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Four Ways of (Mis-)Conceiving Embodiment in Tool Use

François Osiurak^{1,2} & Giovanni Federico³

¹Laboratoire d'Etude des Mécanismes Cognitifs, Université de Lyon, Lyon, France

²Institut Universitaire de France, Paris, France

³Laboratory of Experimental Psychology, Suor Orsola Benincasa University, Naples, Italy

Correspondence

François Osiurak, Laboratoire d'Etude des Mécanismes Cognitifs (EA 3082), Institut de Psychologie, 5, avenue Pierre Mendès-France, 69676 Bron Cedex, France.

Email: Francois.Osiurak@univ-lyon2.fr

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Abstract

A broader conception of the user's perceptual, cognitive, and motor capabilities considers tools as body extensions. By identifying specific tool-related motor-grounded mechanisms, the embodied approach assumes that this "extensional phenomenon" takes place not only at a behavioral level but also at a psychological level. At least four ways of conceiving embodiment in tool use have been offered in relation to the concepts of incorporation, perception, knowledge, and observation. Nevertheless, the validity of these conceptions has been rarely, if not never, assessed. In this article, we attempt to fill this gap by discussing each of these conceptions in turn, with the aim of determining whether it is justified to consider tools as detached objects of a special sort in embodied terms. We argue that tool incorporation is made possible by "distalization", that is, an embodied mechanism specific to tool use. Nevertheless, there is neither empirical nor theoretical support for the hypothesis that specific tool-related embodied mechanisms are involved in perception, knowledge, and observation. In broad terms, there is a tendency in the literature to overinterpret tool use as an embodied phenomenon at a psychological level. Inevitably, this limitation leads us to under-intellectualize the underlying cognitive processes and, as a result, it prevents us from understanding the technical-reasoning skills that allow humans to transform dramatically the physical world.

Keywords: Tool Use; Technical Reasoning; Tool Incorporation; Manipulation Knowledge; Perception and Action; Action Observation.

1. Introduction

“Tools are detached objects of a very special sort. They are graspable, portable, manipulatable, and usually rigid.... An elongated object, especially if weighed at one end and graspable at the other, affords hitting or hammering (a club). A graspable object with a rigid sharp edge affords cutting and scraping (a knife, a hand axe, or a chopper). A pointed object affords piercing (a spear, an arrow, an awl, or a needle)... When in use, a tool is a sort of extension of the hand, almost an attachment to it or a part of the user’s own body, and thus is no longer a part of the environment of the user. But when not in use, the tool is simply a detached object of the environment, graspable and portable, to be sure, but nevertheless external to the observer. This *capacity to attach something to the body* suggests that the boundary between the animal and the environment is not fixed at the surface of the skin but can shift”. (Gibson 1986; p. 40-41)

In the quote above, James J. Gibson gives a description of tools, which has inspired more than three decades of researchers. Tools are *special* detached objects. They are *a sort of extension of the hand*, reflecting the *capacity to attach something to the body*. The possibilities they afford are not restricted to motor or user-centered actions (*graspable, portable*; i.e., actions “on” them) but can also concern mechanical or tool-centered actions (*cutting, scraping*; i.e., actions “with” them; for a distinction between acting on *versus* with, see Johnson-Frey and Grafton 2003). This description is indisputable for the simple reason that it is precisely a description – a behavioral description of what a tool is. Instead, the crucial question is how to interpret this behavioral description in psychological terms. Early cognitive science was not interested in the role of the body in cognition. The ecological approach to perception along with the popular notion of affordance coined by Gibson – the context of the quote above – has spurred researchers to develop a more embodied approach to cognition. This has been so successful that it has become far more informative to characterize an approach as disembodied than embodied. Thus, at least four ways of conceiving embodiment in tool use have been proposed in the literature in relation to the concepts of incorporation, perception, knowledge, and observation. Given that a considerable number of researchers are

committed to the embodied approach, the validity of these conceptions is rarely, if not never, assessed. This article aims to fill this gap by considering each of these conceptions in turn, with the aim of determining whether it is justified to view tools as detached objects of a special sort in embodied terms. To achieve this aim, we first have to specify what we mean by “detached objects of a special sort in embodied terms”. We will consider that this criterion is met if evidence indicates that tool use involves specific embodied mechanisms (i.e., tool-related embodied mechanisms) that are not implicated in other contexts (e.g., non-tool-use actions). Otherwise, an alternative interpretation is that domain-general embodied mechanisms are at work or that no embodied mechanism is involved at all, as suggested by the classical cognitive approach. In the following lines, we detail this criterion for each of the concepts addressed here (**Table 1**).

- *Incorporation*: Tools can be viewed as detached objects of a special sort in embodied terms if their use (i.e., acting with) is based on specific incorporation-related embodied processes that are not involved when someone grasps or moves an object (i.e., non-tool-use action or acting on). Otherwise, the more parsimonious interpretation is that tools are subject to the phenomenon of incorporation as any other object.
- *Perception*: Tools can be viewed as detached objects of a special sort in embodied terms if their use (i.e., acting with) can imply a specific modification of our way of perceiving the environment. Otherwise, an alternative interpretation is that this perceptual phenomenon is not specific to tool use but can be observed in a multitude of contexts. Another alternative interpretation is that perception is not embodied and cannot be modified from tool use or in other contexts.

- *Knowledge*: Tools can be viewed as detached objects of a special sort in embodied terms if their use (i.e., acting with) is based on the activation of motor representations that are specific to tool use (i.e., manipulation knowledge) and not to non-tool-use actions (i.e., acting on). Otherwise, an alternative interpretation is that our knowledge about how to use tools is not embodied (i.e., no manipulation knowledge), implying that motor actions associated with tool use are based on the same selection and planning processes as when someone has to grasp or move an object (i.e., acting on).
- *Observation*: Tools can be viewed as detached objects of a special sort in embodied terms if the observation of their use (i.e., acting with) involves specific embodied processes (i.e., activation of manipulation knowledge) that are not implicated when someone observes another person grasping or moving objects (i.e., acting on). An alternative is that the observation of the tool-use actions performed by others does not activate manipulation knowledge.

To anticipate our conclusions, empirical and theoretical evidence indicates that only incorporation could involve specific tool-related embodied mechanisms, thus justifying that tools are a special sort of *embodied* objects (**Table 1**). However, the specific role of embodiment in tool use remains questionable with regard to the concepts of perception, knowledge, and observation.

< Insert Table 1 about here >

Before turning to this analysis, it is helpful to define more precisely what a tool is so as to complete the above behavioral description offered by Gibson (1986). We will

stick to the classical definition of Beck (1980), slightly refined by Shumaker et al. (2011)¹. According to them, a tool refers to:

“The external employment of an unattached or *manipulable attached* environmental object to alter more efficiently the form, position, or condition of another object, another organism, or the user itself, when the user holds *and directly manipulates* the tool during *or prior* to use and is responsible for the proper and effective orientation of the tool”. (Shumaker et al. 2011; p. 5)

Three important points can be traced in this definition. First, tool use diverges from object transport, which refers to moving an object from one location to another. Tool use alters the form, position, or condition of another object, another organism or the user itself², whereas such alteration is absent for object transport. Second, tool use also diverges from construction behavior, which can be defined as follows:

“Two or more tools and/or objects physically linked to make a functional, semipermanent thing that, once completed, is not held or directly manipulated in its entirety. A construction itself is therefore *not* a tool. Nor is it tool manufacture, because the product is not a tool”. (Shumaker et al. 2011; p. 19)

The criterion of demarcation between tool use and construction behavior is *direct manipulation*: To be considered as a tool, an object has to be directly manipulated during or before the use. Thus, if someone realizes that the roof is leaking, grasps, and holds a glass to collect water, this is an instance of tool use. If this individual puts the glass on the floor and goes away, it becomes an instance of construction behavior. However, if the individual cuts a plastic bottle in half and holds it to collect water, this is an instance of tool making (or tool manufacture in Shumaker et al.’s terms), which becomes again an instance of construction if the individual decides to put the bottle on the floor (Osiurak and Badets 2017). Finally, the third important point concerns the idea that a tool can be

¹ Beck (1980) and Shumaker et al. (2011) have clearly argued that their definitions of tool use and construction are behavioral descriptions that do not imply any psychological or biological prerequisites.

² Here the term object does not refer only to an object with finite boundaries as a stick or a stone but can also include an object with no finite boundaries such as water or ground.

manipulated not only during but also before the use³. Thus, this definition also includes throwing actions, such as when a vulture holds a stone in its beak and throws it at an egg.

2. Incorporation

2.1. *From incorporation to distalization*

More than a century ago, Bonnier (1905) introduced the concept of sense of bodily space as a representation of body parts' dimensions and positions in the space. A short time later, Head and Holmes (1911) extended this concept – relabeled body schema –, specifying its key characteristics, namely, to be dynamically updated, strictly internally coherent, finalized to action and – particularly relevant to the present discussion – plastic. The idea of a plastic body was also conveyed by Merleau-Ponty (1962), who argued that a blind person's stick extends the scope of touch. Thus, the stick becomes a kind of transparent medium: The user does not feel the stick but what the stick touches (see Peck et al. 1996; see also Hirose 2002). In broad terms, a tool in use is a sort of non-neural extension of a “natural” end-effector (e.g., hand, beak), shifting the boundary between the animal and the environment beyond the surface of the skin.

These intuitions have also received strong support from cognitive neuroscience studies. For instance, Iriki et al. (1996) trained macaque monkeys to use a rake in order to get out-of-reach rewards. This training induced a visual-receptive-field enlargement that included the length of the arm *and* the rake. In humans, the use of a mechanical grabber can affect the kinematics of subsequent grasping movements performed without it (Cardinali et al. 2009). The use of a stick also increases the strength of visual-

³ Gibson (1986) was in line with this, mentioning several times the case of “missiles” to illustrate his description of tools.

tactile extinction⁴ in patients with cross-modal extinction so that the extinction extends from the peri-personal space to the extra-personal space (Farnè et al. 2000; Maravita et al. 2001; Farnè et al. 2005; see also Maravita and Iriki 2004). Recent evidence also indicates that tools are treated as sensory extensions rather than as simple distal links between the hand and the environment (Miller et al. 2018). Taken together, these findings clearly demonstrate that tools can be incorporated into the body schema, which constitutes an instance of embodiment inasmuch as the body is extended beyond the skin because of the use of a tool (see Hirose 2002).

Having said that, the question is whether this phenomenon of incorporation involves specific tool-related embodied mechanisms. In fact, the ability to incorporate detached objects into the body schema is not unique to tools as defined above. This aspect was already stressed by Gibson (1986), who argued that “when being worn, clothing, even more than a tool, is a part of the weaver’s body instead of a part of the environment” (p. 41). Here the distinction between clothing and tools is explicit. This phenomenon is also well known with upper or lower limb prostheses in amputee patients. Empirical evidence provides additional support for this. For instance, participants with a brief practice of rolling in a wheelchair give more accurate judgments about their own minimum passage height than those without such practice (Stoffregen et al. 2009).

In broad terms, the phenomenon of incorporation is not unique to tools. Nevertheless, a certain form of incorporation oriented toward action seems to be specifically involved in tool use, namely distalization (Arbib et al. 2009; see also Frey

⁴ Patients with extinction can perceive a contralateral stimulus in isolation but can fail to perceive the same stimulus when presented together with an ipsilesional one. This phenomenon can arise cross-modally (e.g., visual-tactile extinction).

2007). Distalization refers to the idea that, once a tool is grasped appropriately to be used, the hand is no longer the end-effector. Instead, the part of the tool that will be used to act upon another object (i.e., the active part) becomes the end-effector. This implies a (mostly visual) attentional shift, from the hand to the active part of the tool, while it is still the hand that has to be controlled (for discussion, see Osiurak 2017; Osiurak et al. 2017, 2020c). As a matter of fact, this distalization mechanism is more or less explicitly stated in Shumaker et al.'s (2011) definitions: “the user... is responsible for the proper and effective orientation of the tool” (p. 5). This specific point clearly excludes instances of “wearing” and makes the definition less “cognitive-free” than assumed. Indeed, if a species is unable to achieve this distalization, then the probability of being excluded from the club of tool users is very high⁵, generating a certain – though perhaps critical – circularity between the phenomenon of distalization and the definition of tool use. Interestingly, some authors have even been much more restricted in suggesting that the essence of tool-use behavior lies in the user’s ability to control the degrees of freedom of the body-plus-tool system differently to the body-only system (i.e., tooling; Fragaszy and Mangalam 2018; see also Mangalam, 2016; Mangalam and Fragaszy 2016; for discussion, see Osiurak and Danel 2018). In this respect, sponge use by dolphins would not be an instance of tool use because dolphins do not control the rostrum-plus-sponge system differently from the rostrum-only system (Mangalam and Fragaszy 2016). We

⁵ Distalization does not concern all the instances of tool use as defined by Shumaker et al. (2011), particularly in cases where the tool is thrown (i.e., throwing actions). We will not discuss further this aspect. Nevertheless, note that if distalization is considered as the core criterion of tool use, then throwing actions should be excluded from the category of tool-use actions (for a similar view, see Fragaszy and Mangalam 2018).

will not discuss further this proposal, which corroborates that tool use and distalization are intimately linked⁶.

2.2. Incorporation versus physical understanding

The next question is whether all the species possessing this distalization capacity necessarily exhibits tool-use behavior as if this capacity generates a kind of appetite for tool use. The answer is no, for the simple reason that the most significant evidence in favor of the existence of distalization comes from the study of Iriki et al. (1996) in macaque monkeys, which rarely use tools in the wild (see Malaivijitnond et al. 2007). Two key interpretations can be drawn from this. The first is that some species – because of some biomechanical and morphological prerequisites – might acquire distalization through experience. In this context, the species that are more inclined to solve physical problems using external objects could progressively improve the effectiveness of distalization through a greater experience with object-object manipulation situations. This is the case, for instance, of humans or other tool-using nonhuman primate species. Nevertheless, distalization can also be acquired by “forced training” in species that do not spontaneously solve physical problems by manipulating external objects, such as in Japanese macaques. In this respect, some predictions can be formulated. For instance, some avian species such as New Caledonian crows can spontaneously manipulate external objects to solve physical problems and, as a result, show distalization (Hunt 1996; Hunt and Gray 2004; Kenward et al. 2005). Therefore, it can be hypothesized that

⁶ This proposal also allows to draw a sharp distinction between “cloth-like objects” (e.g., gloves, shoes) and tools inasmuch as cloth-like objects do not need to be controlled differently to the body-only system contrary to tools.

non-tool-using avian species could also be trained to use external objects with the beak and should progressively exhibit distalization⁷.

The second key interpretation of Iriki et al.'s (1996) findings is that the phenomenon of distalization is not at the origins of the appetite for solving physical problems through the use of external objects, which is a sign of physical understanding⁸. It is one thing to distalize an object to use it as a tool and another to have the idea of solving physical problems by using external objects. Said differently, distalization and physical understanding are two orthogonal abilities. This proposal is perfectly in line with the idea that tool-use behavior is not a sign of “cognitive superiority”, but simply reflects the ability to distalize the end-effector to the active part of the tool (Beck 1980; Hansell and Ruxton 2008; Shumaker et al. 2011). Several species can be able to develop this distalization mechanism and, as a result, show tool-use behavior while the cognitive origins of the behavior diverge (e.g., “forced learning”, physical understanding).

2.3. Interim summary

The distalization mechanism is an action-oriented form of incorporation, consisting in shifting the attentional focus from the hand to the active part of the tool. This is clearly a specific tool-related embodied mechanism. Such a mechanism might be a key characteristic to define tool-use behavior precisely. In addition, distalization does not mean physical understanding, thereby suggesting that both are orthogonal abilities. The “level of physical understanding” can vary considerably between the different tool-using species, as this is true for animal builders (spiders, beavers, humans; see Hansell

⁷ In other words, distalization can be both innate and learnt.

⁸ The notion of physical understanding does not imply that an individual is able to reason about the physical world at an analogical level. As discussed in more details in Section 4.2., the ability to transfer what is understood technically from a situation to another situation is the key feature of technical reasoning (Osiurak et al. 2010).

and Ruxton 2008; see also Osiurak and Heinke 2018). Finally, this phenomenon of distalization is not passive but needs to be goal-directed. Grasping an object is not enough to make it emerge. Instead, the individual has to intend to use this object as a tool and with another object (the famous Heidegger's hammer).

3. Perception

3.1. Tools are opportunities

Gibson's (1986) definition of tool use along with his concept of affordance suggest that tools can be viewed not only as animal-relative opportunities for action (graspable; acting on) but also as media (i.e., tools) opening up new action opportunities for action (cutting; acting with). On this basis, it can be hypothesized that tools can more or less automatically activate motor programs useful for acting *on* them (e.g., grasping) as well as for acting *with* them on other objects (e.g., cutting). We will discuss this hypothesis in Section 4. Another hypothesis that can be derived from this Gibsonian approach is that tools can modify our way of perceiving the environment. The study conducted by Witt et al. (2005) provided the first evidence for this hypothesis. They asked participants to estimate distances to targets that were beyond their arm's reach as they did or did not hold a reaching tool (i.e., a stick), and with or without the goal of reaching them. Results indicated that targets looked closer when participants intended to reach to them with the tool than without the tool. This effect did not occur when participants merely held the tool without the intention of using it. Since this seminal work, a significant body of evidence has replicated or extended this finding (Witt and Proffitt 2008; Witt 2011b; Bloesch et al. 2012; Davoli et al. 2012; Osiurak et al. 2012, 2014; for reviews, see Osiurak and Badets 2016; Molto et al. in press; for conflicting findings, see De Grave et al. 2011; Molto et al. 2020).

Witt and Proffitt (2008) provided a potential interpretation for this tool-related perceptual bias. Their interpretation is based on the concept of motor simulation, which refers to the imagining of a motor action without necessarily executing it (see Jeannerod 2001). Motor simulation is constrained by the limitations of the body. Thus, people take longer to judge that a difficult grasping is difficult than an easy grasping is easy (Frak et al. 2001). This is consistent with the fact that difficult grasping takes longer than easy grasping when actually performed. So, when people make easiness judgments about grasping something, they simulate this grasping at a motor level, leading them to be subject to the same biomechanical constraints as when performing real motor actions (for other evidence in favor of motor simulation, see Parsons 1987; Decety and Michel 1989; Decety et al. 1989, 1994; Sirigu et al. 1996; Johnson et al. 2002). Interestingly, little energy is wasted simulating different motor actions compared with the costs of performing or attempting to perform all possible motor actions in order to decide which was best (Witt and Proffitt 2008). Thus, given that the use of a tool can lead to less costly motor actions, people might be spontaneously oriented toward tool-use actions, leading them to perceive the world differently and deciding to use tools even if it less beneficial than using the hands (Osiurak et al. 2014; Danel et al. 2017; for similar results with cognitive tools, see Virgo et al. 2017).

3.2. Tools – at best – are opportunities like others

This motor-simulation-based interpretation has been disputed repeatedly (e.g., Molto et al. 2020; for further discussion, see Philbeck and Witt 2015). Regardless, the fact remains that this interpretation can be viewed as embodied. Proffitt (2006) himself used the term “embodied perception” to characterize his economy-of-action account of perception. According to this account, the function of perception is not to build an

objective representation of the physical world, but to anticipate the actions and their associated costs (see also Witt 2011a). Perception is in the service of the principal law of survival, namely, energy consumption must exceed energy expenditure (Proffitt 2006). The question is whether this is specific to tool use. The answer is no. Indeed, a multitude of studies has demonstrated that perception can be modulated by physiological states or biomechanical constraints in non-tool-use contexts (but see Durgin et al. 2009; but see Firestone and Scholl 2016, for discussion about the validity of these findings). For instance, people who are physically fatigued, in declining health, with a low level of glucose, or encumbered (i.e., wearing a heavy backpack) overestimate hill's slant or distances (Bhalla and Proffitt 1999; Proffitt et al. 2003; Schnall et al. 2010). Objects appear farther away when they require difficult than easy grasps (Linkenauger et al. 2009). People also perceive the straight-line distance to an object longer when they have the intention of grasping it by reaching around a wide rather than narrow barrier (Morgado et al. 2013). In other words, motor simulation and perception might be intrinsically tied and involved in the assessment and decisions based on the energetic costs of actions. Nevertheless, this corresponds to a general principle, which can be applied under some circumstances to tool use without being specific to tool use (Osiurak 2014, 2020).

3.3. Interim summary

The intention of using a tool might modify our perception of the physical world. This phenomenon is an instance of embodiment because it originates from the assessment of costs associated with bodily actions, as suggested by the economy-of-action account. Nevertheless, this is not a phenomenon specific to tool use, even if tool use can *indirectly* contribute to this phenomenon: The intention of using a tool – or its

real use – modifies the potential – or real – physiological and biomechanical constraints, which leads to change the perception of the environment.

4. Knowledge

4.1. Direct perception

Gibson's (1986) definition of tool use implies that we can perceive not only the motor actions (i.e., actions *on* tools; e.g., graspable, portable) but also the mechanical actions (i.e., actions *with* tools; e.g., cutting, scraping) offered by tools. This proposal is in apparent contradiction with the idea that an affordance is an animal-relative opportunity for action offered by the environment. Indeed, a knife cannot cut anything. Its *cut-ability* is determined by the physical opposition between its singular properties and those of another object (i.e., acting with). In this regard, the animal's biomechanical and morphological properties are not concerned by this physical opposition (for discussion, see Osiurak et al. 2010). By contrast, the idiosyncratic animal's biomechanical and morphological properties are critical to specify the singular opportunities for action offered by environmental objects in terms of *graspable* or *portable* (i.e., acting on). Here, Gibson only describes the different affordances and does not suggest that we directly perceive the *cut-ability*⁹ of a knife as we can perceive its *grasp-ability*. Nevertheless, the fact that he considers "graspable" (focus on the motor action between the animal's biomechanical/morphological properties and an object; acting on) and "cutting" (focus on the mechanical action between a tool and an external object; acting with) at the same level of description implies that the same cognitive

⁹ It would be more correct to call these tool-centered affordances "xx-with-ability" rather than "xx-ability" (e.g., cut-with-ability instead of cut-ability), because they do not correspond to the actions that an individual can perform *on* but rather *with* the tool compared to user-centered affordances "xx-ability" (e.g., grasp-ability). This nomenclature was, for instance, used by Wagman and Carello (2001).

processes could be at work irrespective of the nature of the affordance¹⁰ (i.e., motor or mechanical). The corollary is that these same cognitive processes could allow the individuals to perceive directly the *grasp-ability* and the *cut-ability* of a knife. The notion of direct perception refers here to the idea that the opportunities for action can be *perceived directly* without requiring additional semantic/declarative knowledge. Let us elaborate on this point.

We now live in a world surrounded by tools whose shape and size are scaled to the most likely user and, as a result, to the vast majority of us (i.e., folk norms; see Drillis 1963; see also Baber 2003, 2006). This can produce the illusion that we perceive directly these tools as ready to be manipulated, making humans mere manipulators, namely individuals for whom the goal is mostly to recognize in each tool the usual manipulation and, as a result, function (Osiurak et al. 2020c). However, this is just an illusion. Indeed, it is a fact that humans have always designed tools with an “interface” in order to make them work. This can be a handle or a switch – or even now a vocal command (for discussion on this aspect, see Norman 1999). The main purpose of ergonomics is precisely to improve these interfaces to ensure comfort and safety. Nevertheless, the idea that tools can be perceived directly as ready to be manipulated is illusory because, if this were true, everyone in the world would be able to spontaneously use any tool simply by looking at it. Of course, most adult humans can recognize, for instance, a switch and suppose that pressing it should generate an effect. However, humans do not directly perceive that a switch can produce an effect. Indeed, the idea

¹⁰ For this reason, Osiurak et al. (2017) recently proposed to limit the term affordances to the opportunities for action offered by the environment in terms of “motor actions”, and to use the term “mechanical action” when the opportunities for action concerns the interaction between two external objects. Note that one of these two external objects can be the body of the user (i.e., reflective actions, such as brushing teeth). In this case, the body is the “object” of the mechanical action.

that a switch can produce an effect is learned because most of us have already had experience of many switches producing a great number of different effects. Also, even if we can suppose that a switch can produce an effect, this does mean that we know which effect is associated with that specific switch. The only opportunities for action we can directly perceive are those that are based on physical properties relative to our biomechanics and morphology. We can perceive whether something is graspable or not, “press-able”, or not, and so on. But we cannot *perceive directly* the opportunities for action that do not involve directly our biomechanics and morphology, namely mechanical actions (Osiurak et al. 2017; see Footnote 10).

This proposal may appear to be in contradiction with experimental findings indicating that participants can, for instance, make relatively accurate judgments about whether an object is *hammer-able* or *poke-able* only by dynamic touch (i.e., without seeing the object; Wagman and Carello 2001, 2003). Dynamic touch refers to the manipulation of an object by means of muscular effort, which can be useful to perceive the properties of a handheld object, particularly, its mass distribution. Given that the object’s mass distribution is critical to make it a good hammer or a good poke – in a given context – there is no reason to challenge the hypothesis that people can perceive the *hammer-ability* or *poke-ability* of an object only by dynamic touch. Nevertheless, this does imply that the information acquired by dynamic touch is sufficient in itself to decide whether the object can be appropriate as a hammer or a poke. In Wagman and Carello’s experiments, participants were presented with a vertically oriented wooden rod firmly situated in a wooden block before beginning the experiment in order to help them make their judgment of hammer-ability. A similar demonstration was provided for judgments on poke-ability. These demonstrations are obviously necessary because no individual can spontaneously decide whether an object is appropriate as a hammer or a

poke without knowing first what the objects are targeted for these different mechanical actions. This corroborates the aforementioned proposal that determining the potential mechanical actions between two external objects cannot be based on the individual's biomechanics and morphology but requires another kind of knowledge that is not embodied, namely mechanical knowledge¹¹ (Osiurak and Badets 2016). As discussed below, mechanical knowledge is not a form of semantic/declarative knowledge.

Finally, another epistemological problem with the direct-perception hypothesis of tools is that it generates an additional fictive affordance category specifically dedicated to tools, which are described in terms of their "*function-ability*" (e.g., hammer-ability, cut-ability). The risk with such a hypothesis is that the term affordance becomes progressively useless, losing its heuristic value by meaning everything and its opposite (Osiurak et al. 2017). Indeed, the concept of tool refers to a behavioral description organized around the key criterion of distalization. Thus, the opportunities for action offered by external objects (as media) are not limited to "tools" but also concerned constructions. For instance, to continue the aforementioned leaking-roof example, an individual can judge a half bottle as "water-collect-able" irrespective of whether they decide to hold it during the collection (i.e., tool use) or put it on the floor (i.e., construction). As a matter of fact, the water-collect-ability of any object is independent of the individual's biomechanics and morphology. Thus, a half-bottle can be appropriate to collect water, as can be a truck tank or a very big cistern. Nevertheless, neither a truck tank nor a very big cistern is graspable. Therefore, if we begin to call affordance any

¹¹ This proposal is sometimes misinterpreted, as if it suggests that the acquisition of our knowledge about the physical world (i.e., mechanical knowledge) does not emerge from our interactions with it. As demonstrated by a significant body of evidence, most of mechanical knowledge is acquired through our interactions with the physical world (e.g., Baillargeon et al. 1992; for a review, see Lockman 2000). In a way, most – if not all – scholars agree with that. Nevertheless, this does not necessarily imply that the knowledge acquired is embodied and corresponds to a simulation of the sensorimotor experience linked to its acquisition.

opportunity for action offered by any external – manipulable or not – object with another external object (e.g., a truck tank is collect-water-able), then the notion of affordance loses its original meaning, namely an opportunity for action based on animal-relative properties. For this reason, as suggested by Osiurak et al. (2017), we will limit the term affordance to the description of the opportunities for action relative to the animal's biomechanical/morphological properties (i.e., acting on), thereby suggesting that these opportunities only can be directly perceived. By contrast, as also suggested by Osiurak et al. (2017) the term mechanical action will be employed to describe the opportunities for action provided by the physical properties of two external objects (i.e., acting with). Contrary to affordances, these mechanical actions cannot be directly perceived because they require additional cognitive processes (notably technical reasoning, see below).

4.2. Manipulation knowledge

Non-tool-use actions (e.g., object transport) can be performing only with motor actions (i.e., hand-object relationships; e.g., grasping, reaching, holding). By contrast, tool-use actions require performing motor actions (i.e., hand-tool relationships) as well as mechanical actions (i.e., tool-object relationships). An embodied account of tool knowledge necessarily assumes that tools elicit motor actions that go beyond the motor actions needed to carry out non-tool-use actions such as object transport. Such an assumption is fundamental to characterize the account as an embodied tool-use account and not, more simply, as an embodied object-manipulation account. For instance, an embodied account of tool knowledge must posit that seeing a hammer activates sensorimotor knowledge describing how to manipulate it as a tool, namely, not only a clenched hand posture (which can be useful for both moving and using it) but also a

broad oscillation from the elbow joint (which is critical to use it as a tool). The notion of manipulation knowledge refers to this kind of sensorimotor knowledge about how to manipulate familiar tools for their usual function¹². The manipulation-knowledge hypothesis has been mainly developed in the field of the neuropsychology of action (e.g., Heilman et al. 1982; Rothi et al. 1991; Buxbaum 2001; Buxbaum & Kalénine 2010), and has also found a sympathetic echo in the literature on memory (e.g., Barsalou 2008, 2009; Borghi and Riggio 2009; Cagliore et al. 2010; Mizelle and Wheaton 2010; Thill et al. 2013).

The manipulation-knowledge hypothesis has received support from the so-called orientation effect reported by Tucker and Ellis (1998). As explained below, the orientation effect does not demonstrate at all that manipulation knowledge is automatically activated by the sight of tools. Nevertheless, it is commonly cited as evidence for this hypothesis (e.g., Pellicano et al. 2010; Watson and Buxbaum 2014), it deserves that we spend some time on it. In their seminal article, Tucker and Ellis (1998) presented participants with pictures of tools with the handle oriented toward either the left or the right. The orientation of the handle was irrelevant to the task (i.e., vertical orientation judgment; upright/inverted). Nevertheless, participants were faster to respond with a left-hand keypress when the handle was oriented to the left and vice versa. The interpretation provided by the authors was that tools automatically potentiate the motor representations associated with them. The robustness, generalizability and interpretation of this orientation effect have been subject to an intense debate (e.g., for conflicting results, Anderson et al. 2002; Cho and Proctor 2010,

¹² The terms visuokinesthetic motor engram (Heilman et al. 1982), action lexicons (Rothi et al. 1991), or gesture engram (Buxbaum 2001), among others, have been employed as a synonym of manipulation knowledge.

2011, 2013; Pellicano et al. 2019; Kostov and Janyan in press; Pellicano and Binkofski in press; for a review, see Osiurak and Badets 2016). Regardless, this orientation effect cannot be interpreted as evidence for the manipulation-knowledge hypothesis because it does not demonstrate that specific tool-use motor actions are activated automatically by sight of tools. Indeed, this effect corresponds to faster keypress responses with the left/right hand according to the orientation of the handle of the tool presented (i.e., left/right). At best, this demonstrates the presence of an embryonic reaching and grasping movements toward graspable stimuli (see Vingerhoets et al. 2009; see also Symes et al. 2007). This overinterpretation of the orientation effect interestingly reflects a contemporary epistemological bias consisting of viewing any stimulus as embodied (for a similar view, see Kostov and Janyan in press).

Most of the evidence for the manipulation-knowledge hypothesis does not, however, come from the orientation effect but from the study of patients with tool-use disorders also called apraxia of tool use (Osiurak and Rossetti 2017). These patients encounter difficulties in selecting the appropriate tools for performing mechanical actions with them as well as in performing the mechanical actions themselves. These difficulties commonly appear after lesions of the inferior parietal lobe (Goldenberg and Hagmann 1998; Goldenberg and Spatt 2009). Based on these findings, it has been suggested that the left inferior parietal lobe is critical for storing manipulation knowledge (e.g., Heilman et al. 1982; Rothi et al. 1991; Buxbaum 2001; Rizzolatti and Matelli 2003; Daprati and Sirigu 2006; van Elk 2014; van Elk et al. 2014). The manipulation-knowledge hypothesis has long been the only – and, therefore, default – hypothesis to explain apraxia of tool use. Thus, when a patient failed to use a tool, this difficulty was systematically interpreted as evidence for impaired manipulation knowledge. When kinematic recordings allowed us to objectify quantitatively patients'

difficulties, these objective difficulties were still interpreted in terms of impaired manipulation knowledge (Poizner et al. 1995). When neuroimaging allowed us to demonstrate that the left inferior parietal lobe is involved in the planning of real tool-use actions, this activation was interpreted in terms of manipulation knowledge (Johnson-Frey et al. 2005). In fact, this hypothesis is even now widely held in the literature. Yet, compelling evidence has invalidated it.

The manipulation-knowledge hypothesis predicts that the left inferior parietal lobe is critical for storing sensorimotor knowledge about how to manipulate familiar tools. This prediction does not coincide very well with the significant number of studies reporting that patients with damage to the left inferior parietal lobe are impaired not only to select familiar tools but also to select, make or use novel tools to solve mechanical problems (Heilman et al. 1997; Goldenberg and Hagmann 1998; Goldenberg and Spatt 2009; Osiurak et al. 2009; Jarry et al. 2013; for a review, see Osiurak et al. 2020c). This robust finding is difficult to interpret in terms of impaired manipulation knowledge for two reasons. The first is that manipulation knowledge is thought to contain information about how to manipulate familiar but not novel tools. Therefore, a strong link such as the one stressed above should not be obtained. The second is that manipulation knowledge is centered on hand-tool relationships, that is, motor actions (e.g., a broad oscillation from the elbow joint, for a hammer) and not on tool-object relationships, that is, mechanical actions. Therefore, manipulation knowledge does not enable people to select an appropriate tool for a specific action with a specific object as well as to make tools, particularly when tools are novel. Instead, the aforementioned findings suggest that the left inferior parietal lobe might be involved in the understanding of mechanical actions whatever the familiarity of the use (i.e., familiar or novel). A recent neuroimaging meta-analysis confirmed this hypothesis, in showing that

the left inferior parietal lobe – and particularly the area PF – is preferentially activated when participants focus on mechanical actions involving the interaction between a tool and an object and not when they focus on motor actions involving a hand posture, for instance, and a tool (Reynaud et al. 2016). Interestingly, this meta-analysis also revealed activation of the intraparietal sulcus in this latter condition.

As stressed above, there is a contemporary bias in the literature consisting of interpreting everything in terms of embodiment. The technical-reasoning hypothesis is a radical alternative to this overinterpretation. This hypothesis posits that human materiality (i.e., tool use, tool making, construction, technical innovation, cumulative technological culture) is grounded on a specific kind of reasoning oriented toward the physical world, namely technical reasoning (Osiurak et al. in 2020c; for similar proposals, see Wolpert 2003; Pinker 2010; Vaesen 2012; Goldenberg 2013). Like any other form of physical understanding, technical reasoning is causal, allowing the individual to anticipate the outcomes of future physical events (Penn et al. 2008). However, it is also analogical, allowing the individual to transfer what is understood from one situation to another situation (for discussion about the human uniqueness of the analogical component, see Osiurak and Reynaud 2020; Rutz and Hunt 2020; Taylor and Jelbert 2020). Technical reasoning is based on mechanical knowledge, that is, a form of knowledge that is acquired through experience with the physical world. The left inferior parietal lobe and particularly the area PF is thought to be critical for technical-reasoning skills. Humans use technical reasoning to solve the physical problems of our everyday life, by generating potential appropriate mechanical actions. Thus, as illustrated in the leaking-roof example, technical reasoning enables the individual to produce the “recipient” solution and to select the object with suitable physical properties. However, the function of technical reasoning is not to select and control the

execution of appropriate motor actions with the appropriate end-effector(s) in order to realize the technical solution generated. This is the specific role of the motor-control system, which involves more superior parietal structures such as the intraparietal sulcus and which is unaware of the goal of the action (e.g., object transport, tool use, construction). For this system, the challenge is to select the most economical motor actions to realize the action intended, which can lead, among other possibilities, to distalize an end-effector (i.e., tool use; see Osiurak et al. 2018; Lesourd et al. 2020).

According to the technical-reasoning hypothesis, there is no need of manipulation knowledge to account for how people use tools¹³ (Goldenberg 2013). This proposal is also based on experimental evidence. For instance, the technical-reasoning hypothesis posits a kind of cascade mechanism inasmuch as technical reasoning first generates the mechanical action to be performed, then placing constraints on the motor actions to be selected by the motor-control system¹⁴. Recent eye-tracking studies have explored the effects of such a cascade mechanism on tool's visual-attentional patterns by showing how visual exploration first concerns the tool's active part (e.g., the head of a hammer), then the tool's manipulative part (e.g., the handle of a hammer; Federico and Brandimonte 2019; for similar results in a motor intention paradigm, see Osiurak and Badets 2014; Badets et al. 2017; see also Badets and Osiurak 2015). Additionally, the way people look at and recognize tools that are part of thematically consistent (e.g., hammer-nail) or thematically inconsistent (e.g., hammer-scarf) pairs appears to be highly suggestive of reasoning-based cognitive processing (Federico and Brandimonte

¹³ The manipulation-knowledge hypothesis can be viewed as an embodied approach to tool use because it posits that knowledge about how to use tools is based on specific tool-related motor representations. In this way, the technical-reasoning hypothesis is a non-embodied approach because it denies the existence of such tool-related motor representations.

¹⁴ This cascade mechanism is obviously reiterative.

2020). Specifically, the visuoperceptual context and the goal of the task seems to influence both the visual-attentional processing and object recognition of tools that are part of object-tool pairs. Indeed, fixation patterns are focused on the tool's manipulative part under thematically consistent conditions and on the tool's active part under thematically inconsistent conditions. Crucially, looking at the tools to recognize them, generate longer fixations on the tools' active areas, irrespective of thematic consistency. Thus, when the visual scene suggests high action readiness (e.g., hammer-nail) the simplest resolution of the cascade mechanism is reflected in a fixation pattern that emphasizes the tool's manipulative part in order to actualize the action (i.e., using the hammer on the nail). Conversely, in a not action-ready visual context or when there is an expressly non-motoric goal (i.e., looking to recognize instead of looking to use), people do not proceed toward the mechanical and motor processing, hence lingering in a semantic processing of the visual scene (Federico and Brandimonte, 2020; see Footnote 10). A similar pattern of results has been found when participants have to decide the appropriateness of a tool-use action performed by another individual (e.g., van Elk et al. 2008; Naish et al. 2013; Nicholson et al. 2017; Decroix and Kalénine 2018, 2019; for similar results in an observational context, see Massen and Prinz 2007, 2009).

4.3. *Interim conclusion*

Embodied accounts of tool knowledge assume that specific embodied knowledge is involved in tool use, namely manipulation knowledge. Compelling evidence challenges these accounts. At an epistemological level, it is nevertheless interesting to understand how this perspective has emerged and gained prominence in recent years. The manipulation-knowledge hypothesis is not new in the field of the neuropsychology of action (e.g., Heilman et al. 1982). Nevertheless, Gibson's writings have inspired cognitive

models of action, leading the authors to propose the existence of a non-semantic route (e.g., Rothi et al. 1991; Rumiati and Humphreys 1998) as well as to introduce the term of affordance (e.g., Humphreys 2001) in their models. As stressed by Tucker and Ellis (1998), although their account “is a representational account of affordances, and therefore very different from the use of the term in the ecological sense, it nonetheless has its basis in a similar emphasis of the intimate link between perception and action” (p. 833). In broad terms, both the Gibsonian ecological approach and embodied cognitive models of action have developed in opposition to classical cognitive models, which are based on the dichotomy between conception (i.e., semantic/declarative memory) and production (i.e., procedural memory).

The emergence of both approaches has been of greatest importance in the field of tool use and, more broadly, action, leading scientists to progressively understand and demonstrate that semantic/declarative knowledge is not involved in tool-use skills, strictly speaking¹⁵ (e.g., Buxbaum et al. 1997: for a review, Osiurak and Badets 2016). All approaches agree with that (i.e., ecological approach, manipulation-knowledge hypothesis, technical-reasoning hypothesis). Nevertheless, this is not because

¹⁵ Even if semantic knowledge appears to be neither necessary nor sufficient to actually use tools, it might be indispensable to create abstract and generalizable concepts associated with tools and objects (e.g., Lambon Ralph et al. 2017; De Bellis et al. 2018; Wurm and Caramazza 2019; see also: Bar et al. 2006; Rogers and McClelland 2004). Hence, whereas mechanical knowledge is necessary to actually use tools, semantic knowledge might be considered as a complementary addendum in order to construct object-related representations. Such knowledge might be usable in everyday life by a reasoning-based agent (i.e., humans or future artificial intelligence), in the context of a cognitive-oriented functioning. Such an integrated perspective has been recently suggested by Federico and Brandimonte (2020) by introducing the concept of “action reappraisal”. Furthermore, semantic knowledge can play a specific role in some specific tool-use situations, such as when people are asked to use tools presented in isolation (i.e., single tool use). Indeed, in such situations, semantic knowledge might be useful to inform the individual about the conventional use of the tool presented, thereby allowing the individual to generate the mechanical action associated through technical reasoning (Osiurak 2014). This can explain why patients with a selective semantic deficit can show difficulties when asked to show how to use a familiar tool presented in isolation but not when presented with its corresponding object (Corbett et al. 2015; Baumard et al. 2016; see also Sirigu et al. 1991; Hodges et al. 2000; Osiurak et al. 2008; Lesourd et al. 2016).

semantic/declarative knowledge is not involved *per se* in tool use that tool knowledge is necessarily embodied/sensorimotor. After all, it is very difficult to describe explicitly what is the principle of support. Nevertheless, even very young infants can understand it (Baillargeon et al. 1992). In addition, the embodied approach leads to under-intellectualize tool-use skills, as if tool use did not require any form of intelligence or reasoning (for a discussion about the over- *versus* under-intellectualization of tool use, see Robertson 2020; see also Osiurak and Reynaud 2020). However, like tool making, construction behavior or other forms of human materiality, tool use might originate in a specific kind of reasoning oriented toward the physical world and based on a kind of knowledge that is neither semantic nor declarative (i.e., mechanical knowledge). In other words, an embodied account of tool knowledge is not the only possible way of overcoming the strong link between conception and semantic/declarative memory initially proposed by classical cognitive models.

5. Observation

5.1. Observing others' motor actions

Human technology is characterized by an accumulation of adaptations that no single individual could invent on their own, a phenomenon known as cumulative technological culture (Boyd and Richerson 1985; Tomasello et al. 1993; Boyd et al. 2011). This phenomenon is indisputably social since this accumulation of adaptations reflects the incredible source of technical inspiration offered by social interactions. Also, the critical question is to understand what is transmitted socially when a learner observes a model carrying out a tool-use action. Some authors have suggested that humans might be unique in being able to copy faithfully not only the mechanical actions performed by the model but also the motor actions associated (Tomasello et al. 1987;

Nagell et al. 1993; Tennie et al. 2010; Tomasello et al. 2005). Said differently, while other species might be able to emulate, only humans might imitate. This account of cumulative technological culture clearly emphasizes the importance of the motor component of the behavior. Yet, it is not an embodied account because imitative skills are not considered here as being directly supported by embodied cognitive process, but as one of the manifestations of higher-level social cognitive skills (i.e., shared intentionality, a concept close to the theory of mind). This emphasis placed on the motor component has nevertheless found resonance in other authors, who have attempted a bridge between the cultural evolution literature and neuroscientific findings. Imitative skills – still considered here as the ability to copy faithfully the motor actions needed to use a tool – have been suggested to involve a frontoparietal network specialized in action observation (e.g., Stout and Hecht 2017). In this view, the specific ability of our ancestors to imitate others' tool-use actions (and particularly their motor actions) has been linked to a possible change in the hominin mirror system, thereby favoring the emergence of cumulative technological culture (e.g., Shipton and Nielsen 2015). This relatively logical link between mirror neurons and imitation has also been repeatedly proposed in the literature on apraxia of tool use (e.g., Buxbaum et al. 2005; Buxbaum 2017; but see Negri et al. 2007).

5.2. Observing others' mechanical actions

This account of tool-use observation (e.g., Shipton and Nielsen 2015; Stout and Hecht 2017) is undoubtedly embodied in that it implies a specific tool-related embodied mechanism allowing humans to imitate others' motor actions involved in tool-use actions. A certain number of empirical and theoretical arguments nevertheless question its validity. First, there is no debate that a frontoparietal network is engaged in action

observation and that this network is roughly the same as the one involved in controlling our own motor actions (i.e., the motor-control system; Decety and Grezès 1999; van Oosterwaalle and Baetens 2009; Thompson et al. 2019). At the heart of the debate is how to interpret the engagement of the motor-control system in action observation (Brass and Heyes 2005). A less embodied perspective suggests that people focus primarily on action goals when observing others' actions, then leading them to simulate their own motor actions useful for achieving the goal (Wholschläger et al. 2003). As a consequence, the same frontoparietal network is engaged when people observe others' motor actions or perform their own motor actions (the sunflower effect; see Osiurak and Reynaud in 2020; see also Osiurak et al. 2020a). This interpretation is consistent with the aforementioned findings that have indicated that people focus first on mechanical actions and then on motor actions in an observational context (Massen and Prinz 2007; van Elk et al. 2008; Massen and Prinz 2009; Decroix and Kalénine 2018, 2019). Second, convincing evidence has shown that chimpanzees can copy mechanical actions faithfully as well as establish traditions despite their supposed difficulties to copy the models' motor actions (e.g., Whiten et al. 1999, 2005; Horner and Whiten 2005; Horner et al. 2006). In other words, tool-use actions can be transmitted socially without requiring the faithful copy of motor actions, thus questioning the interest of a specific tool-related embodied mechanism for action observation. Third, even if culture can be observed in many other nonhuman species such as chimpanzees, cumulative technological culture is absent or at best minimal in nonhuman species. To account for this, Whiten et al. (2003) argued that the significant difference might lie not so much in the social-learning skills themselves, but rather in the complexity of the mechanical actions that humans can represent and, therefore copy or even improve. This proposal is perfectly in line with the technical-reasoning hypothesis in suggesting that our ability to understand the

mechanical actions performed in the physical world – including those performed by others – is critical to the acquisition and improvement of our tool-use skills¹⁶ (see Osiurak and Reynaud 2020). Interestingly, a recent neuroimaging meta-analysis corroborated this proposal in showing that the observation of tool-use actions performed by others activates the classical action observation network. However, the left inferior parietal lobe – and particularly the area PF – is specifically activated when participants observe others performing tool-use actions as compared to non-tool-use actions (Reynaud et al. 2019).

5.3. *Interim conclusion*

The embodied account of tool-use observation suggests that observing others performing tool-use actions automatically activates the corresponding motor actions. The existence of such a tool-related embodied mechanism remains to be demonstrated both at a theoretical level and an empirical level. Increasing evidence seems to indicate that imitative and more broadly social-learning skills might be largely goal-directed, thus emphasizing the role of non-embodied cognitive processes, such as technical reasoning, in social transmission.

6. Conclusion

The present article aimed to examine whether specific embodied mechanisms are at work in tool-use situations. The answer is yes. Tool use is impossible if the individual is not able to shift attentionally from the “natural” end-effector to the active part of the tool (i.e., distalization). As a matter of fact, this conclusion might be somewhat circular

¹⁶ Technical-reasoning skills have also been shown to be a good predictor of cumulative performance in micro-society experiments in which participants have to perform a task (e.g., building a tower) as members of a chain (Osiurak et al. 2016; De Oliveira et al. 2019; Osiurak et al. 2020b, in press; see also Osiurak et al. submitted).

inasmuch as distalization might be the key defining feature of tool-use behavior. Regardless, distalization is a specific tool-related embodied mechanism, justifying the conclusion that tool use is grounded on a specific form of embodiment. The same conclusion cannot, however, be reached for perception, knowledge, or observation. The economy-of-action account assumes that perception is in the service of the principal law of survival and, as a consequence, can be considered as embodied, in orienting the individual toward the least costly actions. However, this embodied mechanism is not specific to tool use, even if it can be applied in tool-use situations. Concerning knowledge and observation, a significant body of evidence seriously questions the role – if not the existence – of tool-related embodied mechanisms in tool knowledge and tool-use action observation (**Table 1**). At an epistemological level, our assessment is much more consistent with the ecological/Gibsonian approach to tool use (i.e., distalization and, to a lesser extent, perception) than its cognitive alternative organized around the concept of manipulation knowledge¹⁷.

This article also emphasizes that any strong embodied account is inappropriate to explain a key facet of tool use, namely, how to select external objects in order to perform mechanical actions. As repeatedly stressed here, mechanical actions are independent of

¹⁷ According to the ecological/Gibsonian approach, animals can perceive directly the opportunities for action provided by the environment (i.e., affordances). As discussed above, this approach is viable only if affordances are considered as being restricted to the motor actions that are relative to the animal's biomechanical/morphological properties (i.e., acting on). This approach can be articulated with the technical-reasoning hypothesis if we assume that technical reasoning is dedicated to form a representation of the tool-use action (i.e., acting with), which then guides the perception of the appropriate affordances (i.e., acting on; for discussion, see Osiurak et al. 2017). In this frame, we do not perceive affordances in order to determine how to use a tool with an object, but rather to realize the action intended by selecting and planning the appropriate motor actions. By contrast, it is difficult at a theoretical level to articulate the technical-reasoning hypothesis with the manipulation-knowledge hypothesis because both aim to explain how individuals determine how a tool has to be manipulated as a tool (i.e., either through technical reasoning or through the activation of manipulation knowledge). Interestingly, although both the ecological/Gibsonian approach and the manipulation-knowledge hypothesis can be labelled as embodied, they strongly diverge at a theoretical level (non-representational approach *versus* representational approach).

the user's biomechanics and morphology. This epistemological flaw is already visible in Gibson's writings, in which he described mechanical actions as affordances. Some examples are provided in the initial quote of this paper, but there are others:

A rigid staff also affords leverage and that use is a *lever*. A pointed elongated object affords piercing – if large it is a *spear*, if small a *needle* or *awl*... A rigid object with a sharp dihedral angle, an edge, affords cutting and scraping; it is a *knife*. It may be designed for both striking and cutting, and then it is an *axe*". (Gibson 1986; p. 133)

This approach was of the greatest importance in order to escape from the classical cognitive perspective according to which conception is necessarily based on semantic/declarative memory (see Footnote 15). However, the risk is also to under-intellectualize tool use, progressively leading to assume that it does need any form of intelligence or reasoning. The thesis we defend is that technical reasoning is the key ability allowing humans to use tools, thus corresponding to a form of technical intelligence or intoelligence (Osiurak and Heinke 2018). In this framework, tool use is nevertheless only one of its manifestations, because it can also be the support for tool making, construction behavior, cumulative technological culture or, more broadly, for any technical solution aiming to solve a physical problem. In this respect, all these manifestations deserve to be studied in a specific field of cognitive science organized around the question of the cognitive origins of human materiality, namely technition (Osiurak et al. 2020c). In this field, tool use would not be central, but simply a behavioral capacity at the crossroad between technical reasoning and distalization. Such a new field of cognitive science cannot emerge if we continue to consider that everything in tool use is embodied.

7. References

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Tool Use and Embodiment

Table 1.
Four ways of conceiving embodiment in tool use

Related concepts	Embodied view: “What is commonly proposed”	Present view		
		What is proposed here	Tool-related embodied mechanism	Domain-general embodied mechanism
Incorporation	Tools can be incorporated into the body schema	Distalization but not incorporation is specific to tool use	Yes (Distalization)	Yes (incorporation)
Perception	Tools can modify our way of perceiving the environment	Tools can modify our opportunities for action, which can <i>indirectly</i> modify our perception of the environment	No	Yes (at best)
Knowledge	Seeing a tool automatically activates the manipulation knowledge needed to use it as a tool	“Manipulation knowledge” is not needed to use tools	No	No clear evidence
Observation	Observing someone using a tool activates the manipulation knowledge needed to use it as a tool	When observing someone using a tool, we focus primarily on the mechanical actions observed, which <i>indirectly</i> leads to simulate the motor actions needed to realize these mechanical actions	No	No clear evidence