



Rethinking *chaîne opératoire* beyond cognitivist approaches

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Abstract

This article proposes a reconsidered *chaîne opératoire* framework drawing on theories of embodied, extended, and enacted cognition. I investigate three hypotheses: (1) the *chaîne opératoire* framework (as it is used) takes a cognitivist approach to the mind, (2) technical tendencies and *milieus* can encompass and support modern theories of embodied, extended, enactive cognition, and (3) that by reconsidering these elements of the *chaîne opératoire* framework alongside contemporary theories of cognition we may re-envision a novel *chaîne opératoire* framework which takes a non-cognitivist approach. First, the development of *chaîne opératoire* and its uses are reviewed and analyzed for evidence of a cognitivist approach. Second, I argue that elements of the *chaîne opératoire* framework (technical tendencies and *milieus*) can and do support contemporary theories of cognition. Similar methods for connecting methodological frameworks with the phenomenological nature of human *being* such as Cognigrams and the Four-Field Co-Evolutionary approach are analyzed to provide context for this work. Following this, I outline a unique approach to the *chaîne opératoire* framework which accounts for theories of embodied, enacted, and extended cognition.

Keywords *Chaîne opératoire* · Material culture · Technology · Cognition · Phenomenology · Network theory

1 Introduction

How can contemporary theories of cognition, such as embodied, extended, and enacted cognition, aid archaeologists? Additionally, can the integration of these theories reframe the way we think about the connection between prehistoric minds and the production of material culture? I set out to discuss how reframing the *chaîne opératoire* framework in light of contemporary theories of cognition can further

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develop the connection between mind and making. Translated literally, *chaîne opératoire* means ‘operational chain’ or ‘sequence chain’ but refers more generally to a methodological approach which documents the processes by which naturally occurring materials are selected, prepared, and transformed through physical manipulation into usable objects. In the most basic sense, *chaîne opératoire* is understood as a method for analyzing “a series of operations which brings a primary material from its natural state to a fabricated state” (Lemonnier, 1986, p. 149). The methodological framework *chaîne opératoire* is the most oft-cited framework used in studies of tools, toolmaking, and production of material culture (especially lithic and ceramic material culture). Through understanding how people navigate the world around them, especially through interaction with and production of tools and material culture, we may gain a glimpse into the mind of the maker. The *chaîne opératoire* framework is thereby used to facilitate discussion of prehistoric minds and material culture. However, *chaîne opératoire* (as it is used) does not often involve theories of cognition explicitly, barring a select few studies which are discussed herein (see for example (Eren et al., 2005; Walls, 2016; Walls & Malafouris, 2016)). This is odd, given the aforementioned correlation between the mind, the maker, and the making. Instead, we often see experimental or heuristic projects using a *chaîne opératoire* approach which infer cognitive capabilities through traces left in the material record. While Leroi-Gourhan, the scholar credited with the development of *chaîne opératoire*, resisted Structuralist and Processualist paradigms, the *chaîne opératoire* framework still was formulated based on a deterministic and teleological view of human evolution (now called selectionist evolution) (Schlanger, 1994). Because of this, I argue that the practical use of *chaîne opératoire* rests on a cognitivist approach to the mind.

The cognitivist approach is presented in the following section, and the connection between this approach and *chaîne opératoire* is underlined. By addressing the theoretical foundations of *chaîne opératoire*, the oft forgotten theories of Leroi-Gourhan, and the issue of incorporating cognitive theories with the framework, the reader will find that there is in fact a need for reconsidering the *chaîne opératoire* framework in regard to Leroi-Gourhan’s technical tendencies and *milieus*. Next, said theories of embodied, extended, and enacted cognition will be explored while also underscoring possible connections with technical tendencies and *milieus* - elements of the *chaîne opératoire* framework. Thereafter, a discussion follows including examples of models which incorporate such theories of cognition with methodological frameworks. To conclude, I propose “*network opératoire*” which re-envision the *chaîne opératoire* approach and which incorporates technical tendencies and *milieus* which are the connections to theories of embodied, extended, and enacted cognition.

I would note that *chaîne opératoire* has a long and storied past. The methodological framework has been interpreted and employed in various ways over the course of nearly eight decades since Leroi-Gourhan’s proposal for *chaîne opératoire* in the 1940’s (Leroi-Gourhan, 1943; Leroi-Gourhan, 1945). *Chaîne opératoire* is, and will continue to be, an extremely valuable tool in many fields of archaeology and prehistory especially in the context of lithic studies (Binford, 1979; Pelegrin, 1990;

Inizan et al., 1993; Pelegrin et al., 1993; Sellet, 1993; Eren et al., 2005; Tostevin, 2011; Assaf et al., 2023). While *chaîne opératoire* has been used extensively in lithic studies wherein experiments in reduction techniques and refitting are utilized, this article does not focus on lithics. The purpose of this is to avoid material-specific debate, to open the topic to a wider audience, and to broaden the conversation about *chaîne opératoire* and the theory it rests upon. While I explore various cases where *chaîne opératoire* has been employed, this is not intended to serve as a comprehensive review of case studies. There are many existing reviews of *chaîne opératoire* and its use cases which may interest the reader (Sellet, 1993; Schlanger, 1994; Dobres, 1999; Audouze, 2002; Martínón-Torres, 2002; Riede, 2006; Bar-Yosef, 2009; Soressi & Genest, 2011; Roux, 2016; Roux, 2019; Lewis & Arntz, 2020; Porqueddu et al., 2023; Slaughter, forthcoming). This study aims instead to revisit the theoretical foundations of *chaîne opératoire*, and to explore the potential for *chaîne opératoire* to incorporate embodied, extended, and enacted theories of cognition. By reframing the *chaîne opératoire* framework in light of contemporary theories of cognition, novel avenues of research surface for discussion.

2 The cognitivist approach

First the cognitivist (also called computational or representational) approach must be outlined. The cognitivist approach proposes that the mind performs internal computations in the way that a computer does, based on internal representations (Ryle, 1949; Stillings, 1995). This approach states that knowledge of how to do a task is based on knowledge of “rules and canons, or by the application of criteria” (Ryle, 1949, p. 46). This is possible because information can be stored inside the mind and drawn upon when the need arises (Popper, 1979). In other words, the mind receives input from the external world, and (like a computer) processes it internally, externalizing it later through output (behavior). This externalization is seen as an expression of an inner blueprint; this is also referred to as blueprint-thinking (Clark, 1997). This cognitivist approach places the mind firmly within the skull – all thoughts, processes, computations, and representations take place internally. The framework used by cognitivists, rational reconstruction, draws on a philosophy of science which developed the notion of symbolically structured reality (e.g., Habermas, 1990; Habermas & McCarthy 1995). This rational reconstruction involves proposing each problem or computation as an abstract input-output map with the goal of seeking the optimal solution (Clark, 1997, p. 80). Transforming information (input and/or output) into symbols used in an equation-like process creates an image of the mind as a passive engine for computing, a disembodied pattern-recognizer and de-coder following along preconceived mental blueprints, roadmaps, or recipes. This standardized, representational, cognitivist, model is overly reductive. No matter how complex such a model becomes it does not take into account the phenomenological experience of being human (Gallagher, 2005).

To be sure, this computational model is suitable to some cognitive functions such as solving an algebraic equation. But it quickly falls apart when considering cases

that involve epistemic actions. Epistemic action defines instances where cognitive output *is a physical action* meant to discover new information that contributes to the successful completion of a problem (rotating puzzle pieces and testing the fit in order to find the correct match is a very basic example of this concept) (Kirsh & Maglio, 1994). There are three main obstacles which appear in the cognitivist approach: (1) the replacement of physical quantities or things with symbols can obstruct opportunities to exploit the physical world as a tool for problem-solving, (2) similarly, conceptualizing a problem in terms of input-output mapping invites a view of cognitive processes as *passive computation*, and cannot accommodate situations as mentioned previously wherein the output involves epistemic action, and (3) that simplifying information into symbols to search for an optimal solution does not account for, or can obscure, the role of history in solving the same or similar problems. As Clark states, “new cognitive garments seldom are made of whole cloth; usually they comprise hastily tailored amendments to old structures and strategies” (Clark, 1997, p. 81). How does cognitivism relate to the *chaîne opératoire* framework? We will see how, in an effort to develop a methodology for understanding production processes, scholars arrived at a cognitivist approach.

2.1 *Chaîne opératoire*: foundations of the framework

The underlying notion of *chaîne opératoire* stems from the postulations of Marcel Mauss who believed that technical gestures are conscious and deliberate (Mauss, 1935). Technologies and technical gestures are widely accepted therefore as the material expression of cultural activity. Technical gestures include any action on matter involving an object or tool (Schlanger, 1994, p. 143). In the most liberal definitions, technical gestures encompass *any* social behavior including even scratching one’s nose (Lemonnier, 1992, p. 1). Mauss also acknowledged that technical gestures are socially and historically context dependent (Mauss, 1935). These technical gestures involve choices (of techniques, materials, and physical actions for example) which constitute components of their social and cultural contexts that are not solely based on functionality. Mauss further states that technical gestures cannot be analyzed in isolation from each other; much later Lemonnier expands upon this to say that when analyzed in isolation, technical gestures can only surmount to a description of their informational dimension such as physical constraints, description of decoration, or morphological categorization (Mauss, 1935; Lemonnier, 1992). Leroi-Gourhan, who developed Mauss’ writings into a framework used the term *chaîne opératoire* to describe “both gestures and tools, organized in a chain by a veritable syntax that simultaneously grants to the operational series their fixity and flexibility” (Leroi-Gourhan, 1993, p. 114). Leroi-Gourhan developed an ethnographic approach to classifying actions on matter, and further determined two categories of these actions: technical facts and technical tendencies (Leroi-Gourhan, 1943; Leroi-Gourhan, 1945). He then utilized models of biology and selectionist evolution to examine techniques (Leroi-Gourhan, 1993). *Chaîne opératoire* as a methodological framework then, is employed to better understand these technical facts, technical tendencies, techniques, gestures, and tools.

How is *chaîne opératoire* actually utilized? What components make up this methodological framework? This is a great question in and of itself as *chaîne opératoire* has undergone decades of interpretation which often result in differing iterations. Schlanger succinctly states, “while the *chaîne opératoire* approach may represent a coherent, practical condition for further research, it remains, left to itself, neither self-explanatory nor sufficient” (Schlanger, 1994, p. 143) (emphasis added). While I tend to agree with Schlanger’s remark it is important to point out that while *chaîne opératoire* may not be self-explanatory nor sufficient when left to itself, it has been used effectively. Its use is highly effective especially in combination with additional research methods. For example, there has been great progress in ceramic studies using *chaîne opératoire* in conjunction with experimental archaeology (Roux & Marie-Agnès, 1998; Roux & Corbett, 1989; Skibo, 1992; Jerolyn Morrison & D. Evelyn, 2008; Jeffra, 2015; Brianna Jenkin, 2022), ethnography (Roux, 2017; Roux, 2019; Padilla Fernández & Sánchez López, 2021), and X-radiography (Berg 2009; Berg 2011; Thér 2015).

An outline of the basic framework, as laid out by Leroi-Gourhan, is necessary for the discussion:

1. Typology of physical properties and modes of action

Materials are classified according to physical properties of the matter and the hypothesized modes of action taken to transform them – these are material properties, physical forces, and actions (Leroi-Gourhan, 1943).

2. Modes of action classified by Elementary forces

Having created a typology of modes of action, these are further classified according to their “finality” – these are elementary means and forces such as percussion, heating, and/or use of water. Through the reduction and classification of modes of action into elementary forces Leroi-Gourhan was then able to observe techniques in production processes through visible patterns (recurring choices of gesture, tool, and material) in their socio-historical context. Physical actions and gestures are analyzed through traces of physical manipulation which can be seen on, and in, material remains via macroscopic and microscopic analysis. Modes of action can also be analyzed through by-products of production (waste and discard) which can be observed within the archaeological record (Leroi-Gourhan, 1943; Schlanger, 2005, p. 19).

3. Modes of action further defined as technical facts or technical tendencies

After establishing physical properties of materials and classifying modes of action, Leroi-Gourhan proposed that we further classify modes of action into two phenomena which he named technical facts (or les faits) and technical tendencies (or la tendance technique) (Leroi-Gourhan, 1943; Leroi-Gourhan, 1945; Leroi-Gourhan, 1993).

Technical facts (operations or tools) are actions which are fixed spatially and temporally and can be observed (such as visible traces of percussion). Technical facts can be classified either chronologically (where it is possible to date archaeological data), or by a “logical order”. The logical order is based on variation of attributes so that these technical facts may be compared via a network of dominant, major, and ancillary attributes.

Technical tendencies are long-term socially informed choices which may at first glance appear to be arbitrary or unnecessary to the production process itself. Implementing a selectionist model of evolution, contemporary at this time, Leroi-Gourhan posited that technical tendencies develop and evolve in a manner similar to the process of natural selection (Leroi-Gourhan, 1993).

4. *Milieus*

Finally, Leroi-Gourhan addresses themes of transmission, diffusion, and innovation. He does this through his concept of three *milieus*: (1) *milieu exterior* (exterior *milieu*), (2) *milieu interior* (interior *milieu*), and (3) *milieu technique* (technical *milieu*).

Milieu exterior includes the natural environment, material culture, and ideas of other groups of people. *Milieu interieur* then describes the intellectual capital of a given group, a notion again akin to the socially extended mind. Unlike *milieu exterior*, here we consider the ideas, beliefs, and memories held *within* a group. This *milieu interieur* contains traditions and perpetuated modes of thought and action which, as a whole, make up the group’s *milieu technique* (or technical *milieu*) – the third key concept. This *milieu technique* is perpetually evolving; new information, skills, and technical gestures can be added to a group’s *milieu technique* in an accumulative process. The *milieu technique* responds to pressure from the *milieu exterior* in the form of responses or borrowing. Technical actions are sometimes responses to external pressure (resource scarcity for example), internal modifications and improvisation can also occur through borrowing from the *milieu exterior* (other groups’ practices). Finally, an accumulation of responses and borrowing can lead to mutation of the *milieu technique* and therefore a mutation of the *milieu interior*.

Leroi-Gourhan’s *chaîne opératoire* refers to the analysis of technical facts, technical tendencies, and *milieu*. So, how does this *chaîne opératoire* approach relate to cognition, if at all? If we accept the logic that all technical gestures are conscious and deliberate, this information can lend itself to an intimate view of the ancient producer’s logic, tool-usage, and complex social, ecological, and cognitive elements involved in ancient technological activity (Lemonnier, 1992, p. 1; Schlanger, 2005, p. 19). However, Leroi-Gourhan used a selectionist evolutionary model to approach the interrelated nature of things (objects, tools, material culture), which according to Leroi-Gourhan are products of the biological and social realms (Leroi-Gourhan, 1993). This evolutionary model rests entirely on a cognitivist understanding of the mind.

2.1.1 The evolutionary and cognitivist foundations of *chaîne opératoire*

A discussion of the selectionist evolutionary approach of *chaîne opératoire*, followed by examples of *chaîne opératoire* made up of technical facts, demonstrate that technical facts are the link between cognitivism and *chaîne opératoire*. A notion which seems to have been left out of many discussions of *chaîne opératoire* is that the framework was built upon a selectionist evolutionary model and a cognitivist theoretical foundation. Through a quick glance at any of Leroi-Gourhan's works, the reader finds tools such as arrows and hand axes organized by levels of sophistication. These classifications lead to outdated conclusions that one ethnographic group is more sophisticated than the other. For example, *Gesture and Speech* (published in French in 1964, translated to English in 1993) illustrates in great detail the parallel development of this outdated evolutionary model and the *chaîne opératoire* framework (Leroi-Gourhan, 1993). One could open the book to any page and find themselves reading this type of language:

“[The] enmeshing of tools and gestures in organs extraneous to the human has all the characteristics of biological evolution because, like cerebral evolution, it develops in time through the addition of elements that improve the operational process without eliminating one another. Earlier we saw that the brain of *Homo sapiens* still preserves all stages acquired since the fish stage, and that each stage, overlaid by the next, continues to play a role even in the most sophisticated forms of human thought.” (Leroi-Gourhan, 1993, p. 242).

This selectionist evolutionary model clearly utilizes a cognitivist lens in its approach to integrating *chaîne opératoire* and the mind. Let us recall Leroi-Gourhan's theory that the *Homo sapiens* preserve all stages of cognitive development acquired since its early evolution from the “fish stage”. This quote, and the passage overall, exemplifies the notion that our mind functions like a receptacle for storing information, and as a central planner which allows for the function of manipulating symbols or internal representations. This cognitivist approach places the mind firmly within the skull - all thoughts, processes, computations, and representations take place internally.

Following Leroi-Gourhan, Lemonnier develops *chaîne opératoire* through the lens of anthropology (Lemonnier, 1986; Lemonnier, 1992). Despite also relying on a cognitivist approach, Lemonnier's *chaîne opératoire* remains a popular method. The following figures display two (of six) methods Lemonnier suggests for description and analysis. These methods reduce a technological process to a predetermined linear order of operations based on mental representation (or blueprint-thinking). The actor has an internal representation of the object or task at hand, they execute the actions *onto* or *toward* the matter, and the output results in the change in material from its original state to its manufactured state Fig. 1.

Another Fig. 2 demonstrates the same style of a predetermined operations based on mental representation (blueprint-thinking) to describe two carpenters' processes:

These figures demonstrate a clear cognitivist approach to a technological process. This *chaîne opératoire* approach made up of technical facts only is illustrated by operations based on blueprint-thinking. There is no depiction

EACH STEP IN A SEQUENCE COMPRISES:

(Indicators)	SCIENTIFIC NAME, LOCAL NAME, PLACE, TIME				
(Elements)	[AGENT + TOOL → GESTURE + ACTION ON MATTER] (RAW MATERIAL) = STATE OF MATTER				
TECHNOLOGICAL RELATIONS	human animal inorganic energy	active passive machine	kind of percussion assemblages	raw material partial products	products
SOCIAL RELATIONS	property control decisions				

Fig. 1 Description and analysis of a sequence (Lemonnier, 1992, p. 31)

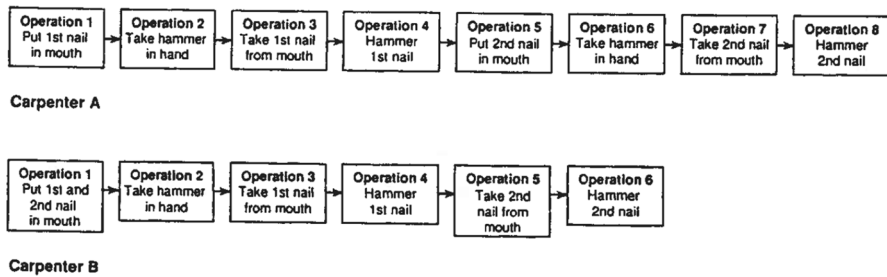


Fig. 2 Description and analysis of a sequence (Lemonnier, 1992, p. 33)

of the interrelated nature of each technical fact in Lemonnier's *chaîne opératoire*. Let us recall the three issues with cognitivism outlined previously: (1) the replacement of physical quantities or things with symbols can obstruct opportunities to exploit the physical world as a tool for problem-solving, (2) similarly, conceptualizing a problem in terms of input-output mapping invites a view of cognitive processes as *passive computation*, and cannot accommodate situations wherein the output involves epistemic action, and (3) that simplifying information into symbols to search for an optimal solution does not account for, or can obscure, the role of history in solving the same or similar problems. In Lemonnier's *chaîne opératoire* it is unclear how one can include the exploitation of the physical world for problem-solving (issue 1). There is a sense of passive computation and furthermore no accounting for epistemic action (issue 2). Finally, although in Fig. 1 there is a row designated for "social relations" in the *chaîne opératoire*, it is unclear how these social relations affect the process of doing (issue 3). It becomes clear that the link between cognitivism and *chaîne opératoire* is a *chaîne opératoire* made up solely of technical facts. I would note also that the visual depiction of the *chaîne opératoire* framework matters greatly. Throughout this article I re-envision the *chaîne opératoire* framework to better represent the theoretical developments which I incorporate into the framework.

3 Non-cognitivist approaches to technical facts

How can a *chaîne opératoire* approach made up of technical facts *not* be cognitivist? Is there a way to analyze technical facts in a non-cognitivist manner? In Lemonnier's figures depicting *chaîne opératoire* one issue which is particularly noticeable is that epistemic action is not accounted for. By accounting for epistemic action (instances where cognitive output *is a physical action* meant to discover new information that contributes to the successful completion of a problem), there can be a non-cognitivist approach to *chaîne opératoire*. Cognigrams exemplify a *chaîne opératoire* approach made up of technical facts which *does* account for epistemic action (Haidle, 2010; Lombard & Haidle, 2012; Haidle & Stolarczyk, 2020; Haidle, 2024).

This Cognigram (Fig. 3) for the production of fire depicts eight phases of technical facts employed in producing fire. It is clear that while this Cognigram may only illustrate technical facts, we see that there are multiple foci involved, each of which contains phases which are related to other foci. For example, within the initial focus (production of fire) there are subsequent perceptions of sub-problems (such as fire, flame, spark, tools, and raw material) which need solving in order to satisfy the initial focus. Epistemic action is evident in this Cognigram. Cognitive output *is a physical action* (such as “Phase 1” search for long-burning raw material) meant to discover new information (search for suitable material for fire) that contributes to the successful completion of a problem (producing a source of heat). Each of the phases in this Cognigram illustrates epistemic action. It is clear that while there is an initial perception of a need, and some partial planning, there is no predetermined blueprint for satisfying the need (production of fire). This Cognigram approach demonstrates a non-cognitivist approach to a *chaîne opératoire* made up of technical facts. However, I submit that this Cognigram approach to *chaîne opératoire* still does not account for technical tendencies and *milieus*.

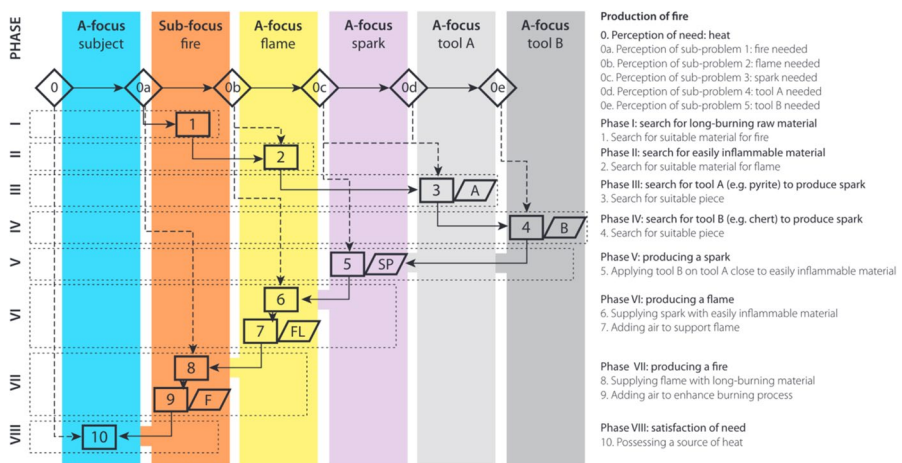


Fig. 3 Cognigram for the production of fire (Lombard & Haidle, 2012)

Another noteworthy approach is Fairlie and Barham's *chaîne opératoire* study which takes a Gibsonian perspective of task structuring and tool-making events alongside cognition (Fairlie & Barham, 2016). Born out of ecological psychology, Gibson's theories of affordances and perception-action accounts for perceptual information gathered from the environment wherein responses are learned through experience or action (Gibson, 1979). Through this perspective, variables in task structuring and tool-making can be notated as relevant data in understanding cognition (Fairlie & Barham, 2016, 646). Fairlie and Barham criticize the Cognigram approach as overly hierarchical and modular (Fairlie & Barham, 2016, 647). They state that the Cognigram approach overly simplifies the nature of task-structuring, that the Cognigram cannot account for the long-term perceived needs of multiple individuals or groups with differing motivations. They also argue that the increasing complexity of Cognigrams may incorrectly suggest a gradual linear change in cognitive evolution. Their perception-action approach is meant to address and overcome these issues. The methodology involves video recording tool-making activities and using visual observation to identify behavioral variables such as: posture, mobility, tool, and object moving, tool and object choice, and tool organization, among others. Later, "Task Diagrams" were constructed to show potential modular structure for each task and behavioral variables. An example of a Task Diagram is shown below (Fig. 4).

The Task Diagrams are meant to illustrate each task divided into units and further divided into Action Sets (groupings of similar gestures such as "mobilize"). On the left we see gestures, whereas on the right we see changes in behavioral variables as well as the affordances which allow for the toolmaker to progress to the next Action Set. This approach is effective in observing the relationship between an action, related affordances, and the subsequent action. This gives us more information about the technical facts involved in a process as well as the way in which materials inform our way of thinking and doing. This approach does not underscore epistemic action in the same way that Cognigrams do, but the notion is clearly present in the sense that our actions

Oldowan Core and Flakes	Tools Objects and Final Affordances
Mobilize; choose raw material	Medium hs and core
Mobilize; assume seated posture	Hammerstone & raw material stable
Tilt core to search	Suitable area located visually
Prepare striking platform, tap, strike	Flake detached
Assess flake visually and haptically	Keepers stored separately
Repeat previous 3 action sets as a unit until end of Stage	Enough keepers collected (6) Put down medium hs Put down core
Select flake for retouch	Flake
Retrieve small hammerstone	Small hs Hammerstone and flake stable
Small unifacial removals from ventral side around perimeter	Retouch completed Hammerstone and flake put down

Fig. 4 Task diagram of oldowan core and flakes (Fairlie & Barham, 2016)

(cognitive output) affect and are affected by affordances, from which information is available to the toolmaker, that leads to the completion of a task.

One concern I have with these Task Diagrams is that although there is suggested movement or linking from one action set to another, there is an apparent emphasis on the 1:1 relationship of an action or group of actions and the related affordances. This 1:1 relationship of action and affordance can limit analysis of highly complex processes. In contrast, I appreciate the visual enmeshment of foci, phases, perception, and action that the visualization of Cognigrams offers. In both Task Diagrams and Cognigrams there is excellent work toward developing a framework for integrating embodied, extended, and enacted cognitive theories into tool-making sequences. However, I maintain that both Task Diagrams and Cognigrams only support a *chaîne opératoire* approach made up of technical facts. There are still technical tendencies and *milieus* which, once incorporated, will offer a way to relate both concrete and abstract elements of making and doing with a framework such as *chaîne opératoire*.

When we look closely at the real-world behaviors of planning agents, it is clear that there is a complex interplay between perception, planning, action, and the surrounding environment. It's also important to note that in many cases, actions do not have the desired effect and problem-solving requires re-thinking and re-planning. Additionally, in some cases, the plan or blueprint is only partial and therefore carrying out the partial plan is dependent on the local environment. Instead of cognitivist models, a multi-factor decentralized approach to cognition is needed. This is not to say that cognition has zero computational activity. Instead, there is a complex interplay of multiple forces through which the brain is embodied and emerges: bodily, mechanical, some fully external, and some internal. Cognition is not about content or internal representations; it is an active process through which we are able to understand the world, solve problems, judge, explain, and more generally speaking - do things (Gallagher, 2013). To be sure, the brain (the organ) has always been constrained by the nature of the evolutionary process, and it must create new solutions and form adaptive strategies on the basic existing cognitive functionality and resources. However, the *mind* is empowered by its ecological surroundings which allows us to exploit other agents, actively seek input, manipulate computational tasks, and offload acquired information into the world.

Leroi-Gourhan's impetus for developing *chaîne opératoire* was to uncover the intermeshing of gestures and tools, an idea which lends itself naturally to phenomenological theories of cognition. He stresses through discussion of technical tendencies that tasks can be carried out not only through blueprint-thinking but through socially learned behavior. It's clear that in developing *chaîne opératoire*, Leroi-Gourhan struggled to reconcile his forward-thinking theory with his grounding in a cognitivist, deterministic, teleological background. His intention was to develop a framework based on a paradigm which did not yet exist. So, *chaîne opératoire* relied on what was considered to be a sound basis - cognitivism, biology, and evolution. While a *chaîne opératoire* approach made up of technical facts can, as we see now, take a non-cognitivist approach, I argue that it still cannot support the phenomenological philosophy of cognition in *chaîne opératoire*. It should be obvious now that there is indeed room to explore how we might broaden the scope of *chaîne*

opératoire by moving away from the cognitivist model, and by including elements such as technical tendencies and *milieus*.

4 Technical tendencies and *milieus*

Now, as we have seen in the previous section, a *chaîne opératoire* approach made only of technical facts illustrates a predetermined order of operations based on a blueprint-thinking which is deterministic, and cognitivist. But Leroi-Gourhan indeed offered another perspective, one which is often left out of use cases of *chaîne opératoire* because it has never been integrated into what we consider *chaîne opératoire*. Leroi-Gourhan posited that transmission, diffusion, and innovation (cognitive functions) could be analyzed through technical tendencies (or *la tendance technique*), as well as his three key concepts *milieu exterior*, *milieu interieur*, and *milieu technique* (Leroi-Gourhan, 1945). First, there must be a clear understanding of technical tendencies and *milieus*. Second, I develop the connections between technical tendencies and *milieus* with theories of embodied, extended, and enacted cognition.

How are technical tendencies linked to theories of embodied, extended, and enacted cognition? These technical tendencies are *socially informed* choices; that is, they are aspects of cognitive function which are affected by the social ecology, by institutions, practices, and beliefs. All cognitive functions are also affected by being within a body; therefore they are embodied (Varela et al., 1991). We can understand technical tendencies then as related to the embodied mind and the socially extended mind, a theory which encapsulates the extended and enacted cognition as well as social affordances (Gallagher, 2013) and emotionally embedded engagement with the world”, much of which is shaped by tools, technologies, ecological factors, and social practices (Gallagher, 2013, p. 8). Technical tendencies are therefore linked to socially embodied, extended, and enactive cognition and cannot conform to a cognitivist framework. They are dynamic, embodied, extended, and enactive processes rather than a mental state, computation, or static internal representation. It is for this reason I believe that technical tendencies have not been incorporated within *chaîne opératoire*. To do so would be to create a fold in the otherwise one-dimensional cognitivist *chaîne opératoire*.

Similar to the broad perspective of technical tendencies, Leroi-Gourhan theorized that transmission, diffusion, and innovation should be analyzed from the greater perspective of a social group in its entirety, not only the individual. He posited that these cognitive functions (transmission, diffusion, and innovation) could be analyzed through his three key concepts previously outlined in Leroi-Gourhan’s *chaîne opératoire*: *milieu exterior*, *milieu interieur*, and *milieu technique* (Schiffer 1994, 2003). *Milieu exterior* enables us to observe the entanglement of a group’s cognitive function with the natural environment, material culture, and ideas of other groups. Does this not bring to mind embodied, extended, and enactive cognition (Varela et al., 1991; Wheeler, 2011; Gallagher, 2013; Malafouris, 2013; Kiverstein, 2020)? So long as a person or group is *engaged* (Malafouris, 2013) with an element of the environment, that element is a constituent of the cognitive process

(Gallagher, 2013). This *milieu exterior* can include the material cultural ecology (Ingold, 2012) as well as socio-cultural practices, ideas, or beliefs. In the case of *milieu exterior*, we specify ideas or beliefs of *others*. Similar to technical tendencies, *milieu exterior* offers a link between *chaîne opératoire* and socially extended, enacted cognition. *Milieu interieur* describes the ideas, beliefs, and memories held within a group. Where *milieu exterior* describes cognitive functions affected by others outside of a group, *milieu interior* describes cognitive functions affected by others *within a group*. Again, this brings to mind theories of socially extended, enacted cognition. Finally, the *milieu interieur* contains traditions and perpetuated modes of thought and action which are the group's *milieu technique* (or technical milieu) – the third key concept.

As previously outlined, the *milieu technique* is perpetually evolving. It is posited that acquisitions to the *milieu technique* are seldom erased (Pfaffenberger, 1992; Clark, 1997; Malafouris & Koukout, 2018). In other words, technology and techniques (within the *milieu technique*) often show an “imprint” of the context from which it arose because they must be built upon or with influence from existing sociocultural resources (Pfaffenberger, 1992, p. 500). The *milieu interior* is not static, in order to “keep the network [of a sociotechnical system] functioning” it may *require* technical or social modification (Pfaffenberger, 1992, p. 502). This idea of a perpetually evolving *milieu technique* was quite novel at the time Leroi-Gourhan proposed it, and is relevant to recent studies of cultural memory and skill which will be addressed in the forthcoming discussion (Lombard & Haidle, 2012; Walls, 2019). I propose that these three *milieus* can be understood through theories of extended and enacted cognition. Hereafter, technical tendencies and *milieus* should be understood to encompass these theories of embodied, extended, and enacted cognition.

Was *chaîne opératoire* cognitivist to begin with, or did we make it that way? To be sure, in the development of *chaîne opératoire* a cognitivist proposal was offered for the analysis of technical facts. Scholars have used this methodology successfully for many decades now. However, some have come to criticize *chaîne opératoire* in that it lacks the capacity to grapple with Post-Processual and Process Archaeology paradigms (Schlanger, 1994; Schlanger, 2005; Dobres, 1999; Audouze, 2002; Malafouris & Gosden, 2015). And while Leroi-Gourhan certainly struggled to reconcile technical facts with technical tendencies and *milieus*, they were there all along. Unfortunately, these aspects of the theoretical background of *chaîne opératoire* remain to be integrated. This signals to me that there has not been a thorough assessment of the theoretical development of *chaîne opératoire* and of Leroi-Gourhan's philosophy. I propose that by integrating technical tendencies and *milieus* with *chaîne opératoire* we may find that embodied, extended, and enacted theories of cognition find their places easily within this framework.

5 Methods for incorporating technical tendencies and *milieus*

As I have stated, a *chaîne opératoire* made up of technical facts – which is a popular understanding of “*chaîne opératoire*” – takes a cognitivist approach. But I believe that this *chaîne opératoire* of technical facts is only part of what was intended. There

is in fact plenty of forward-thinking cognitive theory nesting within *chaîne opératoire*, it only needs integrating. I submit that the theories of technical tendencies and *milieus* developed by Leroi-Gourhan encompass many current approaches to cognition. These approaches include: (1) embodied cognition which proposes that the mind is affected by being in a body (Clark, 1997; Clark, 2008; Gallagher, 2005; Varela et al., 1991), (2) extended cognition which claims that what is outside the brain is not necessarily outside the mind and that cognition is not only a matter of internal representation (Rupert, 2009; Wheeler, 2011; Silberstein & Chemero, 2012; Gallagher, 2013; Malafouris, 2013; Kiversteinn, 2020), and finally (3) enactive cognition puts the two aforementioned theories into action – literally cognition takes place as it is enacted in time and space (Gallagher, 2013; Malafouris, 2013; Kare Stokholm Poulsen, 2019; Walls, 2019). Methods for incorporating embodied, extended, and enacted theories of cognition with analytic frameworks are discussed hereafter. These methods serve as examples I draw upon later in proposing a *chaîne opératoire* framework which incorporates theories of embodied, extended, and enactive cognition.

These theories of embodied, extended, and enacted cognition in relation to material culture have been approached via methodologies including sensory anthropology and Four-Field Co-evolution which I find particularly compelling. As opposed to Cognigrams and Task Diagrams which address technical facts, these two approaches offer insight into how we might integrate social nuances (i.e., technical tendencies and *milieus*) with an analytical framework (i.e., *chaîne opératoire*). Turning away from Western cognitive science, and away from the Euro-American five-sense model without doing away with an anthropology of culturally unique senses, Geurts follows the tradition of phenomenological anthropology with central themes of embodiment and orientation (Geurts, 2003). This approach is rooted in cultural psychology and cultural phenomenology in an effort to produce a framework for reconciling the sensorial experience of being human with culturally specific notions of personhood, identity, and meaning-making grounded in the interrelational nature of the embodied experience, thought, feeling and cultural-psychological orientations. Another notable effort to understand cognition from a culturally-grounded position is the “Four-Field Co-evolutionary” model (Lombard and Högborg, 2021). Through a grounding in well-developed models such as embodied, extended, and enacted cognition, in addition to Material Engagement Theory (Malafouris, 2013), and her own studies of evolution and anthropology, the Four-Field Co-evolutionary model suggests taking into account all relevant biological aspects, technology, society, and ecology as four dynamic reciprocal influences which feedback resulting in causal influence and evolution of each element (Lombard & Högborg, 2021, 144). In this model, all aspects of culture including social learning, the socio-economy, and technology are included.

Walls also takes a phenomenological approach to cognition and *chaîne opératoire* incorporating Material Engagement Theory and ethnoarchaeology in his work studying Inuit kayak-making (Walls, 2016; Walls & Malafouris, 2016). Walls proposes that the Inuit kayak-making practices are learned not through internal schema (blueprint-thinking) but instead learned and shared through active engagement, generational memory, and situated cognition – learning is a

didactic process which is highly social and situated not only in physical spaces but in the generational memory and beliefs of the Inuit people (Walls, 2016; Walls & Malafouris, 2016). Not only is the cognitive aspect of production situated in this way, but also hunting skills are informed by the sensorial experience of making the kayak. The kayak must glide straight forward into range in order to harpoon the target – this skill is acquired not only through gliding practice on the water but also through the sensory experience and memory of the didactic process of making a symmetrical kayak (Walls, 2016; Walls & Malafouris, 2016). In continuation of this work, Walls and Malafouris propose that “knowing is a fundamentally creative process involving social, material, and environmental dimensions that are situated in intergenerational praxis” based on a study of the knowledge and improvisation of Nattilingmiut caribou hunts (Walls & Malafouris, 2016, 625). They argue that the skill involved in the caribou hunt is not learned through internal representations (blueprint-thinking) but through creative improvisation, sensory awareness, physical fitness, and personal experience (individual and generational memory). Again, we find that cognition is not an internal process. It is specific to each individual or group’s experiences, sensorial makeup, beliefs, and skill-sharing practices. In Walls’ (Walls, 2019) work, he draws on a postphenomenological and Material Engagement Theory approach to propose that human ways of *being* were not developed based on their “pre-evolved” capacity for symbolic representation (blueprint-thinking) but on technical experience which is developed through a transformational process wherein hunters develop the self and intentionality by “attuning subjective capacities for sensory awareness and creative responsiveness” in the dynamic field of environmental practices which make up a hunt (Walls, 2019, p. 265). In other words, the self, cognition, and therefore the skilled use of the bow and arrow is an emergent property of technical practice. This emergence of self and cognition arises between and through the hunter and the technology, situated in the dynamic environment of the hunt, enacted and embodied through *doing*, all of which is inherently social.

It is imperative to beware of the bias of the analyst in such ethnographic or ethnoarchaeological studies. We must consider Gosselain’s critiques especially on the origins of ethnography (Gosselain, 2016). Gosselain reminds us that the origins of ethnoarchaeology are rooted in what are ultimately deeply racist Western views of non-Western peoples. These views describe non-Westerners as exotic, primitive, more closely related to prehistoric peoples, and who are furthermore perceived as “living fossils” (Gosselain, 2016, p. 219). It is imperative that the analyst be aware of these origins and to not exoticize others, or to consider non-Western groups as “untouched” by Western technology. Despite whatever awareness the analyst may have of these issues, Pink warns that the observer may also fall into the trap of becoming sensorially engaged in the ethnographic study themselves; therefore ethnography must also become a reflexive and reflective science (Pink, 2015).

The ambition of the three aforementioned approaches to cognition is to understand cognitive processes broadly as they relate to a structure while also acknowledging the primacy of the human experience of *being* and its fundamental role in cognition. This is precisely how *chaîne opératoire* must be reconsidered: to understand technological

and cognitive processes as they relate to a structure while also acknowledging the enmeshment of the human *being* with gesture, tool, material, as well as both the abstract and physical environment (which, if you recall, was the initial proposal for *chaîne opératoire*). I propose that Leroi-Gourhan's technical tendencies and *milieus* should be considered as crucial elements of any *chaîne opératoire* alongside the already well-represented technical facts. These technical tendencies and *milieus* are the link between *chaîne opératoire* and embodied, extended, and enacted cognition.

6 An overdue overhaul

How can *chaîne opératoire* be reconsidered in a way that reflects the immensely abstract nature of human *being* and cognition, while also relating to a methodological framework? First, we must re-envision *chaîne opératoire*. Despite the name, we should not consider *chaîne opératoire* as a framework for visualizing a chain of operations, or predetermined blueprint-thinking. This one-directional, one-dimensional, sequential visualization is so central to the framework that to break away from it we must reimagine the framework visually. In order to do so I consult network theory as a means of bringing together the various elements which I argue *must* be included within a *chaîne opératoire* approach. Can a *chaîne* (*chaîne opératoire*) be considered an element of a network of *chaînes* (as in ANT)? First, a definition of *chaîne* is needed. While *chaîne opératoire* refers to the methodological framework, I propose the term *chaîne* to refer specifically to a selected sequence of events (technical facts) and enmeshed elements (technical tendencies and *milieus*) within a technological process. In the case of pottery, a *chaîne* could refer to the process of procuring and preparing clay for use, or of the formation methods of a vessel, related textile practices, enmeshed gender ideologies or politics, or even the cosmological views related to firing. A *chaîne* can also refer to any combination or all of these events and elements depending on the nature of the study. A *chaîne* can and does intersect, overlap, and connect to other *chaînes* as well. So, while we can isolate one *chaîne* with a beginning and end for analysis, it is important to acknowledge that this is a tool for analysis and is not indicative of the nature of *chaînes*. Let us then define a *chaîne* as a selected sequence of events (technical facts) and enmeshed elements (technical tendencies and *milieus*) within a technological process, chosen for analysis. This term *chaîne* allows us to delineate the part of a production process under consideration, while acknowledging the larger network of *chaînes* within which it exists.

If we consider *chaînes* as part of a *chaîne opératoire* network, we may incorporate technical tendencies and *milieus* (aspects of embodied, extended, and enacted cognition) more effectively within the framework. Engaging with a network approach to *chaîne opératoire* I propose to consider each technical fact, technical tendency, or element of the *milieu* as a node with infinite possibility for connections to other nodes on a multi-dimensional network. This network of entangled *chaînes* replaces the traditional one-directional, one-dimensional, linear depiction of blueprint-thinking that *chaîne opératoire* is often associated with. It is important to amend the usual visualization of *chaîne opératoire* because its popular depiction can encourage a cognitivist approach, mental representationalism, and

blueprint-thinking. Envisioning *chaîne opératoire* as a network comprised of entangled *chaînes*, it is possible to add connections to nodes wherever there are connections to any technical fact, technical tendency, or element of the *milieus*. This allows for a scalable “*network opératoire*” comprised of *chaînes* which is inclusive of all crucial elements of the *chaîne opératoire* framework.

To compare the popular depiction of *chaîne opératoire* with my own re-envisioning, I begin with Fig. 5 which shows stages of cutting clay with a string tool. This cognitivist *chaîne opératoire* approach isolates technical facts along a one-directional, one-dimensional, plane indicating blueprint-thinking toward a predetermined goal. Each node represents a technical fact isolated from technical tendencies and the *milieus* (physical and non-physical ecology) of the maker(s). From the left we identify the potter is using their hand(s), to hold a string taught, and apply force to remove clay from a pottery wheel.

Instead, we should re-envision *chaîne opératoire* as a *network opératoire* of intersecting nodes. To begin we may re-envision the cognitivist *chaîne opératoire* depicted in Fig. 5 by tracing further connections. This can be re-envisioned as depicted in Fig. 6 which incorporates additional related technical facts. However, we must also include technical tendencies (Fig. 7) and *milieus* (Fig. 8).

Elements of technical tendencies and *milieus* are included wherever they may be connected to the process of making. Where there are intersections between technical facts, technical tendencies, and *milieus*, we see how embodied, extended, and enacted cognition can be integrated. We may now also trace connections in any direction to isolate *chaînes* for further investigation. This re-envisioned *network opératoire* offers a non-cognitivist perspective of the *chaîne opératoire* framework. This *network opératoire* accounts for a multi-dimensional scalable network of entangled *chaînes*, while also allowing for the isolation of individual *chaînes* for analysis. This is one of infinite visual representations possible, for wherever there are nodes, there can be connections. While this specific *network opératoire* highlights the making of an object, this framework is not object-centered. Furthermore, the lines represented here are not finite – they may connect, overlap, and expand wherever there are connections. The proposed *network opératoire* framework can apply to any process and is not limited to *chaînes* which have a clear beginning and end. Furthermore, this is a two-dimensional visualization for the sake of simplicity however, we should imagine this network in three-dimensions to include the possibilities of space and time as elements of a *network opératoire*.

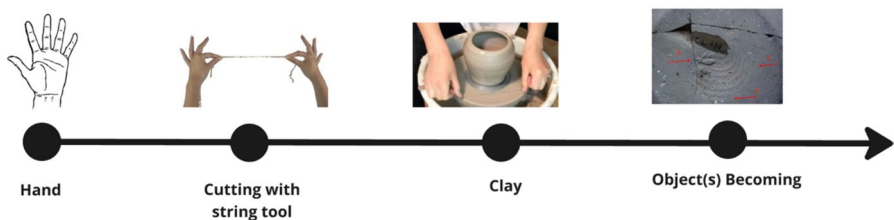


Fig. 5 Cognitivist approach to *chaîne opératoire* in the case of removing clay from a wheel using a string tool

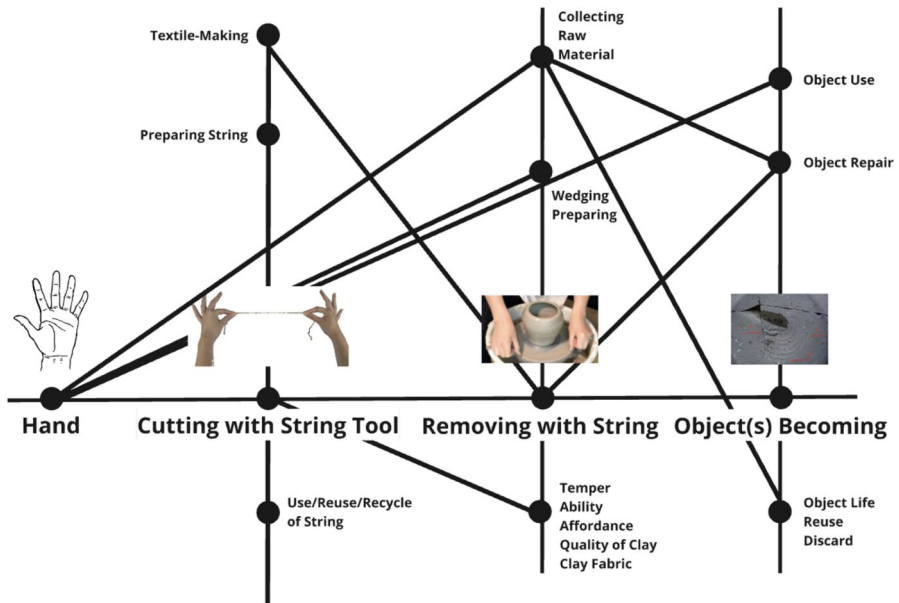


Fig. 6 Reconsidered *chaîne opératoire* as a *network opératoire* comprised of technical facts

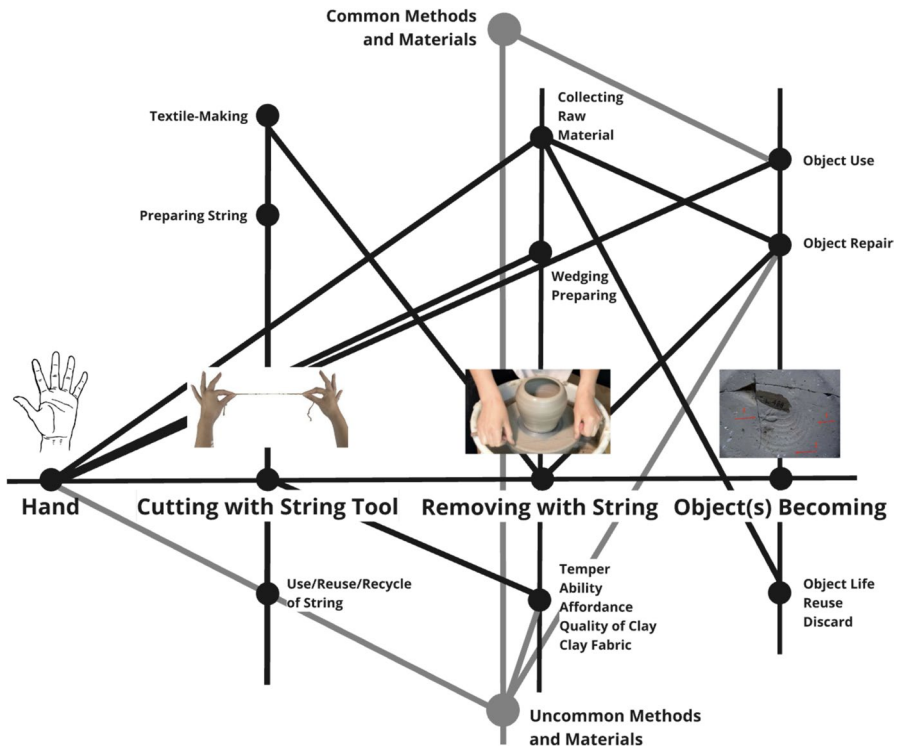


Fig. 7 A *network opératoire* which includes technical tendencies in gray

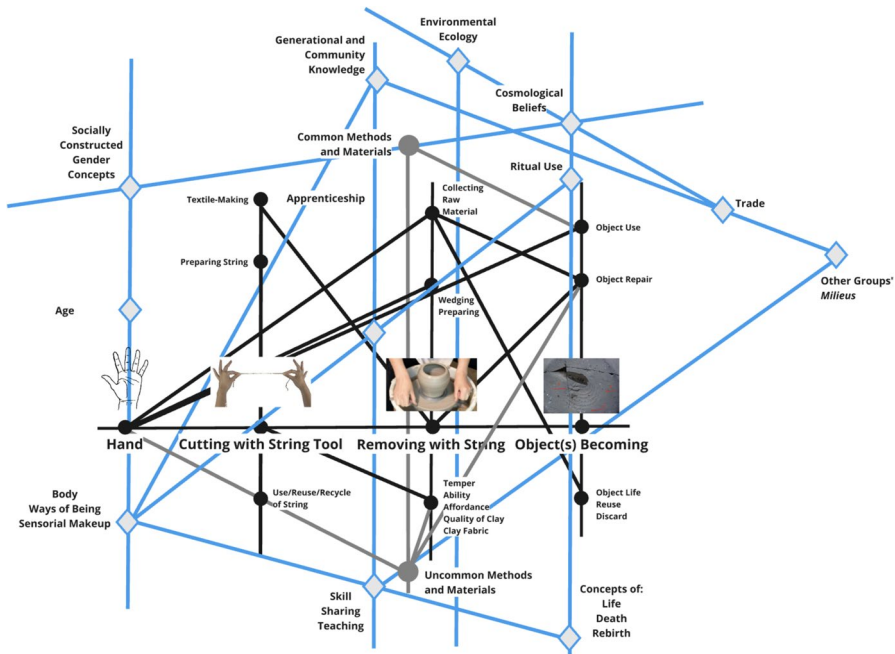


Fig. 8 A network opératoire which includes *milieus* represented in blue

After defining *chaînes* and re-envisioning *chaîne opératoire*, we must understand how this can function in practice. Additional methods must be introduced in order to incorporate technical tendencies and *milieus* (embodied, extended, and enacted cognitive theories) within the *chaîne opératoire* framework. Utilizing the concepts of technical tendencies, *milieus*, bodily ways of knowing (Geurts, 2003), and the Four-Field Co-Evolutionary model (henceforth Four-Field model) (Lombard & Högberg, 2021), I propose to reconsider the methodology of *chaîne opératoire*. Instead of analyzing processes through technical facts according to the cognitivist approach and mental representationalism (see Figs. 1 and 2), or through technical facts although through a non-cognitivist approach (see Figs. 3 and 4), we should regard *chaînes* as *phases of becoming* via this network of technical facts, technical tendencies, and *milieus* (see Figs. 5, 6, 7 and 8). In doing so, agents (objects or non-objects) and their cognitive functions are reframed as *in process* through and with each other. A process, agent, or object, is henceforth in a constant state of *becoming* (Malafouris, 2013). In order to integrate these technical tendencies and *milieus*, I have proposed to draw on approaches such as bodily ways of knowing (Geurts, 2003), and the Four-Field model (Lombard & Högberg, 2021). I offer below a reconsidered *chaîne opératoire* framework which includes the aforementioned elements. This framework is comprised of six elements, succinctly listed below, which have been developed throughout the article.

- (1) Consider *chaînes* as a as a selected sequence of events (technical facts) and enmeshed elements (technical tendencies and *milieus*) within a technological process, chosen for analysis.
 - a. Identify where other related elements of the process may intersect with this *chaîne* to create a network of *chaînes*.
- (2) Gather pertinent ethnographic data related to technical tendencies and *milieus* (following methodologies such as Geurts' bodily ways of knowing and/or the Four-Field model).
- (3) Consider how technical tendencies and *milieus* (entangled materials, the environment, socio-cultural ways of knowing, learning, and remembering) may affect elements of the *chaînes*.
 - a. Include these as additional *chaînes* wherever they intersect (See Figs. 7 and 8).
- (4) Examine and analyze this decentralized multi-dimensional network in relation to all aforementioned connections and intersections, as opposed to one singular *chaîne*.
- (5) Utilize the ability to trace connections throughout space and time ad infinitum so long as there are connections via technical facts, technical tendencies, and *milieus*.
- (6) This *network opératoire* (a network of *chaînes*) now demonstrates technical facts, technical tendencies, and *milieus*. Through incorporating these elements, we appreciate that the *network opératoire* represents a continuous *process of becoming*. Furthermore, we see where theories of embodied, extended, and enacted cognition are reflected in this re-envisioned *network opératoire*.

7 Concluding remarks

The approach I have outlined is a re-envisioning of the *chaîne opératoire* framework which accounts for non-cognitivist approaches. While there have been theoretical discussions of cognition and *chaîne opératoire* (Schlanger, 1994; Schlanger, 2005), and discussions of integrating non-cognitivist approaches with a *chaîne opératoire* composed of technical facts (Lombard & Haidle, 2012; Fairlie & Barham, 2016), I hope to have offered a methodology which is useful in practice and which includes theories of embodied, extended, and enacted cognition by way of incorporating technical tendencies and *milieus*. I propose that there is no need to reinvent the wheel so to speak; *chaîne opératoire* has always possessed the capability of integrating theories of embodied, extended, and enacted cognition. This fact has unfortunately been bypassed. By revisiting the theoretical background upon which *chaîne opératoire* was conceptualized, we see that technical tendencies and *milieus* are similar to the contemporary cognitive theories known as embodied, extended, and enacted cognition. The re-envisioned *network opératoire* I propose

stands alone in that it takes a non-cognitivist approach while also addressing technical tendencies and *milieus*. It is clear that theories of embodied, extended, and enacted cognition can aid archaeologists greatly by reframing, reconsidering, and re-excavating, existing methodological frameworks such as *chaîne opératoire*. I hope it is clear that while the *chaîne opératoire* has been seen as a cognitivist framework, it was not intended to be. *Chaîne opératoire* came into existence through groundbreaking notions of the phenomenological nature of human *being* and the enmeshment of gesture and tool. While *chaîne opératoire* has been utilized as a cognitivist framework, a *network opératoire* approach has the capacity to offer much more. In this case, a *network opératoire* approach includes technical tendencies and *milieus* as connections to embodied, extended, and enacted cognitive theories and furthermore reframes the way we think about the links between prehistoric minds and the production of material culture.

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