, for example, with perception or action, would have dedicated sensorimotor formats, whereas modal formats are typically characterized in terms of associative neural circuits (cf. Barsalou 2016). According to this reading, the identity criterion for formats is neural: modality specific brain activities are assumed to correlate with modality specific formats, and conversely, non-modality specific brain activations would designate non-modality specific representational formats. In other words, brain activity typically associated with movements would code in motoric formats, brain networks typically associated with perceptual tasks would store in perceptual formats, etc. for any neural substrate. On this view, modal formats would be the way in which sensorimotor brain areas do store information, whereas amodal representational formats would be the way in which associative pathways do convey data. More generally, *for any brain structure A which gets typically activated during a given sensorimotor task S, A is said to code in a modal representational format M, while for any brain structure B typically activated during a given non-sensorimotor task N, B is said to code in an amodal format.*

Some authors have criticized the neural based criterion for modal/amodal formats. According to somebody, it is not obvious that the so called “perceptual” or “motoric” brain structures are clearly identifiable as such (Machery 2016). *Boundaries* between sensory, motor and cognitive circuits could be (and are) disputable: for example, whether temporal poles are part of the cortical base of vision may be controversial, and one might even question whether the prefrontal cortex physically realizes any perceptual process. Although there are certainly clear cases of “visual” networks like the primary visual cortex or V1, where to draw the boundaries of those networks or whether those networks are “visual” for every subject (e.g. congenitally blind patients) is still a

matter of controversy (cf. Zeimbekis and Raftopoulos 2015)⁴³. Structural ambiguities, so the critic goes, would carry with them ambiguities at the format level as well: if perceptual areas are unclearly identifiable then perceptual formats unclearly identifiable either.

Others have criticized the neural based criterion for a different reason. According to them, neural circuitries are *not informative* of representational formats, in the sense that being typically activated in sensorimotor tasks does not provide by *itself* a reason for a brain region to encode information in a “sensorimotor” way: for example, being typically active during legs’ movements does not suffice for coding in a motoric format and being typically triggered during object detection tasks is not enough for coding in a perceptual format (cf. Martin 2016; but see also Leshinskaya and Caramazza 2016). According to this argumentative line, single regions could operate over multiple, qualitatively distinct representational formats. For example, there are reasons to believe that neural pathways typically found activated in sensorimotor tasks do operate in non-sensorimotor formats (Shepherd 2018, Quilty-Dunn 2019). If that is correct, so the critics goes, evidence on modal activation would not *ipso facto* be evidence on modal format, for the way in which an area encodes data seems independent from the tasks it is typically associated with (cf. also Mahon and Hickok 2016). One thing is neural activation, quite another is cognitive organization, and inferring the second from the first, so the objection goes, seems like committing an inferential mistake⁴⁴.

Empirical considerations asides, there is at least one conceptual reason why the neural based criterion seems problematic. Indeed, the reason appeals to the very characterization of format as

⁴³ The so called “cognitive penetrability of perception” seems a reason to be suspicious of the neural based criterion for modal/amodal formats, as well as it seems to be problematic to identify clearly the senses (cf. Machperson 2011).

⁴⁴ A reason why neural criterion is fallacious may also appeal to considerations on “reverse inference” (Poldrack 2006). Caveat: information about localization by themselves are not enough to predict the format a system is operating upon but adding contextual data of some kind (e.g. which other areas activate, which frequencies oscillate) might help a bit.

discussed above. Remind that format properties are supposed to be non-physical properties of a representational vehicle: the way a sentence like ‘Beware, children crossing’ encodes its content has nothing to do with its medium, for a sentence could be realized by different materials and yet being the same sentence. This is how the notion of format is supposed to apply to public representations. Now, *mutatis mutandis*, the same considerations may apply to cognitive representational (i.e. modal/amodal) formats as well. That is, modal/amodal formats properties are non-physical properties of cognitive processes: for example, the way in which my memory processes store the number 45243 is independent from its neural realizer, in the sense that memory could be realized by quite different brain areas – or even non-neural circuits – and yet encoding that very information in the same way. If this so, modal/amodal formats have not to be mistaken with neural properties, for the modal or amodal formats, just like sentences or icons, are supposed to be *formal* properties of cognitive representations, perhaps the structures computations are sensible to, and so independent from the physical features of our brain regions. Just like ‘Beware, children crossing’ represents its content by means of primitives and rules of combination, modal vs amodal storages of DOG would amount to a set of cognitive primitives and combinatory principles – perhaps computationally described – and the same would hold for any cognitive representational format.

Now, if this is so, considerations on modal vs amodal formats in processing action verbs like ‘kick’ or ‘lick’ would have taken into account the ways in which linguistic information gets encoded and processed. For example, what ‘kick’ explicitly encodes, what we should derive from ‘lick’, whether those verbs could be accessed and altered in isolation, or which kind of errors we typically do while we process them. In other words, postulating modal rather than amodal formats would be a matter of *cognitive organization* rather than neural implementation, and failing to see that distinction seems to be problematic (cf. Ch 2). For that reason, if one takes formats to be the

explanatorily relevant notion for EC effects and then looks at neural level to see whether the effects are explained by modal or amodal *circuitries*, it seems she is looking, so to speak, in the wrong direction: just like someone who wants to understand how ‘Beware, children crossing’ encodes its propositional content by looking at patterns of inks on a piece of paper, rather checking its abstract propositional properties, a neural criterion’s supporter seems to be somebody who wants to understand how cognitive representations encode, for example, DOG by investigating which piece of brain gets activated, rather than checking their abstract computational characteristics.

As a result, either one drops modal/amodal format assumptions and just focuses on “perceptual” or “motor” neural activations, or, if she takes formats on board, she has to consider non-physical (computation-sensitive) features of cognition. That is, either one explains DOG-related inferences by appealing to activations in “perceptual” areas and drops formats or, if she appeals to formats, she has to explain DOG-related inferences by postulating organizational properties that are *independent* of implementation considerations, therefore, she drops neurons⁴⁵.

Both options seems to be quite expensive for the present position to commit with. If modal/amodal formats are just neural activations typically triggered during perceptual or motoric tasks, then, one might ask, why should not one call them “sensorimotor activations” instead of “modal formats”? That is to say, if talking about representational formats is just another way of talking about brain activity, one may legitimately suspect that “format” talk does not quite add anything interesting to a “neural” talk. On the other hand, neural based criterion’s supporters may want to be realist on representational formats and so they may take format properties to be a fact

⁴⁵ One way to refuse the dilemma is to say that modal/amodal status of a representation should not be red off purely from its formal properties. This is fair enough. Our point here is conditional: *if* modal/amodal properties are format properties, and *if* format properties are formal properties, then modal/amodal properties are formal properties. This is the implicit line modalists assume (e.g. Barsalou 1999, Prinz 2004). Many thanks to Daniel Weiskopf for having raised the question.

of the (cognitive) matter which supposedly settle EC issues. If so, it seems they have to explain what they take formats to be and how format features relate with brain features. Indeed, the burden of the proof that formats are neurally based seems to be on their side⁴⁶.

3.4.2 *The semantic criterion*

There is a second, even more common view, according to which formats are a matter of semantic relations. On this view, modal formats are defined as bearing *non-arbitrary* relations with their contents, while *arbitrary* content-relations are distinctive of amodal formats (cf. Barsalou 1999, Glenberg and Kashak 2002, Mahon and Caramazza 2008, Hickok and Mahon 2016). For example, on MEE, the way perceptual formats represent a dog does non arbitrarily refer to a dog, in the sense that perceptual features of a dog supposedly selected by modal formats non arbitrarily refer to that dog. And the same applies to motor formats. According to AEE, instead, the way amodal formats represent dogs entertains arbitrary relations with dogs, in the sense that amodal symbols arbitrarily refer to dogs. There is nothing in an amodal symbol that non-arbitrarily stands for dog.

In other words, the identity criterion for representational formats is semantic. *For any arbitrary relation I with content C, and for any non-arbitrary relation N with C, amodal formats bear I with C, while modal format bear relation N with I.*

Now, as seen, semantic criterion has been typically used by MEE to solve the symbol grounding problem (Barsalou 1999, Glenberg 1997). It is not so obvious, however, that modal formats are actually better suited to solve the puzzle of how cognition is grounded, for it is not so obvious that modality specific formats bear non-arbitrary contents, with amodal formats possessing contents arbitrarily (e.g. Shapiro 2011). For example, it is not entirely clear how the perceptual way to code

⁴⁶ Daniel Weiskopf suggests a further solution, that is a): isolate modal psychological processes from higher cognitive activity; b) determine which formal properties explain those processes. This is interesting. So, in this Marr-like view, modal formats are formal features of cognitive vehicles which explain perceptual processing characteristics. I believe this very nicely fits with what I said.

for dogs non-arbitrarily relate to dogs, as opposed to how linguistic representations such as ‘dog’ bear arbitrary relations with their extensions. Whether perceptual representations (i.e. representation that are involved in paradigmatic perceptual tasks) possess semantic properties typically associated to image-like representations, seems in fact controversial. It is a rather unsettled empirical question whether perceptual representations of dogs entertain their contents the same way in which an image-like public representation of a dog does (Machery 2016). Likewise, it is not obvious that representations recruited during paradigmatic non-perceptual tasks possess semantic properties typically associated to language-like representation: that is, for example, whether the concept DOG refers to a dog in the same way the word ‘dog’ does it in English.

But even conceiving modal formats to be (in some sense) image-like, and amodal formats being (in a sense) language-like, it does *not* seem to *follow* that modal representations bear their contents non-arbitrarily, with arbitrary relations being specific just of amodal representations. Although image-like representations are often treated as having a “more constrained” relation with their contents (perhaps because of *resemblances* considerations), there are reasons to conceive them as possessing their contents *as arbitrarily as* language-like representations. Wittgenstein (1953) has convincingly argued that images do not carry with them their rules of application, and Goodman (1976) has followed him by claiming that resemblance (over which images are typically defined) can hardly fix contents. For example, it seems there is nothing in a picture of a dog lying on a sofa which makes it a picture of a dog lying on a sofa rather than a picture of a dog sleeping (or resting) on sofa. We always have to interpret the picture in light of a context to see it one way or another. That is to say, the picture does not interpret itself. As for resemblance, random signs on a beach resembling a dog lying on a sofa does not seem to refer to a dog lying on a sofa very

much, whereas wooden sticks assembled as to represent a dog lying on a sofa may not resemble it at all.

Now, if the Wittgenstein-Goodman considerations are on the right track, then even if modal representations are image-like, as symbol-grounding scholars hold, they would indeed bear arbitrary relations with their contents, and therefore, they could not be considered “more grounded” than their amodal counterparts.

There seems to be a *further* consideration pertaining the semantic criterion for cognitive formats. Recall that format properties of a public representation are formal properties of its vehicle. Thus, format properties of 1) are the primitives of that sentence plus the syntactic rules governing their combinatory rules (regardless of its content), and the format properties of 2) are the primitives of the road sign image plus their combinatory rules (regardless of its contents). These considerations do apply, *mutatis mutandis*, to cognitive representations, insofar as they are considerations about the format of cognitive representations. Thus, the modal formats of a cognitive representation would be equivalent to the primitives of that representation plus the syntactic rules that govern their combination (regardless of its content), while the amodal format properties of a cognitive representation would coincide with its primitives structures plus their combinatory principles, etc. for any alleged format property of a cognitive token.

However, this seems inconsistent with the semantic criterion, for the semantic criterion wants referential features (e.g. arbitrariness, homomorphism) to matter for identifying representational (cognitive) formats, while format properties are individuated just by syntactic features of representational (cognitive) vehicles. Defenders of the semantic criterion may for example want formats of 1) to be captured by *arbitrary* relations between the sentence ‘Beware, children crossing’ and the state of affairs the sentence designates, while conceiving formats of 2) to be

identified by *analogical* relations between the icon and its content. The point holds for cognitive phenomena too: modal formats would be characterized by analogical relations with their contents, and amodal formats would be conceived as the arbitrary way in which a cognitive representation brings about its content.

Now, the semantic criterion theorists has to face the following dilemma. Either they consider modal vs amodal formats as *content-involving* features, and in so doing they conflate format and content properties of a representation, or they give up their idea entirely, and admit that format properties are purely *syntactic* properties of a representational (cognitive) vehicle. Both ways seem to be pricey.

If they go for the first option, it seems they have to explain how exactly they take *content-involving format* properties of a (cognitive) representation in the first place. Again, it seems there is nothing in the content of 1) and of 2) that makes them storing it in two different ways, and it seems those diverse storage ways are what should be called, respectively, the formats of 1) and the format of 2). Likewise, it seems there is nothing in the content of a modal/amodal cognitive representations which makes them storing in two diverse ways. For instance, storing my pin code visually vs linguistically has nothing to do with my pin code.

In other words, a defender of a content-involving notion of format is forced to explain *how* contents matter for formats. For example, she has to explain how content of 1) matters for 1) to code in a discursive format, or how my pin code number matters for my cognitive processes to code it in a sensorimotor format. Without such explanation, one may suspect that the role of content in a content-involving notion of format is just *honorific*: despite its label, there is nothing in the content of 'Beware, children crossing' or in my pin code that makes 1) storing it in a discursive format, or my memory processes to encode it in a motoric one.

The *second* option for the semantic criterion theorists is not cheap either. In fact, taking format properties to be purely syntactic properties of a (cognitive) vehicle seems equivalent to *giving up* the content-involving notion of format altogether. So, if a modal representation of a dog is a set of syntactically identified features, or if an amodal representation of 'kick' are computational-sensitive properties, then the fact that the first representation refers to a dog while the second refers to the meaning of 'kick' is irrelevant. *But* claiming so, is equivalent to admit that the content-involving account of formats is false. Format properties of (public or cognitive) representations are non-content involving features of their vehicles⁴⁷.

3.4.3 The computational criterion

So, neither the neural nor the semantic criterion for identifying (cognitive) representational formats seem quite unproblematic, for what seems capture the notion of format are both non-physical and formal properties of a given vehicle. One may thus conceive modal/amodal divide as a matter of algorithmic features – or better, as *computation-sensitive properties* of cognitive representations. Computational properties are typically identified independently from both their semantic interpretations and their physical realizers (e.g. Piccinini 2008, 2015). Indeed, different computational procedures are available to calculate the elementary arithmetic function '+', and a variety of physical realizers are capable of implementing each such computational procedure. Besides being abstracts, computations are typically said not to carry representational contents *essentially* (Egan 1995, Paternoster 2003, Piccinini 2008; see Sprevak 2010, Rescorla 2012 for a different view). For instance, algorithmic procedures used to solve 5+4 are said to be just sensible to the form '5', '+' and '4', regardless of whether those symbols are interpreted as referring to

⁴⁷ Note that the semantic criterion is generally used by EC defenders to explain how concepts refer to their extensions (by means of modal formats) – symbol grounding. If what said is right, the semantic criterion does not work the way EC fans believe (for modal formats do not have privileged referential relations). What is more, taking formats to explain EC effects would leave input-output relations irrelevant, which is exactly the opposite outcome EC theorists do wish for.

natural numbers, soft drinks or heavenly bodies. For those reasons, cognitive formats may coincide with formal properties of representational vehicles over which cognitive computations would operate, for computation-sensitive representational features do seem to satisfy both the *non-physicality* and the *formality* conditions of formats. The format of '5+4' are the formal-syntactical features effective procedures are sensible to, algorithmic criterion theorists could claim, and so, cognitive processing like recalling the pin code number would operate on a modal vs amodal representational format depending on the formal-syntactical features these processes are sensible to⁴⁸.

So, for any computationally identified (embodied) cognitive process C, there are formal-syntactic properties F, such that C is sensible to F, and F are considered to be the formats over which C operate, under the computational view of formats.

Now, the computational criterion seems a nice enough solution to the problem of identifying formats. Consequently, one might think FSEC would benefit from it. So, once we take cognitive formats to be what cognitive computations operate over, what are the consequences for modalist vs amodalist accounts of EC data? Does the computational criterion help to solve OPEC? That is to say, are there formal-syntactic "modal" features and formal-syntactic "amodal" features such that we could check which of them would better explain embodiment effects? We believe this is not obvious.

Indeed, for this to happen, there should be a formally-syntactically determinable way in which information coded in modal format could be distinguished from information stored in amodal format. That is, there should be a way to identify modality vs amodality formats that does not

⁴⁸ To defend computational criterion is to identify formats with the "algorithmic level" of Marr's (1982) cascade, i.e. identify formats with the structures cognitive computations operate upon.

neither take physical considerations about brain networks, nor it has to consider semantic inputs-outputs relations.

A number of reasons play against it. First, it is unclear how computational view of formats distinguishes modal from amodal computationally-sensible properties. Despite the great amount of theoretical efforts spent in computational modelling (cf. Sprevak and Colombo 2018), it is controversial that there are formal-syntactic features “sensorimotor computations” are sensible to (and even that there are sensorimotor computations);, and conversely, it is not at all a settled matter that there are formal-syntactic properties “associative computations” are sensible to (and even that there are associative computations).

As said (cf. §2.2.4), while it seems clear what it means for public representations to have (non-physical/non-semantic) format properties, things are not so neat with cognitive phenomena: one thing is to say that ‘Beware, children crossing’ has a syntactically defined way to encode its content, quite another is to say that there is a syntactically defined way in which my perceptual system store DOG. On this line, attributing formal-syntactic features, such as the ones of natural languages or images, to (embodied) cognitive processes, *may* be metaphorical⁴⁹. It seems we do not yet know at the present stage whether there is a form-syntax in which my pin bank code gets stored by my memory system, or whether KICK is encoded in formally identifiable structures, and thus, claiming that such cognitive tokens do possess those structures seems just a metaphorical way of speaking⁵⁰.

⁴⁹ There certainly have been attempts to spell out what it means for an arbitrary physical system to have a system of symbols with certain formal properties (cf. e.g. Piccinini 2015). The extent to which these attempts do justify a realist account of formal-syntactic cognitive formats is unclear, however. Thanks to Daniel Weiskopf for a note on this.

⁵⁰ Simone Gozzano wonders why format distinctions work so well with public, but not so much with cognitive representations. The point here is that we may not yet apply the distinctions, for 1) inner representations, unlike public ones, are not of easy manipulation, and so 2) we could not yet know how to establish their syntactic characteristics (if any). Thanks a lot for the comment.

Thus: the computational account of cognitive formats does not seem it could either be confirmed or disconfirmed, for it is unclear whether there actually is a set of formally defined cognitive formats over which the sensorimotor systems (or the associative systems) do operate, and therefore, it is unclear how to check whether, in order to explain the embodiment effects, it is better assuming modal representational formats rather than amodal ones. If there are no formally defined representational features over which sensorimotor systems operate, there is no way to check whether those features do in fact store information in any relevant task – and the same applies to non-sensorimotor systems. So, for example, if there is no clear way as to decide whether my processing of the word ‘kick’ is accomplished by computing some formal-syntactic features, there is no clear way as to decide whether that task is better captured by postulating those features either – being those features, in *some* sense, “modality specific” or not.

There is a *last* worry which might concern the computational criterion of format. Even if one could determine modal/amodal specific sets of formal-syntactical features in our mind-brain systems, it is not evident how the modal vs amodal formats distinction would still hold within that formal-syntactic view of formats.

In fact, if one believes the fast reaction times of my pin-code’s retrieval to be better explained by assuming sets of formally identified structures computed by my motor system, rather than my associative areas, then it seems my motor systems – rather than my associative circuits – are of little explanatory relevance, for all it matters, from an algorithmic viewpoint, are the form of symbols and the combinatory principles. Insofar as formal-syntactic features of cognitive systems are allegedly the explanatory powerful units, neither *implementation* properties – i.e. being typically realized by the motor system – nor the *semantic* properties – i.e. being the typical trigger of motor commands – seem to be of much interest to explain the pin-code’s retrieval effect, or any other embodiment phenomena.

But then, one may reasonably argue, modal vs amodal is *not* a *relevant* distinction to be drawn anymore, as long as the distinction is typically drawn precisely on the base of implementation and content-involving considerations. To say that DOG is stored in a modal format is generally equivalent to say that DOG is stored in perceptual or motor *circuitries*, and perceptual or motor circuits are typically characterized in terms of perceptual *inputs* and motoric outputs – and these considerations apply to amodal tokens too (see Wajnerman Paz 2019). In other words, if what we said is correct, there seems to be no interesting divide

Between modal-related and amodal-related formats, and so it seems there is *no interesting divide between MEE and AEE within an algorithmic notion of format*: all and only it matters to explain EC effects would be the formal properties of the structures a cognitive system (being it sensorimotor or not) would operate upon, and formal-syntactic properties of cognitive representations are what they are independently of the system that computes them (being it sensorimotor or not).

As a result, the computational view seems to imply a *deflationary notion of EC*, where embodiment effects are cashed out in terms of *efficiency* properties, rather than of bodily-related characteristics (cf. Ch 2 § 2.4). It is because a set of formally identified representational features are *easily* computed by our motor system that we assist to legs-related activations during ‘kick’ processing, and so, according to the algorithmic view, it is because those formal characteristics are *compatible* with the computations behind that linguistic task that the EC effect at hand occurs – regardless of either the realizers or contents of these structures.

Take again the road sign with a schematic picture of two children holding their hands. Now, the format features of such iconic representation are supposed to be more efficiently processed by a car driver approaching a kinder-garden area than the format features of the sentences ‘Beware, children crossing’. This is presumably the reason why we find the iconic version nearby the kinder

gardens. It just has the right format as it were. Take then the set of formal features allegedly computed by our motor systems during the pin code memory retrieval. Now, these formal features are supposed to be more efficiently processed during the pin code memory task than the formal features computed by the non-motor systems. This is presumably why we observe the embodiment effect we observe. Motor system has just the right set of formats.

Once again, little of the fact that those formal features are realized by our motor systems, or that they represent our hands' movements as typing the pin number (off-line) would explain, for example, the reaction times of the memory retrieval task as much as little of the fact that 1) and 2) are realized by inks' spots in pieces of iron, or that they represent the event of children crossing would explain why 2) provokes cars slowing down behaviours more efficiently than how 1) does it. Instead, what explains both phenomena seems to be the efficiency of format features for each such task: format features of the iconic representation in 2) are efficient for letting car drivers slowing down, format features of motor systems are efficient for retrieving our pin code number, etc. for any format and any task.

More precisely, the idea that a computational account of formats implies a deflationary EC, could be stated as follows: for any set of formal properties $F_1, F_2 \dots F_n$, such that $F_1, F_2 \dots F_n$ are instantiated by the cognitive representation R , and for any embodiment effect E , if F_1 better explains E than F_2 , then F_1 more efficaciously produce E than F_2 , regardless of others non-formal properties of R . If that is the case, then, on the computational account of formats, *modality vs amodality considerations are explanatorily vacuous*, for modal and amodal formats are generally individuated by physical realizers or semantic features of R .

3.5 Conclusive remarks

To sum up. We have seen how FSEC seems to face troubles once the notion of format gets analyzed down. FSEC wants to explain bodily-related contributions to non-bodily related tasks by means of postulating two ways in which our cognitive systems would encode the information: modality vs amodality specific formats. Modality (EC) and amodality (non-EC) views seem explanatory equivalent as regarding embodiment effects, and one move in the direction of solving such impasse may be to analyze the identity criteria for formats, that is, to see which conditions are used to distinguish representations coded in modal vs amodal formats. Neural based and content-involving identity criteria seem to be the most (at least implicitly) adopted ones. Both conditions, however, seem to be unsatisfactory, for different reasons. Neural organization does not seem to be predictive of formats' nature: sensorimotor *activations* would not imply sensorimotor formats. Thus, activations in a perceptual area during DOG-related inferences does not ipso facto prove DOG to be stored in a modality specific formats rather than encoded in an amodality specific ones. Semantic criterion, we have seen, is also not unproblematic: sensorimotor contents would not imply sensorimotor formats. Thus, the fact that a system typically codes *for* concrete objects does not ipso facto prove that it encodes in a modal format, and so, being that system involved in a high level tasks is not ipso facto a reason for MEE. There is a third criterion that may better capture the (non-neural/non-content involving) nature of formats, according to which modal formats are *formally* identified data over which sensorimotor systems compute (the computational view). Thus, the fact that perceptual systems compute specific formally identified data, plus the fact that those data are also computed in higher level conceptual tasks would be a reason for MEE. Even if the computational view seems conceptually viable, it may be a bit of an empirically immature idea: no set of formally identified data over which sensorimotor systems operate seems has been founded so far. But then, if the identity criteria for modal – and, by

contrast, amodal – formats are one way or another problematic, one may well conclude FSEC not quite being a promising way to go to solve the opacity of EC: if it is unclear what modal vs amodal formats actually are, it would also be unclear how to confirm whether inferences on dogs, action verbs processing, pin retrievals etc. are carried out in a modal vs amodal format. As in the case of BFA (Ch 2), the solution to OPEC has to be founded elsewhere.

CHAPTER 4

A number of scholars have agreed about format as not being an explanatory powerful unit of embodied cognition (cf. e.g. Barsalou 2016, Martin 2016). According to them, the empirical evidence on bodily related contributions to higher level cognitive tasks would instead be better described as evidence on *neural reuse*: embodied cognition just amounts to the reuse of sensorimotor brain *circuitries* for high cognitive functions. The present chapter is concerned with that view, i.e. the Neural Reuse view of Embodied Cognition (hence, NREC), with the double goal of presenting its merits and underlying few shortcomings. We first present the idea of reuse as applied to artefacts and biological traits: what does it mean for something to get reused, where ‘something’ is either a hand-made item or a naturally selected organ. Neural reuse as an organizational principle of the brain is thus presented and compared with item and trait reuse: we will see what it means for a piece of the brain to be reused and compare it with what it means for a chair to be reused as a door stop. Neural reuse as applied to EC cases is then put into focus: again, we will examine what exactly is stated in NREC and how it relates with neural, artefactual and biological reuses. The fourth section examines the merits of NREC over its competitors: once reuse mechanisms are analyzed down, EC phenomena seems to be more perspicuous. The fifth and final section is meant to be a bit more sceptical: even if the EC evidence may be more sharply captured, assuming NREC may have few unexpected implications an EC defender might not quite happily go along with.

4.1 Reuse: the very idea

Going for camping over the holidays makes for somebody good sense. In fact, bringing one's tent or picking up a caravan may not only be a cheaper solution than going for bed and breakfast or renting a country house. It may well also be more fun: nature-lovers may appreciate having the cicadas' noise all around night-time, kids could play safely in wild environments, plans must not be fixed that much in advance, among other niceties. Apart from tastes about vacations, there is an interesting aspect that characterizes camping-style holidays: one regularly *arranges* things up in order to solve different problems. For example, I might find myself in the situation of having to grab a hot moka pot without having any pot holder available nearby. Camping can be fun, but can also be rather uncomfortable. Fortunately enough, there is a solution at hand: a pair of swimsuit is hanging over my head. I believe they suit the task, thus I *reuse* them as a pot holder.

This shows the obvious fact that items made for *one* purpose might be (and often are) reused for *another*: in the present case, a pair of swimsuit originally designed to *go* swimming get recycled to *hold* a moka pot. Artefacts' reuse is a widespread activity within campsites: cars' boots are often redeployed as wardrobes, with luggage left opened in the back so that tents do not get overloaded and clothes get easily recovered, ropes are typically used as drying rack with hanging laundry being sometimes reused as privacy's protector (obscuring the visual field of neighbours), forks are rarely reused as grater (damn, we have forgot it!), etc.

Camping is not unique in this respect however. Items' reuse is in fact a pervasive praxis in our ordinary life too: chairs are occasionally redeployed as doorstops, newspapers get frequently recycled to clean glasses, etc. Whatever they are designed for, many items happen to be reused on a daily basis for a set quite divergent purposes. What seems to happen in all those ordinary cases is that the physical *structure* of those items happens to be available and serve for purposes

different from the ones those items have originally been designed for: the physical structure of chairs happens to be available and serve to hold the doors, pieces of a newspaper happen to be available and serve to clean some glasses, etc.

To put it in more precise terms, we could say that, for any item A with a set of physical properties $P, P' \dots P_n$ originally designed to cover the function F , and for any sequence of functions $F', F'' \dots F_n$ different from F , A gets reused if and only if one or more properties $P, P' \dots P_n$ implements one or more functions $F', F'' \dots F_n$.

Turning from artefacts to organisms, we found that evolution is, so to speak, a rather talented reuser. Birds' feathers evolved for heat regulation purposes later on turned for use in birds' flights, lungs of many basal fish happens to be recycled as gas bladder, just to mention a few classical examples⁵¹. Less cited cases: male urethra becomes a conduit for sperm, reptilian jawbones becomes components of mammalian ears, panda's wrist bone becomes a thumb. Now, evolved traits do share with domestic items the tendency for reuse: as a pair of swimsuit originally designed to go swimming get redeployed to hold a moka pot, a bird's feather originally selected for heat regulation purposes has got redeployed for aerodynamic functions. Both cases seems in fact to be cases in which a given physical structure, being it a selected trait or a designed artefact, happens to be available and serve for functions different from the ones they have been originally designed (or selected) for. Thus, the peculiar structure of birds' feathers, with all their tiny and juxtaposed layers, happened to serve flying-functions although they were selected to insulate birds from cold temperatures: perhaps because of their *light, flexible* and *mobile* characteristics they could have covered that function. And the same pattern seems to apply to other traits as well: a male urethra might have happened to be long and narrow enough to allow the sperm

⁵¹ Evolutionary biology calls these cases of redeployment 'exaptation' (cf. Gould and Vrba 1982). We will not compare the two notions, as such a comparison seems irrelevant to for our scopes.

passing all the way through (as much as it happened for urine), the panda's wrist is just as enlarged and elongated as it needs to solve the problem of grasping objects, etc.

In other words, for any trait T with a set of physical properties $P, P' \dots P_n$ originally selected to cover function F , and for any sequence of functions $F', F'' \dots F_n$ different from F , T is conceived as to be reused if and only if (at least one) of the properties $P, P' \dots P_n$ implement (at least) one of the functions $F', F'' \dots F_n$.

4.2 The Neural Reuse Hypothesis

Now, neural reuse hypothesis (cf. Anderson 2010; cf. also Anderson 2007, 2008, 2014) is the idea that reuse is *pervasive* in brain circuits. According to neural reuse hypothesis (hence NRH), neural structures would in fact share with other evolved traits (and designed items) the tendency for reuse⁵². Just like birds feathers were originally selected for heat regulation and swimsuit have been originally made for protecting oneself while swimming, *brain elements* got originally selected for some cognitive functions.

Broca's area, for example, seems got originally selected to cover speech production cognitive functions, in the sense that, just like physical features of birds' feathers have been selected to solve problems of heat regulation and physical features of swimming suits are exploited so as to let us go swimming without being naked, physical characteristics of our frontal lobes have been selected to cover speech production function. Besides, the analogy with evolved traits or designed items, according to NRH, seems hold all the way down: brain elements originally selected to solve a given cognitive function get reused to realize a different one (or even multiple cognitive purposes).

⁵² I will first present NRH and then I will problematize some of its aspects.

As a result, it seems that Broca's area does not only implement language speech functions, for it also seems activated during action-related and imagery-related tasks, such as movement preparation, action sequencing, action recognition and imagery (Anderson 2010, p. 245). Thus, just like birds' feathers got redeployed with flying-functions and panda's wrists got reused as thumbs, according to NRH, parts of our frontal lobe got redeployed for action-related and imagery-related functions (among others), although the function they were originally selected to is perform speech production tasks.

In other words, on NRH it is common for brain circuits originally established for one cognitive function to be reused, during evolution or normal development, for others, multiple cognitive and behavioural functions (Anderson 2010, p. 245). This is presumably because evolutionary (or ontogenetic development) considerations may favour reusing existing components for new tasks over developing new circuits de novo (Anderson 2010, p. 246). I may well be in the situation where the only available item in the context I can use as a pot holder is a pair of swimsuit. *Mutatis mutandis*, it could well be the case that the only available neural structure to employ in action-related or imagery-related (among others) tasks is a brain region of the frontal lobe we use to call "Broca's area".

So, if NRH is right, many neural elements are redeployed for multiple cognitive functions (cf. Anderson 2016) and this explains why, according to NRH, many brain elements are indeed active in multiple cognitive tasks (Anderson 2007). A review of 1.469 fMRI experiments, where activations of 998 anatomical regions have been evaluated in relation to 11 tasks (3 action, 2 perceptual, 6 cognitive), seems have shown how a typical brain region is in fact active in more than one task across different domains (action, perception, cognition) – cf. Anderson 2010. As a result, 968 regions (about 95%) have been on average found activated in at least 4 different (action/perception-related or cognitive-related) tasks; moreover, roughly 565 regions (more than

50%) were observed triggering in sensorimotor tasks, about 540 of which were also supposedly active in nearly 3 cognitive-related (attention, emotion, language, reasoning, mathematics, memory) tasks; lastly, 193 regions (around 20%) have been found just involved in cognitive-related tasks, 143 of which (approximately 72%) have been registered as activated also in 3 (on average) other cognitive-related tasks – just to mention few data (cf. Anderson 2014 for a more detailed discussion of the NRH evidence).

Because of these – and other – reasons, brain regions have taken not to be selectively activated and precisely dedicated to specific large scale cognitive phenomena like visual perception, audition or speech production. If these data are true, selectivity and dedication are in fact not features of our neurofunctional architecture: each cognitive function is not implemented in a dedicated, relatively small, fairly circumscribed brain region (Bergeron 2007)⁵³. No cognitive function, according to NRH, straightforwardly maps into a neural structure, i.e. no region is selective and dedicated to visual perception, as well as to audition, speech production, etc. Rather, each brain area, according to NRH, does support a set of different functions across various domains, and it does so, apparently, by forming a coalition with multiple, nested and overlapping neural elements (Anderson 2016): so, for example, speech production functions would just be supported by sets of multiple circuits, some of which, being assembled in various ways, would instead implement imagery-related and action-related functions⁵⁴.

Thus, if NRH is right, functional differences between task domains cannot be just accounted for by brain regions, in the same sense in which functional differences between organs cannot be accounted for by their physical structures alone. There is nothing in the panda's radial bone that

⁵³ Anatomical modularity and NRH are indeed inconsistent views. That is the so called “phrenology vs anti-phrenology war”. See e.g. Bergeron 2007, Carruthers 2006, Anderson 2014.

⁵⁴ Caveat 1: multifunctionality (one structure with multiple functions) has to be contrasted with reuse (one structure with a function get reused for another function). Caveat 2: NRH needs to assume original functions, but that assumption seems in tension with NRH itself. See § 4.4.1.

makes it serving as a wrist rather than serving as a thumb, just as there is nothing in the Broca's area that makes it supporting speech rather than action tasks. Functional differences between task domains are instead individuated by the different ways neural circuits get used and reused, just as functional differences between artefacts are captured by the different ways in which items structures get redeployed: thus, imagery-related tasks would differ from action-related ones in the fact that Broca's area gets reused in two different brain networks, just as the difference between protecting oneself while swimming and holding a hot pot may be captured by how a swimsuit gets reused. In other words, according to NRH, the very same neural structures are very often reused to cover different functions and so these diverse functions could not straightforwardly be mapped into one neural structure.

Accordingly, for any neural structure N with a set of physical properties $P, P' \dots P_n$ originally selected to cover a given cognitive function F , and for any sequence of cognitive functions $F', F'' \dots F_n$ different from F , N is conceived as to be reused if and only if (at least one of) $P, P' \dots P_n$ realizes (at least one of) $F', F'' \dots F_n$.

4.3 The Neural Reuse view of Embodied Cognition

NRH seems *neutral* with regard to brain regions and cognitive functions: what NRH seems to claim, in fact, is that circuit got selected to support one cognitive function and turned out useful to support another one, regardless of both which particular region gets actually reused and which function exactly it is reused for. Indeed, neural reuse applies to Broca's area as reused in action and imagery functions as well as to the occipital lobe in blind patients as reused for numerical processing tasks (Bedny 2017), or to the fusiform gyrus as reused by experts for playing chess and checking radiological images (cf. Bilalic and Campitelli 2018).

All such cases are cases of neural reuse as all such cases are cases where a brain region (i.e. Broca's area, occipital lobe, fusiform gyrus) get reused for diverse cognitive purposes (respectively: language and imagery, vision and mathematics, face recognition and chess/images recognition. Evidence showing activation of a single region for multiple tasks would ipso facto count as evidence about that region as being reused for those tasks. And such an evidence, according to NRH, is founded in many regions (associative and not) with many tasks (complex or not) which thus proves how reuse is a common feature of our brain architecture.

Nonetheless, even though NRH motivational issue is to explain a whole range of diverse brain activations data, there is a *subset* of those studies that naturally fits with NRH: call it the Embodied Cognition type of data – which is the evidence typically taken in support of EC (§1.1.1.). Indeed, *sensorimotor activations* during non-sensorimotor tasks seem to be cases of *sensorimotor neural redeployments*: they seem to be cases where a brain area originally selected for a sensorimotor (e.g. perception or action) task gets later on reused for a non-sensorimotor tasks (e.g. concept processing)⁵⁵. So, action-control activations in action-observation tasks (Gallese, et al 1996; cf. also Rizzolatti and Sinigaglia 2006) would amount to action-control circuitries as redeployed in action-observation tasks. And similarly, “gestures” areas interferences with speech production tasks (Alibali et al 2014) would allegedly be cases of “gestures” areas reused for speech production tasks, “fingers control” networks contribution in number processing (Andres et al 2007) would coincide with “fingers control” networks reused in number processing etc.

This is how NRH copes with OPEC. EC related findings, according to EC defenders, show that cognition somehow depends on bodily features. But we have seen what those findings would exactly show is rather underspecified – this is OPEC (cf. Ch 1). NRH can provide a solution to OPEC,

⁵⁵ For the theory to work, NRH has to assume that certain areas get involved in specific tasks and then reused in others. This poses some pressure on the original function individuation. See 4.4.1.

for these empirical findings seem could prove how body-related areas do get reused in cognitive-related tasks. Call that solution the Neural Reuse view of Embodied Cognition (henceforth, NREC)⁵⁶.

On NREC, what pre-motor activations in action-detection tasks would actually show is that some circuits, originally deployed for action-control purposes, turned out to be redeployed for action-detection functions. Thus, just like a piece of cotton designed to be a swimsuit could be reused to serve as a pot holder, or just like the pandas' radial bone selected as a wrist could be reused as a thumb, neural circuits originally selected to support grabbing functions could have been redeployed (during evolution) to detect someone else grabbing. And the same would apply to the other EC findings: brain circuitries established to support perceptual tasks got reused to perform concept processing, motor regions originally established for action-control functions got redeployed for language processing purposes, visual areas got reused to support colour judgments, etc.

All these EC-related evidences, according to NREC, would be better explained by assuming neural reuses, in the sense that what those data speak of is a reuse of sensorimotor areas for non-sensorimotor functions. Or, to be more precise, for any sensorimotor brain activation *S* observed during a non-sensorimotor task *N*, NREC claims, assuming structure *S* to be redeployed for function *N* would better explain such an activation. If that is the case, NREC may continue, then whether a cognitive process should be considered embodied – or not – would depend on whether a sensorimotor brain circuit would get reused to support that process – or not. Thus, according to NREC, whether spatial cognition, action detection, perceptual judgment, words understanding, number processing etc. are embodied would depend on whether circuits originally selected to

⁵⁶ NREC is more or less explicitly defended by Anderson 2010, 2014, Barsalou 2016, Martin 2016. For similar positions, cf. Gallese 2008, Hurley 2008.

support perception or action control turned out to be redeployed to support each of those operations. So, for example, if circuits originally established for action-control purposes turn out to be redeployed in action observation processes (among others), then action observation processes are embodied under NREC.

In other words, according to NREC, any cognitive process C has to be considered embodied if and only if brain circuitries originally established to support a sensorimotor task S happen to be reused in support of C. And since such a sensorimotor reuse seems quite a widespread feature of our neurofunctional architecture, NREC may reasonably conclude, embodied cognitive processes would be quite widespread phenomena too – under NREC.

4.4 Reasons to buy NREC

4.4.1 *The unity of redeployment*

A number of reasons might support NREC as a solution to the Opacity Problem (OPEC). First, *sharpness*. NREC seems to give a metaphysically and epistemologically sharper notion than traditional EC formulations. Recall, again, the opacity of embodiment – OPEC. EC has traditionally considered embodied cognition as a matter of body contributions to cognition, with few specifications about what the terms ‘body’, ‘contribution’ and ‘cognition’ would actually mean. The exact role of, say, action-control processes in action-observation tasks is typically left underspecified, with the result of having a too vague EC formulation for the evidence to confirm it: do action-control processes just facilitate action-observation tasks, or they are rather a constituent part of them? The available evidence seems not able to corroborate these traditional formulations of EC, up to the point where the positions of EC defenders and EC detractors are

somehow hard to discriminate (cf. Mahon 2015a). If it is unclear what it has to happen for cognition to be embodied, it may not be quite obvious whether it happens too.

This seems not to be the case for NREC, however. NREC seems sharper. One reason is that NREC specifies the *unity of embodiment*, as it were. As mentioned, neural circuitries are the unity of reuse, in the sense that what gets reused in NRH cases are neural circuits⁵⁷. And more generally, we have seen, what of any item or trait gets redeployed are the *physical features* of that very item or trait. When we say that a panda's wrist turned out to be a thumb, or when we talk of a chair redeployed as door stop, what it seems we are actually speaking of is that a bunch of physical properties get respectively reused as a radial bone or a chair.

In other words, for any object, what of that object gets reused are its physical features. To be more precise, for any structure *S* with function *F*, if *S* gets reused for *F'*, and $F \neq F'$, what of *S* gets reused are the physical properties *P*, *P'*... *P_n* of *S* – and *not* its function *F*.

As a result, a case of embodiment under NREC is a case where neural properties of *some* kind get redeployed: what should happen for a piece of cognition to be considered embodied on NREC is that pieces of our brain originally selected for perceptual-related or action-related functions get redeployed in high order tasks. Thus, the unity of neural reuse, under NREC, are the brain structures which have been *originally selected to support perceptual-related or action-related* functions. So, for example, for one to assess whether an action observation task is actually embodied, she has to check whether (at least) some of the brain areas that support that task have originally been selected for action-related functions; similarly, if one wants to set whether concept tasks of some kind do instantiate embodiment she has to test whether some brain circuits

⁵⁷ Although Anderson himself refers both to brain networks (Anderson et al 2013) and elements (Anderson 2016) as the unity of neural reuse.

activated in those tasks have originally been selected for percept-related functions; etc. for any EC case.

In other words, one reason why NREC may cash out a sharper notion than more traditional EC formulations is that it seems clearer, on NREC, where one should look to prove cognition to be embodied: one should look into brain regions originally involved in perception – e.g. V1 – or action tasks – e.g. motor cortex. Reuse obviously *presupposes* use: panda's radial bone can get redeployed as a thumb since radial bone got selected for something else (wrist), forks can get reused as graters as they are designed for something else (picking up food). *Mutatis mutandis*, neural reuse would presuppose *neural use* as well: motor cortex can be said it got redeployed for language processing since it has been selected for another function (presumably motoric), visual cortex can be said to be reused for concept tasks as it got selected for another one (perhaps vision), etc. Embodied cognition under NREC predicts that neural properties which support high order cognitive functions were originally selected to support sensorimotor functions: if neural properties recruited for action-observation O were originally selected during action-control tasks A, then O is embodied under NREC. And NREC seems to be conceptually sharper than traditional EC positions for it allows this very prediction. It predicts that there is EC when *structures* originally selected for a sensorimotor task get reused in a non-sensorimotor task.

4.4.2. Functional analysis

There is at least another reason why NREC may be said to provide a sharper formulation of EC. The reason, it seems, has to do with the neural reuse *mechanisms* itself. The idea that the abovementioned evidence on body related contributions on non-body related tasks should be better explained by assuming neural reuse. Consider, again, the case of mirror neurons. If NREC is right, what the evidence about mirror neurons would show is that circuits established for action-

control tasks turned out to be reused for action-observation (observation, mind-reading etc.) functions. Now, what embodiment would consist in this case is the fact that the same set of neurons get used (original function) and reused (derived function): it is the mechanisms by which a neural population got used in action-control tasks and then reused in action observation processes that makes action observation embodied under NREC. Lets analyse these NREC mechanisms.

First. If the unity of general reuse are the physical properties of what gets reused (neural properties in neural reuse), the reuse mechanisms do essentially involve – *at least* – two distinct functions: the original function and the derived one(s) (original and derived neural functions in neural reuse). As a matter of fact, any case of reuse is case where some structural features are arranged as to cover an (original) function and so rearranged as to cover one or more (derived) functions. Structural features of panda's radial bones are arranged by natural selection as to cover wrist-functions and rearranged as to cover thumb-functions, structural features of a swimsuit are designed to swim and reused as to grab a moka pot⁵⁸.

One could then characterize reuse as a mechanism which takes a given structure S designed or selected to cover a certain function F as *input*, and gives back the same structure S implementing another function F' (different from F) as *output*. This could help in clarifying a bit EC phenomena: EC-kind of reuse could in fact be characterized as a mechanism which takes brain structure B selected to cover a sensorimotor function S as input and gives it back non-sensorimotor function N. So, mirror mechanisms would take circuits selected for action-control functions as input and provide them with realizing action-observation functions as outputs – and so forth, for any pair sensorimotor inputs and non-sensorimotor outputs.

⁵⁸ This obviously implies there could not be reuse with just one function involved: one could not say that structure S designed for function F gets reused to cover function F', if F and F' are identical. This would be a case of simple use, even though in some cases it might be tricky to assess whether $F \neq F'$.

Now, so conceived, NREC seems to provide a conceptual advancement in at least two directions. On the one side, it seems there is a *function-concerning issue*. Which *original* function the structure at hand is exactly deployed for? And which derived function gets precisely redeployed for? Identifying the original/derived pairs of functions seems in fact a prerequisite of any mature theory of reuse: thus, if one wants to understand what is going on when a swimsuit gets reused as a pot holder it seems she has to understand both what the function of a swimsuit consists of, and what exactly it means for something to be a pot holder.

Functional identification seems an advancement of NREC over its competitors: what parietal cortex is deployed for? How should we identify action-observation as opposed to mind-reading functions? If one wants to understand what is going on when parietal cortex gets reused in language processing tasks it seems he has to individuate both its original (action-related) and its derived (language-related) functions. By giving a precise enough task analysis of cognitive functions, NREC theoretical apparatus appears to have the resources to provide a conceptually sharper EC notion than traditional EC formulations: if one could individuate both the original and the derived functional properties of mirror neurons, it seems, she could presumably also better explain the findings on mirror neurons activity.

4.4.3 *Functional relations*

But NREC might be innovative for another reason. Apart from functional analysis, what of reuse cases should be considered are the *relations between functions* (and between cognitive functions in neural reuse cases). That is to say, for one to capture the precise nature of reuses' mechanisms, she should not only analyze the functions those mechanisms actually bring about. She might also have to examine, for any case of reuse, the *type of link* those functions do entertain. Thus, if I want to understand what happens when I reuse a swimsuit as a pot holder I may want to investigate

how swimsuits actually relate with pot holders: for example, whether swimsuits are *similar* in function to pot holders, or rather, as it seems, whether they are *dissimilar* – the function of being a swimsuit seems *non-conserved* when a piece of cotton gets reused as a pot holder (cf. Ch 2, §2.5). Reuse mechanisms are such that, for any case of reuse, one have the chance to establish whether the original functions are – or not – analogous with the derived ones – i.e. whether original functions get conserved, semi-conserved or non-conserved during reuse. As we have already discussed, if some structure S which is used for function F and gets reused for function F', we have a case of

- 1) Conservative reuse iff F and F' are identical
- 2) Semi-conservative reuse iff F and F' are similar
- 3) Non-conservative reuse iff F and F' are dissimilar

But consider again the panda's case: panda's *wrist* gets redeployed as a thumb. Now, as soon as its radial bone gets redeployed as a thumb, it seems it got to *cease being a wrist*: have an opposing thumb instead of a rotating hand made for pandas good evolutionary sense, so much so that it turned out to be a good solution, perhaps for better grabbing food, to *trade* wrists with thumbs. Once panda's radial bone get reused as a thumb it is no longer used as a wrist. Panda's case seems then to be a case of reuse where the link occurring between original and derived functions is one of *replacement*. So, we have a case of replacement when some structure S gets selected (or designed) for function F and reused for function F', and S cannot both realize F and F' at the same time (F' replaces F).

Feathers' case does not seem to exemplify functional replacement, however. When birds' feathers got reused for flying they did *not* seem to lose the function they were selected for. Indeed, they still protect birds from cold temperatures. Feathers' case is in fact a case of functional *expansion*,

rather than replacement. Thermoregulation expands, so to speak, into flying functions, in the sense that, while feathers let birds flying, they still implement thermoregulatory functions. In other words, we have a case of functional expansion when a given structure *S*, originally selected (or designed) to cover function *F*, gets reused to cover another function *F'*, and *S* can both implement *F* and *F'* at the same time (*F'* expands *F*).

Now, these functional connections are not only useful to understand general reuse mechanism. Indeed, they may also help in getting clear EC cases of reuses. Take again the mirror neurons case. For one to capture the precise mechanism of mirror activations, it may in fact be of some help examining the links between the original – action-related – and the derived – non-action-related – functions of these circuitries. That is to say, one could explore the kind of links mirror neurons – original and derived – functions entertain. Thus, one may want to know whether action-observation functions (mirror neurons turn out to be reused for) *conserve*, *semi-conserve* or even *non-conserve* action-control functions (mirror neurons might have been selected for). That is, whether action-control tasks are functionally similar to action-observation cognitive purposes, and if they are, under which functional parameter those two tasks are supposed to be similar⁵⁹.

Besides, if one interprets mirror activations as cases of neural reuse, she may also want to further clarify whether the reuse of those circuitries is actually a case of functional *substitution* as opposed to an example of functional *expansion*. If the latter (as it seems), then mirror neurons reuse would be similar to birds feathers' reuse: birds feathers do not lose their thermoregulatory functions while redeployed for flying-purposes and mirror neurons do not lose (it seems) their action-control functions while redeployed in action-observation tasks – and other cases of neural redeployments might instantiate other functional relations; more on that later. Evidence about

⁵⁹ Neural reuse interpretation of embodiment seems to imply a functionalist notion of embodiment: EC under NREC is in fact a matter of neural structures selected for sensorimotor functions and reused for non-sensorimotor functions.

mirror neurons does typically shows activations *both* during action-control tasks, such as grabbing a tea cup, and during action-observation tasks, like observing someone else grabbing a tea cup, and these activations would in turn show how action-control functions do *expand* into action-observation ones. Unlike the functional replacement in panda's radial bones, mirror neurons do not seem to lose their grabbing functions when reused for the purposes of observing someone else movements.

4.4.4. *The sharp mechanics of NREC*

There may be more conceptual distinctions to draw in reuse mechanisms, being them neural or not. And unquestionably one may give a much more fine grained characterization of the above mentioned distinctions – perhaps by looking at how structures instantiate functions in each case of sensorimotor cases of reuse. What interests us here, however, is that, if the above described distinctions do capture some interesting characteristics of reuse mechanisms, they do capture interesting characteristics of embodiment mechanisms as well – if NREC is right.

Indeed, NREC conceptual apparatus seems quite well equipped to explain the whole set of EC-kind of data, and that is perhaps why it is gaining momentum within the EC field (Anderson 2014, Barsalou 2016, Martin 2016). By postulating neural reuse to explain EC-related data one would give quite a precise account of EC theses, for neural reuse would give quite a precise description of what should happen if cognition is embodied given the data. Both in terms of the unity of EC (§4.3.1): a piece of cognition can be embodied if the circuits that support it got originally selected for sensorimotor tasks. And in terms of the mechanics of EC: if these circuits get reused for non-sensorimotor tasks than we have a case of EC. Accumulating details about the physical properties and the functional organization of reuse mechanics along the lines sketched above would eventually furnish NREC with a machinery capable of accurately interpreting the EC findings.

Which physical features do the so called “mirror neurons” exactly correspond to? Is there an action-control function they got originally selected for? And if there is one, can we possibly provide an accurate functional analysis of it? Moreover, what these neurons are exactly reused for? Can we have a fine analysis of their derived functions too? Also: which relation action-control and action-observation functions entertain? Are action-control functions semi-preserved, replaced or even expanded when mirror circuitries get reused for action-observation tasks?

Now, NREC does not only seem to have the tools to raise such questions. It seems also equipped to answer them. And if it is well equipped to answer them, we have reasons to think that NREC is well equipped to finally solve OPEC either.

Take once again the panda case. One may wonder whether panda’s wrist got actually reused as a thumb. There is a pretty obvious way to accommodate the curiosity: again, panda’s wrist got reused as a thumb when (and only when) the structure that has been selected to cover panda’s wrist-functions (sustain hand, favour rotator movements etc.) turned out to support thumbs-functions as well (hold tools, grab food etc.). All one has to do to check whether panda’s wrist has been reused as thumb, is then to examine which structure is used to support wrist-functions and whether that structure does cover thumb-functions as well.

The same would apply for other cases of reuse. Whether swimsuits got reused as pot holders, forks as graters, whether feathers got redeployed to fly, urethra to conduit sperm would indeed depend on whether structures of different sorts, from waterproof materials to pieces of metal, are originally designed/selected to swim or pick up food, for thermoregulation or urine conduction, and afterwards reused to hold a moka pot or to grate the parmesan, to fly or to conduce sperm. If that is the case, all one has to do to understand whether those cases of reuse actually occur is then to examine which structure is used for swim or pick-up functions, thermoregulation or

urinary-functions, and whether that structure does cover functions like pot-holding or grating, flying or sperm-conducting too.

So, for any structure S and any pair of functions F and F' , if one wants to verify whether S gets used for F and reused for F' , she has to understand 1) which structure is exactly S , 2) whether S realizes F and 3) whether S does realize F' too.

Mutatis mutandis, the *confirmation* principle of NREC goes along similar lines. One may wonder whether visual areas get reused in concept tasks, or whether action-control neurons get redeployed for action-observation functions. Indeed,

reuse of the first kind does happen when (and only when) neural structures originally selected to instantiate some perceptual functions (e.g. detect edges) support concept functions (e.g. attribute visual features to a category member). And reuse of the second kind happen when (and only when) neural structures originally selected to instantiate action control functions (e.g. hands' control) support action-observation tasks (e.g. observe someone else moving her hands). All one has to do to check whether visual areas get actually redeployed in concept tasks, or whether mirror neurons are reused for action observation functions is to check which areas are involved, whether these areas are selected for vision/action-control and if they realize action-observation/concept tasks too.

If those conditions end up being satisfied, then concept processing and action-observation tasks have to be considered “embodied” under NREC. For example, if one finds out that brain circuits selected to keep track of visual properties of e.g. dogs would have also been recruited to attribute visual properties to dogs (e.g. Kellenbach, Brett and Patterson 2001) then visual property attribution task is “embodied” under NREC. On the contrary, if brain circuits originally selected for action-related functions, such as grabbing a teacup, are founded not to support higher order

cognitive functions, such as observing someone else grabbing a teacup, then these higher order cognitive functions have not to be considered “embodied” under NREC.

More generally, for any brains structure S with a pair of functions F and F' , where F is a sensorimotor function and F' is a non-sensorimotor function, if one wants to check whether S got used for F and then reused for F' , she has to understand 1) which structure is S , 2) whether S realizes F and 3) whether S realizes F' either.

NREC verification principle seems perspicuous enough. That is, it seems it provides clear enough conditions for a piece of cognition to be considered embodied. Either a brain circuit gets used for a sensorimotor task or it does not; and either that brain circuit gets reused for a non sensorimotor function, or not. If it does, then according to the available data there is embodiment under NREC. Otherwise, there is not. This way, neural reuse seems to give an empirically sharp notion of EC: either action-control circuits do get reused for action-observation processes. If they do, those processes are embodied. Otherwise they are not.

NREC fine mechanics also specifies the functional identities and relations have to occur in our brain for a cognitive process is to be conceived embodied on NREC. Either action-control functions instantiated by the motor circuits *expand* into action-observation ones, or they do not. If they do, action control functions *do* not get lost when motor circuitries get redeployed for action-observation ones. If they do not expand, action-control functions get lost when circuits get reused in action-observation tasks. And functional expansion (*trade* or *preservation*) seems an empirically testable idea: it seems easy to check whether motor circuits do (or do not) expand their action-control original functions when reused in action-observation tasks, as well as it seems easy to check whether swimsuits do expand their covering original functions when they get reused to hold moka pots.

4.5 Functional issues about NREC

As said, there are reasons to buy NREC. Neural reuse account of EC data seems conceptually clearer and empirically more powerful than other more traditional EC accounts: buying NREC would have the double advantage of clearing up what EC should mean, and therefore of providing a clear way to test it. One might wonder whether this is actually the case, however. For example, one may suspect functional analysis of “sensorimotor” areas not quite being a simple work. Is there a brain circuit selected for sensorimotor tasks? And which derived task that circuit is exactly redeployed for? Is it just one derived task, or are there many? Moreover, one could say functional relations between neural use and neural reuse cases may also be tricky. For example, it is not obvious how mirror neurons reuses of in action-observation functions do relate with that circuit when it gets deployed during action-control ones. Is the original function really semi-preserved? That is, are these neurons used and reused for similar functions? This section is devoted to those questions.

4.5.1 Functional analysis issues

Let’s begin with the functional analysis problem. Remind that, for any case of reuse, there must be a use: one could *reuse* a swimsuit as a pot holder precisely because it was *not* a pot holder but, in fact, a swimsuit. The same applies to NREC: there is no sensorimotor circuitries reuse without a sensorimotor circuitries use, that is to say, if there is no original function of those circuitries there could not be a derived function either. Now, the functional analysis problem is the problem of providing a satisfying *analysis* of both *original* and *derived* functions. This seems easy enough in the case of artefacts: a swimsuit is an item designed to be worn by people engaging in a water based activity, while a pot holder is a piece of textile used to cover the hand when holding hot

kitchen cooking equipment, like pots and pans. When I find myself reusing a swimsuit as a pot holder I can easily identify both original and derived functions of that item.

The problem seems not quite as easy for “sensorimotor” neural reuse, however. Firstly, for an inferential issue. From the fact that a brain area, say the occipital lobe, is observed to be typically active during visual tasks, does not quite seem to follow that such brain area got selected for “visual” functions: it might also well be that the occipital lobe does cover other (more general) functions, perhaps shape recognition ones, with vision being just one (though massively reused) sub-function the occipital lobe has been selected for (Ricciardi and Pietrini 2014). Typically, NREC appeals to *phylogenetic* considerations to fix functional priorities: we arguably did see long before we acquired language processing abilities, and thus, on NREC, even though it is both active during visual perception and language processing, the occipital lobe is been selected for vision. Seeing rather than language processing is the original function of occipital lobe under NREC.

The problem with phylogenetic criterion of functional priority is that it does not seem to be *precise* enough: it does not tell us, for example, if the occipital lobe has originally been selected for shape recognition rather than for seeing. It is hard to say which function do exactly happened to come phylogenetically first⁶⁰.

If so, one may say, NREC phylogenetic criteria to fix functional priority of (sensorimotor) areas are too loose: attributing original function on the base of the phylogenetically oldest task a given area would support does not quite help, for it seems difficult to say what is the phylogenetically oldest task that area has supported. But this seems in turn to be problematic for NREC: if the original functions under NREC criterion seem underspecified, then neural reuse mechanisms postulated by NREC seem underspecified too. In fact, if we do not know whether the occipital lobe got originally

⁶⁰ Identify biological proper function has in fact been a notoriously difficult task. Cf. Nanay 2010.

selected for visual functions rather than shape recognition ones, we could hardly understand what does it mean for the occipital lobe to be reused in language tasks either. Indeed, if we do not understand what a swimsuit is, we can hardly understand what it means for a swimsuit to be redeployed as a pot holder, and so on, for any original function and any redeployment mechanism. EC under NREC would then stop being a precise notion, for one condition for embodied cognitive process under NREC was to recognize which function a neural structure got originally selected for. Whether occipital lobe activations does show language processing to be embodied under NREC would firstly depend on whether that neural structure has originally been selected for visual perception functions (and secondly whether they are reused for language processing functions). But if it is not clear whether the occipital lobe has originally been selected for visual functions, as opposed to shape recognition, it seems unclear whether occipital activity proves language processing to be embodied under NREC either.

The functional analysis problem, NREC might well reply, does not *specifically* afflict neural reuse accounts. Structure-function mapping is *the* problem for any theory dealing with brain architecture (Price and Friston 2005, Poldrack 2010): that is, every such theory wants to identify, for any brain structure, one (or many) cognitive functions, and for any cognitive function, one (or many) brain structures, and there seems to be no consensus on whether one theory does solve that problem better than another. This way, having a hard time in identifying the exact function a given neural structure got selected for, would not hit NREC as such, for the functional analysis problem concerns any structure-to-function theory. Moreover, NREC may additionally object, the functional analysis problem does not undermine NREC, and it can be bypassed. Even assuming the phylogenetic criteria to be insufficiently precise as to determine the original function the occipital lobe got selected to, it seems pretty safe to say it is a *perceptual* function. Or one may be unsure on whether the parietal lobe got selected for action rather than action-programming functions,

but few neuroscientists would claim no pieces of parietal lobe go selected for motoric functions. In other words, the idea that brain circuitries, like occipital or parietal lobes, got selected for sensorimotor functions seems uncontroversial and that would suffice for NREC to bypass the functional analysis problem: if we know that the parietal lobe got selected for motor functions we would also know what happens when the parietal lobe gets redeployed during non-motoric tasks – for example, during action-observation tasks. In fact, NREC might claim, it is sufficient to observe a brain structure selected for a sensorimotor function and then redeployed for a non-sensorimotor one to have an episode of embodied cognition – under NREC. And because it is easy enough to identify brain areas originally selected for sensorimotor functions, NREC would conclude, it would be also easy to determine whether that brain is active in non-sensorimotor tasks: for example, we know that mirror neurons have originally selected for action-control type of processes, so, if we find them redeployed in action-observation tasks we do have an action-observation cognitive process, under NREC.

One may not be very satisfied with this reply. Indeed, a possible rejoinder may go along the following lines. Describing certain brain areas as being originally selected for *generic* perceptual and motoric functions does not quite seem to coincide with a fine grained functional analysis of those areas. It is a bit like describing an item as designed to go swimming. There are quite few things that fit the description: swimming goggles are designed to go swimming, and so are waterproof clocks, fins, masks, snorkel. But, the argument could go, to say that an item designed for swimming got reused to hold a moka pot does not quite seem informative: one thing is to say that a fin got reused as pot holder another is to say that a mask got reused as pot holder. Either one has a fine grained way to identify the designed function of a given item, or the notion of redeployment (as applied to that item) turns out to be imprecise. There are many items designed

for swimming, and having a rough idea about which of them get reused as a pot holder brings about a rough understanding of that item's redeployment.

Now, the argument could apply to NREC as well: for example, to say that the occipital lobe got selected for sensory tasks and reused for lexical processing functions does not tell much. In fact, one thing is to say that the occipital lobe is selected for *visual* tasks and reused for lexical functions, another is to say that occipital lobe is selected for *shape recognition* tasks and reused for lexical functions, and the fact of not being able to distinguish the two readings seems it renders NREC explanatory imprecise. NREC would thus face the following dilemma: either it identifies the exact function an area got selected for, or it has to admit that, after all, NREC is not the explanatorily fine grained account that we have supposed. Both ways, NREC has costs. On one side, it is not obvious how NREC can precisely identify original functions of brain areas, for the phylogenetic criterion does not seem precise enough. On the other side, having a precise enough identity criterion for original functions is a necessary condition for NREC to be an explanatorily satisfying account. If NREC could not set up exactly which (sensorimotor) function gets originally instantiated by the occipital lobe, it seems it could not tell what exactly happens when the occipital lobe turns out to be recycled for another (non-sensorimotor) function. Both ways, NREC would be *less sharp* than supposed. That is, neural reuse mechanisms as applied to EC phenomena would not provide the precise conditions for any cognitive process to be considered embodied. A good theory of (neural) reuse presupposes a good theory of (neural) use, and perhaps, one might argue, NREC theory of neural use – i.e. a theory of original functions – is not quite as good as one would wish for⁶¹.

⁶¹ A possible way out for NREC is to take *tasks* instead of functions. On that reading, brain circuits have *potentials* to accomplish certain tasks, and with a bit of neuroscience/psychology division of labour we end up identifying such tasks. I am unsure the original task issue could be easily solved. I do agree however, on the importance of physical potentials for certain tasks/functions. Cf. §4.5. Thanks to Daniel Weiskopf for a comment on this.

4.5.2 Functional relation issues

Another set of problems that might trouble NREC concerns functional links between (neural) use and reuse. Call it functional relations problems. As we have seen above, any case of reuse presupposes a case of use: swimsuit reuse presupposes swimsuit use, panda's wrist reuse presupposes panda's wrist use and so forth. But we have also seen how reuse cases can entertain different functional links with their use counterparts. A swimsuit reused as a pot holder *extends* its function, in the sense that one can put it on and go swimming right after having it reused to hold a hot moka pot, while panda's wrist redeployed as a thumb *replaces* its original function, that is, the panda's radial bone lose its wrist-functions after having been reused as thumb. Besides, item reuse may *semi*-preserve or even *non*-preserve the function that item got originally used for: so, a car boot does seem to preserve its "containing-function" when it gets redeployed as a wardrobe, whereas a swimsuit does not seem preserve any "swimming-functions" when it get reused as a pot holder.

Functional relation issues concern those links as applied to neural reuse cases of sensorimotor structures (NREC). How are use and reuse cases of one and the same sensorimotor structure actually connected each others? Is that structure redeployed for a similar function or it rather instantiates an entirely different one? What computations do sensorimotor structures perform? And how do they compute the diverse functions? These questions well illustrate the functional relation problems. What follows is dedicated to analyze them.

How are high-level cognitive reuses of certain neural circuits related to their original sensorimotor function is an interesting question, both conceptually and empirically. One may take it as an already settled matter. In fact, NREC might consider mirror neurons reuse in non-motoric (action-observation, mind-reading etc.) tasks as a case of *semi*-preservative reuse: action-control

functions mirror neurons got selected for would be similar to non-action control functions (action-observation, mind-reading etc.) they got redeployed for, in the sense that both in the use and reuse cases mirror neurons instantiate action-*programming* functions. Indeed, semi-preservation seems necessary for NREC to stress the importance of original (sensorimotor) functions for derived (non-sensorimotor) ones: if mirror neurons did not preserve action-control functions when reused in action-observation tasks, then action-control would be unimportant for action-observation in the mirror neurons case – which would lead NREC to defend a rather deflationary EC position, if EC at all (more on this later). Besides, EC cases seems to be cases of functional extension rather than replacement: when mirror neurons get reused in action observation tasks they seem not to lose action-control functions, for the very same set of neurons do seem to be active both in action-control and action-observation tasks. So, NREC seems to consider NREC cases as both semi-preservative and extensive in kind with *little* concern⁶².

One may ask which function is exactly semi-preserved for each NREC case. It seems clear enough what gets semi-preserved for each item or trait reuse: car boot semi-preserved its containing-function when reused as a wardrobe and male urethra does semi-preserved its conducting-function when reused as a sperm conduit. However, it does not seem quite as easy to pinpoint the exact semi-preserved function for each NREC case. For example, one might wonder whether what gets semi-preserved in parietal lobe redeployment during action-observation tasks are in fact action-programming functions. Or one may question whether imagery-functions are what is semi-preserved when the occipital lobe gets reused during concept processing tasks. If that is NREC identity criterion, one may object, it would not be a very satisfying one, for one would expect NREC to give a way more fine grained individuation of semi-preserved functions: as one may want

⁶² To my knowledge, no NREC defender explicitly says which kind of reuse embodiment cases would actually exemplify, for nobody, to my knowledge, has made explicit the different type of reuses, as we have drawn in the present chapter.

to refine the containing-function realized by car boot and wardrobe, perhaps by specifying they both contain middle sized objects, she may also want to specify, for NREC clarity, the imagery-functions of reused occipital lobe. Without a fine grained criterion for semi-preserved functions, NREC would be less sharp than advertised: to say that action-programming is the semi-preserved function in mirror neuron reuse cases is for cognitive neuroscience like saying that liquid-conduction is semi-preserved in urethra reuses for physiology. It does not quite seem to make those fields advancing very much. Nonetheless, it seems, the NREC individuation criterion for semi-preserved functions does not have to be (and in most cases it is not) that loose grained⁶³. To be fair, this problem does not specifically apply to NREC, for it does affect any function-structure theory, although it seems worth mentioning it.

Similar problems seem to apply to the idea of functional extension. It is not entirely clear what one should mean by claiming that sensorimotor functions are extended into non-sensorimotor ones in NREC examples. Consider, for example, the case of birds' feathers. Birds' feathers redeployment is a clear case of functional extension in the sense that birds' feathers did not lose insulating-functions when they got reused for flying. Now, consider the male's urethra case. Male's urethra reuse is another clear case of functional extension as long as male's urethra does not lose its urine-conduction functions when redeployed for conducting sperm. However, these cases seem to differ in at least one relevant respect: while birds' feathers seem can both insulate and let them flying at the *same* time, male's urethra seems could either conduct urine *or* sperms. Birds' feather is a case of inclusive extension. We have inclusive extension if a structure S which is selected for function F got redeployed for function F1, and F1 and F2 are both implemented by S at the same time. Male urethra is a case of exclusive extension. If a structure S which is selected for function F1

⁶³ For example, monkey premotor cortex seems to have a "motor vocabulary" (Rizzolatti and Sinigaglia 2006), where individual cells or population of cells code for particular hand actions such as holding, grasping, breaking and so forth.

got reused for function F2, and F1 and F2 are not both realized by S at the same time there is an exclusive extension.

Now, NREC defenders may also want to draw similar distinctions with respect to sensorimotor reuse cases. That is, they may want to make it clear whether sensorimotor cases of neural reuse do instantiate exclusive rather than inclusive relations between the original and the derived cognitive functions. Thus, for example, mirror neurons activations during action-observation tasks may well be a candidate for exclusive extension, for mirror neurons seem to either realize action-control functions or action-observation ones, switching from one task to the other, a bit like the swimsuit switches from covering-functions to pot-holding ones. Indeed, it seems tough to use a swimsuit for to cover oneself *and* reuse it for pot-holding at the same time, as it seems unlikely that mirror neurons get used for action-control and reused in action-observation tasks at once: either they are used to grab a tea pot or they get reused to observe someone grabbing a tea pot.

On the other side, NREC may also want to clarify whether sensorimotor cases of neural reuse do sometimes exemplify functional extension inclusive in kind. EC cases of inclusive extension may for example embrace phenomena usually called sensorimotor “simulation” (Barsalou 1999, Lakoff and Johnson 2005, Prinz 2004). Thus, activations of early visual cortex during conceptual tasks, which are sometime explained by appealing to simulation procedures run over perceptual-like states, may be a good candidate for inclusive extension, since during those tasks visual cortex seems to realize perceptual and conceptual functions simultaneously. Just like birds feathers seems to both insulate and let them flying at the same time, visual cortex seems both realize sensory and conceptual tasks simultaneously, and this might capture the “simulative aspect” of concept processing: for example, when we are told we simulate dog-related perceptual processes during dog-property verification task, what may happen is that, in point of fact, brain areas originally selected to perceive doggyish stimuli (among others) get redeployed for dog-property verification

tasks (among others), and the relation occurring between perceiving-functions and conceptual ones is one of inclusive extension.

It is not obvious that those inclusive vs exclusive considerations do apply these EC phenomena, however. For at least two reasons. On the one hand, it is not fully clear whether the sensorimotor simulation case is actually a case where the early visual cortex realizes both a perceptual and a conceptual function at once, since it is not fully clear whether early visual cortex could not just realize a more general common function, say e.g. visual imagery, which would get semi-preserved when early visual cortex is reused for conceptual tasks. Sensorimotor simulation case may well be interpreted as a case of semi-preservative reuse, as opposed to inclusive extension: when redeployed in dog-property verification tasks, one might argue, visual cortex may be more akin to car boots reused as wardrobes than to birds' feathers reused for flying. On the other hand, it is not obvious that every case of mirror neurons reuse is a case of exclusive extension, for mirror neurons may well implement action-control and action-observation functions at the same time. Learning by imitation may be one such case. If I have to learn, for example, a skilful activity such as dancing, I would tend to imitate the way that activity is carried out by skilful persons, such as experienced dancers. Now, mirror neurons seem to support that very learning activity, in the sense that they seem to support both action-control (i.e. body movements) and action-observation (i.e. others' body movements) functions (Calvo-Merino et al. 2005). If so, then learning how to dance by imitating an experienced dancer can be considered a case of inclusive extension: mirror neurons would in fact fire both during action-control and action-observation tasks, and such tasks happen to be carried out at the same time in the dancing case. Thus, contrary to what said above, mirror neurons reuse may sometime be more like birds' feathers reuse, where insulation and fly functions are co-implemented (inclusive extension), than like

male's urethra reuse, where urine and sperm-conduction functions do not get implemented simultaneously (exclusive extension)⁶⁴.

Taken together, the above considerations seem to show how neural reuse mechanisms and distinctions as applied to EC cases are yet to be understood: despite the apparent clarity of inclusive vs exclusive divide, it is not obvious whether evidence confirms each EC case to be a case of inclusive rather than exclusive reuse. But if inclusive vs exclusive divide leaves underdetermined what happens in exemplar cases of EC reuses, then, one could well maintain, these inclusive vs exclusive distinctions do not quite solve the opacity of EC.

There is a third family of problems concerning functional relations. We have seen how NREC does implicitly conceive sensorimotor cases of neural redeployments as cases of semi-preservative neural redeployments: however loose-grain its original sensorimotor functions are identified, when a brain circuit gets redeployed to support a non-sensorimotor task, original functions are typically assumed to be semi-preserved all along. It does not seem to be (and it has not to be) an issue, for NREC, that EC reuses are non-conservative in kind. Nonetheless, it is not so obvious that all sensorimotor cases of neural reuse are cases of semi-preservative reuse. Indeed, the fact of defending NREC, one could just argue, does not necessarily force one to adopt one specific functional relation over the others: that is to say, when reused in non-sensorimotor tasks, brain structures *may* non-preserve sensorimotor functions. Not every case of sensorimotor neural reuse, one may in fact insist, would exemplify the same relation between cognitive functions, as well as not every case of artefact or biological reuse exemplify the same relation between biological or artefactual functions. Car boot preserves its containing-function when redeployed as

⁶⁴ Weiskopf points out that the task level analysis can neutralize the exclusive/inclusive dilemma, for 1) experimental settings treat tasks exclusively, and 2) the point is to check which physical arrangements support original/derived tasks. I am not sure whether 1) solves the dilemma rather than dissolving it. 2) is perfectly consistent with the deflationary outcome of the chapter, cf. § 4.5.

wardrobe, while swimsuits do not preserve any original function when reused as pot holders. Male urethra conduces liquids both in use case (urine) and in reuse one (sperm), whereas birds' feathers do not preserve insulating functions when reused to fly. In other words, for any occurrence of reuse R, R can either be an instantiation of semi-preservative reuse S or it can be an instantiation of non-preservative reuse N, despite R involves artefacts A or biological traits B.

Now, if this is true of design and biology reuse, one may ask, why should not be true of neural reuse either? After all, one could argue, are not brain structures biological elements subjected to recycling mechanisms? Indeed, NREC seems to leave the possibility of having non-preservative sensorimotor redeployments open, for non-preservative relations seem to be a possibility both in artefactual and biological redeployments, plus, as an evolutionary theory of brain architecture, NREC takes brain structures to be biological elements. Thus, the argument would go, if one buys NREC, he has to be ready to accept EC non-preservative reuses, as well as if one buys a biological notion of reuse, she has to allow for biological non-preservative reuses, or, if one consider artefactual reuse cases, she may note that artefacts reuses are (often) non-preservative. Strictly speaking, NREC should be a bit cautious with regard to semi- vs non-preservation commitments: there are certainly (many) cases of sensorimotor neural reuses which semi-preserve their original functions, but there could also be cases of sensorimotor reuses which do not preserve their original functions at all. The fact that there are many cases of sensorimotor semi-preservative redeployments for non-sensorimotor tasks does not quite prove there are no non-preservative sensorimotor redeployments for those very tasks, as much as one cannot quite prove there are no artefactual and biological traits reuses of non-conservative kinds from the fact that there are many cases of semi-preservative artefactual and biological traits reuses. Of course, NREC may well say, mirror neurons activities would semi-preserve action-programming functions when reused in *action-observation* tasks, visual regions would semi-preserve visual-imagery functions when

reused in *concrete*-concept processing etc. for many sensorimotor areas and many non-sensorimotor tasks. But, NREC cannot exclude that, for a subset of sensorimotor areas and a subset of non-sensorimotor tasks, there may well be non-conservative reuse cases: birds' feathers reused for flying and swimsuits reused for holding a hot moka pot may well not just be isolated, non-brainy cases of non-conservative redeployments. The question, now, is: are there any examples of non-conservative redeployments of sensorimotor areas, or the earlier considerations are a purely speculative, logical consequence of applying neural reuses to EC?

One may go along the first line. Consider, for example, the case of abstract concepts (or words) processing. Notably, abstract concepts (or words) processing pose a challenge for EC (e.g. Mahon and Caramazza 2008). It seems clear enough, so the challenge goes, that sensorimotor systems do contribute to action-related and perceptually-loaded concepts processing: so, for example, as experimental data seem to show, hearing the word "kick" more strongly activate somatotopic areas of primary motor cortex associated with legs (Pulvermuller et al 2005), or entertaining the concept DOG activates perceptual areas typically involved in seeing, hearing, smelling etc. dogs (Barsalou 1999; see also Pecher, Zeelenberg, and Barsalou 2003, 2004). It is less clear, so the challenge continues, whether and to what extent sensorimotor systems do contribute to *non* action-related and *non* perceptually-loaded concepts processing: so, for example, it is not immediately obvious that words like "democracy" or "truth" do actually trigger the primary visual cortex. According to some scholars (Barsalou 1999, Prinz 2004), however, EC can meet the challenge: for example, sensorimotor circuits would actually contribute to "democracy" or "truth" processing, in the sense that, according to such authors, when we attend "democracy" or "truth" our sensorimotor circuits are involved.

Now, reframed though NREC, these would be cases where circuits originally selected for sensorimotor tasks (e.g. perceiving acts of voting, visualizing a match) got redeployed for entirely

non-sensorimotor functions (think of democracy, reason about truth). If so, though, it seems they are cases of non-conservative reuse: seeing a voting event and reasoning about democracy seem to have as few functions in common as there are between go swimming and holding an hot pot, or even as between thermoregulation and fly functions. Thus, for example, it seems there is little in common between seeing people queuing up behind a voting booth and reasoning about constitutional referendums, as much as there it seems there is little in common between wearing a cloth designed to engage in water-based activities and holding a hot coffee moka pot. But then, if there are sensorimotor activations during abstract concepts processing tasks, one could argue, and if what said on NREC is on the right track, then abstract concepts cases are a cases of non-conservative reuses: even though, for example, our visual cortex seems to be involved during abstract concept tasks, there would be little interestingly visual, auditory, gustative etc. that gets preserved in such redeployment. Indeed, that seems an interesting implication of NREC as applied to abstract concepts: either one assumes there is no sensorimotor reuse for abstract concepts tasks, or, if says there is one, that is non-conservative. Both options seem pricey for a NREC supporter. In fact, taking the first option amounts not to meet the abstract concepts challenge: there would not be any sensorimotor involvement in abstract concepts tasks. On the other hand, to say that sensorimotor brain areas are non-conservatively reused in abstract concepts processing tasks seems just amount to say that there is little sensorimotor contribution to those very tasks. Either ways, once we postulate NREC, the challenge of abstract concepts becomes even more challenging.

4.6 Structural issues about NREC

Consider, again, the case of panda's wrist. What it seems to happen when the panda's wrist got redeployed as a thumb is that the *physical* properties of panda's radial bone, which originally got selected to instantiate wrist-functions, turned out to be *useful* to realize thumb-functions: for purely accidental circumstances, panda's radial bone just happened to have, for example, enough flexibility to implement thumb-functions. This seems to be the case for every case of redeployment: a swimsuit physical features do insulate enough to implement pot holding-functions, birds' feathers are light enough to realize flying-functions and so forth. Physical properties, as we have seen earlier, seems the unity of redeployment: whatever item or trait gets actually reused for whatever new function, what of that item or trait gets reused are its physical properties. Functions do not seem to be the kind of things that can get reused (cf. also Ch 2). It seems weird to say that the function of being a wrist get reused as a thumb: when we say that panda's wrist get reused as thumb, what we rather intend is that the physical structure that realizes a wrist got redeployed to realize a thumb.

Not only physical properties are the unity of reuse. They also seem responsible for the reuse's *efficiency*. It is the fact that panda's radial bone was, for example, flexible enough that made it a convenient solution to the problem of grabbing food, or being light enough made birds' feathers well suited for flying functions. Surely, reuse mechanisms are often less than optimal: a swimsuit does insulate enough to prevent us from being burned when we reuse them to hold a hot moka pot, but they can also be bulky and cumbersome, a fork can be reused as a grater even though it its are perhaps not as thick and sharp as the grater's ones, etc.

The point here is that, one crucial aspect of reuse mechanisms seems to reside in how efficient they are, i.e. how efficiently an item or trait realizes a derivative function, and that efficiency

seems to depend on items/traits physical features, i.e. whether their physical features efficiently realize the derivative function: panda's wrist reused as a thumb turned out to be efficient, for panda's radial bone was just flexible enough to efficiently realize thumb-functions while a fork reused as a grater does not turn out to be quite efficient, for a fork is typically not thick (sharp, fine grained etc.) enough to efficaciously implement grating functions, etc. Now, if that is the case, then original functions seem to be superfluous within the reuse economy, for what seems it matters in reuse mechanisms are which physical features realize which derived functions, regardless of what those features originally realize and which relations do occur between those functions⁶⁵: what seems it matters in panda's wrist reuse are which physical features (e.g. radial bones flexibility) realize which functions (thumb), regardless of what those features were originally selected for (wrist-functions), and which relations do occur between the original and the derived functions (conservation, extension, etc.).

Well, one might wonder what happens once we apply these considerations to sensorimotor cases of reuse. Indeed, what it seems to happen when sensorimotor circuitries get redeployed in non-sensorimotor tasks, is that *physical* (i.e. neurophysiological) features of those circuitries, which got selected to implement sensorimotor functions, turned out to be useful to implement non-sensorimotor tasks either: for purely accidental circumstances, visual cortex happens to have just the right cytoarchitectonic features to realize concepts processing tasks. And the same would apply to all EC cases under NREC: so, motor cortex would be connected enough to realize linguistic tasks, limbic circuitries would have the right cytoarchitecture to realize memory functions, etc. In other words, physical properties would be the unity of sensorimotor reuses:

⁶⁵ Notice also that the "physical realizer efficacy" point holds for original functions too, in the sense that, for any reused structure S, there a set of physical features P of S that realizes the original function F, and P render the realization of F more or less efficient. Notice also that P could be – and typically is – different from the set of physical properties P' of S that render the realization of derived function F' more or less efficient. For example, birds' feathers non-conductivity and their lightness would respectively make the realization of thermoregulation and flying functions more or less efficient, despite non-conductivity and lightness are two different physical properties of birds' feathers.

whatever sensorimotor area get reused for whatever non-sensorimotor task, what gets reused are these systems' physical (neurophysiological) features.

Not only physical features are the unity of sensorimotor reuse. They seem also responsible for its efficiency. It is the fact that visual cortex happens to have such and such cytoarchitectonic features that makes that structure a convenient realizer of concepts processing tasks, or it is the fact that motor cortex happens to have such and such connections that makes that area a convenient realizer of action verbs processing tasks and so on. Thus, one crucial aspect of sensorimotor reuse mechanism seems to lie in how efficient they are, i.e. how efficiently sensorimotor areas realize non-sensorimotor tasks, and such efficiency seems to depend on these areas' physical features, i.e. whether those features efficiently realize non-sensorimotor functions: for example, motor cortex cytoarchitectural features would conveniently realize certain language functions (e.g. action verbs processing), while the would be less efficient to realize other, still, non-motoric functions (e.g. non-action verbs processing), as much as the panda's radial bone characteristics do efficiently realize thumb-functions without being them quite as efficient in realize non-thumb functions (e.g. nose-functions).

There is at least one interesting and perhaps a bit *surprising* consequence of such efficiency considerations. In fact, if what we said is on the right track, sensorimotor functions turn out to be *not* relevant under NREC, for what seems it matters in occipital or parietal lobes reuse cases are which physical features of such lobes realize more or less efficiently non-sensorimotor functions and their more or less efficient realization seems to be *independent* from the fact that such areas were originally selected to realize sensorimotor functions: for example, what it seems it matters in parietal lobe reuse are which cytoarchitectural connections allow it to implement action-verb processing tasks, regardless of whether that lobe was originally selected for, perhaps action-control tasks, and which links occur between action-control and action-verbs processing

(conservation, extension, etc.). Admittedly, if what makes the occipital or parietal lobes reusable for non-sensorimotor tasks has to be found in the physical features of these brain elements or circuits, then the fact that such brain elements or circuits were selected for sensorimotor tasks does not seem quite relevant for such reuses, and neither seems relevant how sensorimotor functions do link with non-sensorimotor ones: it seems of little interest that occipital lobe got selected for visual tasks when it comes to understand what is going on in occipital lobe redeployment, as much as it seems of little interest that the panda's radial bone got selected for wrist-functions when it comes to understand what happens in panda's wrist redeployment. One reason why we tend to consider original functions relevant for redeployments may be that we still call the redeployed structures with the original-functions' names. Thus, a swimsuit redeployed as a pot holder gets generally called "swimsuit" rather than "pot holder", a chair redeployed as a door stop gets still called "chair" rather than "door stop", and of course, sensorimotor areas redeployed in non-sensorimotor tasks get still typically called "sensorimotor" instead of "non-sensorimotor" areas. If we take NREC at face value, then the myth of original (sensorimotor) functions in (sensorimotor) redeployments seems to be misplaced: EC under NREC would not regard the sensorimotor contributions to non-sensorimotor tasks as much as a theory of panda's radial bone redeployment in thumb-functions would not be interested in wrist functions, or a description of swimsuits redeployment as potholders would not be concerned with swimsuit functions. In other words, NREC would suggest EC to stop bothering body-related considerations and look carefully on the neurological features which happen to realize non-sensorimotor tasks in neural redeployment EC cases.

4.6 Conclusive remarks

The present and final chapter wanted to do four things. First, it has introduced the notion of reuse, as applied to technological and biological structures in general, and to neural reuse mechanisms in particular. We have seen what one should mean when she says that something get reused for something else, where “something” and “something else” are meant to be neural structures and cognitive functions, respectively. One particular interpretation of neural reuse hypothesis (Anderson 2007, 2010, 2014) is taken into account (NRH), and we tried to show both what claim NRH exactly does and which reasons support that very claim. We then have introduced the neural reuse hypothesis of embodied cognition (NREC), according to which EC evidence should be interpreted as showing neural reuses of a peculiar kind: EC cases would be cases where neural structures selected to realize sensorimotor functions get reused to realize non-sensorimotor ones (Barsalou 2016). The third section is dedicated to the theoretical and empirical advantages of buying NREC: mechanisms and distinctions of reuse machinery seem to be just the right resource to sharpen EC evidence, so much so that NREC may well be considered as the definitive solution to the opacity problem of EC (Ch 1). The fourth section wants to spell a word of caution: even though NREC may well capture EC kind of data, new problems (or old problems put in a new way) seem to come once the NREC apparatus is taken to work. It seems not fully clear how NREC identifies the sensorimotor functions, which relation they entertain with non-sensorimotor ones, and whether sensorimotor functions are actually relevant in EC cases kind of reuse. If what we have suggested is correct, the answer to the third question is no: NREC does imply a deflationary position on EC, according to which sensorimotor functions seems not relevant for neural reuse cases of EC, and the physical features making non-sensorimotor tasks efficaciously realized are what EC should look for.

CONCLUSIONS

And so what? One might legitimately ask. We have started off our work by introducing one single problem. The Opacity Problem of Embodied Cognition. And we have ended up showing a range of difficulties any theory that wants to solve this problem by relying on the notions of format and/or reuse seems it has to deal with. Yet, such a plot may leave somebody unconvinced. The following conclusive notes want to delineate the credits of this project, against possible general scepticisms, and provide some possible lines for further investigations.

First of all, the Opacity Problem of Embodied Cognition (OPEC) seems a genuinely *interesting* problem. Both conceptually and empirically. We have been collecting so many data on alleged body contributions to cognition, but it seems we have got little understanding of what exactly those contributions amount to, how much of the body is actually involved, and indeed which section of cognition gets “bodily” affected. The disproportion between the quantity of empirical evidence and the quality of conceptual investigations going under the banner of ‘embodied cognition’ should motivate scholars to target OPEC in the first place. OPEC does in fact solicit everybody working within EC to make it explicit which property makes a cognitive process embodied, and whether or not evidence confirms such property to be instantiated by that process. Few scholars have emphasized the *urgency* of asking EC defenders (and critics) to specify what they intend by ‘embodied – and similar expressions – and the present dissertation has vindicated exactly that urgency. This may well be the first credit of the project. Having introduced and argued for the import of OPEC: precisely quantified claims are more the exception than the rule in EC, and we asked to have more of them.

A second point may reside in the *family of solutions* we have taken in consideration: solutions that conceive (both conjunctively and disjunctively) the notions of bodily formats and neural reuse to

be definitive of EC. For one thing, Bodily Format Approach to EC (BFA) has not received that much of a theoretical attention: most accounts have tended to focus on constitutive vs causal relations between bodily subject matters and cognition, with the result of having perhaps produced rather than resolved OPEC. The idea that EC cases amount to cases of body formats reused have in fact been taken seriously only by a small number of researchers. Maybe because OPEC has not gathered that much of a theoretical attention too, and BFA is one of the few EC accounts that explicitly targets OPEC. Or maybe because BFA is a too moderate view to attract the radical EC interests. We believe BFA deserves more theoretical attention, exactly because it is a rare case of OPEC-targeting account, and because its moderation, in our opinion, is a virtue rather than a vice. In any case, by providing a dedicated and detailed treatment of BFA together with a reconstruction of the circumscribed debate emerged around it, we believe we have filled an important gap of EC literature.

Not every aspect of BFA proves to be convincing. The whole discussion on bodily-formats redeployment solution seems have missed two crucial questions so far. What are bodily-formats? Which kind of reuse BFA talks about? The third contribution of the dissertation is thus critical. There seem to be a set of identity puzzles, so we argue, and these identity puzzles seem to annoy BFA. First, it is unclear *what bodily formats amount to* on BFA. We have gone through possible readings of the notion (e.g. neural, computational, semantic), and we have shown that, for each reading, there is a problem of *ambiguity*. Bodily formats do not seem specified enough. Besides, reuse mechanisms seem of different sorts (e.g. semi-conservative, non-conservative), and it is unclear which of them BFA subscribes – plus, it is not obvious b-formats and reuse are consistent notions. Thus, a negative result: we have showed how BFA *does not solve* OPEC, for it maintains that EC cases are cases of bodily formats reused, but it neither says what are bodily formats exactly nor how they get reused in EC cases. BFA makes explicit which property makes a cognitive

process embodied, but it does not clarify what it should happen for this property to be instantiated by that process.

If bodily format reuse solution is problematic, we have then asked, what about format *and* reuse solutions? Do identity puzzles for BFA apply to the Format Shift in EC (FSEC) and Neural Reuse View of EC (NREC) too? We believe 1) a further input may come from analyzing the positions that conceive sensorimotor *cognitive formats/brain reuses* as the core defining notions of EC phenomena, and 2) the kind of puzzles which troubles BFA may trouble these accounts either. With this in mind, we have introduced FSEC, and showed how identity criteria for cognitive formats (*neural, semantic, computational*) seem one way or the other unsatisfactory. Neural organization does not seem to be predictive of cognitive formats, cognitive formats do not seem to be content-involving properties, and even if we consider them cognitive computation-sensitive features, it is unclear whether there are cognitive computation-sensitive properties in the first place. On the other hand, we have analyzed the fine mechanics of neural redeployment (*unity of reuse, functional analyses, functional relations*), and we shown how, once it is applied to embodiment phenomena, it turns out unclear how NREC identifies *sensorimotor functions*, which *relations* are taken to entertain with non-sensorimotor functions, and whether sensorimotor functions are actually *relevant* in EC cases of reuse. There are reasons to think that neural reuse reframe of embodiment phenomena is an *interesting project*, but there are also reasons to suspect that NREC has not *yet* gone all the way down to resolve OPEC.

A fifth, final point. Chapters 3 and 4 have defended, among other things, two relatively original positions. Chapter 3 has defended a *syntactic view on formats*, according to which format features of representations coincides with their formal-syntactic features, so formats are neither physical nor semantic features. For example, the format features of a sentence are the formal features of its primitives plus combinatory rules, and thus format properties of that sentence neither

coincides with its physical realizer nor with its content. Chapter 4 has instead defended a *physicalist account of reuse*. What of any item gets reused are the physical properties of that item, regardless of what such properties have been originally used for. Thus, for example, when a chair gets reused as a doorstop, what of that chair gets reused are its physical characteristics, its length, width or heaviness, regardless of the fact that chairs get designed to seat.

Now, once applied to sensorimotor cases, these considerations seem to have the following *deflationary* outcome. On the one hand, if to code in a sensorimotor format is what makes a cognitive process embodied, then embodied cognition would have *little* to do with body control brain activations and even body features, for sensorimotor format properties would be sets of formal-syntactic (computational) properties, and formal-syntactic (computational) features have little to do with body control areas (realizers) and body features (contents). *Embodied cognition under the syntactic view of formats would only be a matter of efficiency*: EC cases would be cases where it is efficient for a process to code information in a sensorimotor format as much as it is efficient for a car-driver to have the traffic signs coding the information in an iconic format. And one could raise a similar point with respect to the physicalist view of neural redeployment. If what makes a cognitive process embodied depends on sensorimotor regions reuse, then embodied cognition would have *little* to do with sensorimotor functions, for what gets redeployed in EC cases would be the physical features of those regions, *regardless* of their original sensorimotor functions. Again, *embodied cognition under a physicalist view of neural reuse seems to be just a matter of efficiency*: EC cases would be cases where it is efficient for a sensorimotor region to be reused in a given cognitive task as much as it would be efficient for a chair to be reused as a doorstop. Their physical properties allow it.

Perhaps, one may say, the deflationary view of EC does not quite solve OPEC, for it does not say which property makes cognition embodied, and whether the evidence confirms such property to

be instantiated. What it does, however, is giving some clues on where to go, once we assume format and reuse to be crucial EC notions. The deflationary view (via format and reuse) may advise two moves to de-opacify EC. First: *it suggests to stop looking at sensorimotor brain areas and body-related features such areas typically control, and focus instead on the computational characteristics (or computational sensitive characteristics) that may (or may not) facilitate the alleged embodied cognitive process.* Second: *it recommends not to pay that much of attention to the original functions of sensorimotor regions, while investigating which physical characteristics of those regions facilitate (or not) each embodied process.* By doing so, we might end up with a less body-related idea of EC, but desirably, with a less opaque one either.

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APPENDIX

EC = Embodied Cognition

OPEC = Opacity Problem of Embodied Cognition

BF(s) = Bodily format representation(s)

BFA = Bodily format approach to Embodied Cognition

FSEC = Format shift on Embodied Cognition

MEE = Modal view of Embodiment Effects

AEE = Amodal view of Embodiment Effects

NRH = Neural reuse hypothesis

NREC = Neural reuse view of Embodied Cognition