Comments for the American Philosophical Association Central Division Meeting, 2024
Symposium: Is Computation Medium Independent?
Zoe Drayson (UC Davis): Yes
Corey Maley (Purdue): No

Whether computation is medium-independent depends on what you mean by "medium-independence"

Danielle J. Williams
Washington University in St. Louis
danielle.williams@wustl.edu

Describing computation as "medium-independent" was recently popularized in the physical computation debate with the introduction of the mechanistic account of physical computation. The mechanistic account is theory of what it is to be a mechanism that has the function of computing. It is not a theory that draws the relation between a formal computational description and an implementing system. However, since the popularization of the term, it seems to have taken on a life of its own by some without them paying careful attention to how it's understood within the theory in which it's presented. Medium-independence, is not, for example, a concept that can be used interchangeably with the concept of multiple realizability. Yet, it often is. So, why does this happen?

There are two main places where the term "medium-independence" crops up when it comes to theories of computation. The first is Haugeland (1985). In *Artificial Intelligence: The Very Idea*, Haugeland gives a theory of formal systems. He describes formal systems as "independent of the medium in which they are embodied where the same formal system can be materialized in any number of different media, with no formally significant difference whatsoever. For Haugland, "digital, formal systems may have "higher-level sameness" while differing in the physical structures that make them up" (pg. 58). For Haugeland, "higher-level" means the formal, descriptive level.

Compare this idea to **multiple realizability**. According to the Putnam/Functionalism picture, multiple realizability is the idea that mental states can be realized by different physical states. Functionalism takes this idea and asserts that we can describe those mental states formally—sometimes computationally, without reference to the physical realizers. Here we can see that what Haugleland is describing is something like the *multiple realizability* of formal systems. In the Haugeland sense, medium-independence is something like multiple realizability. Call this **MR-MI.**

A theory of computational implementation makes good on the MR-MI's promise when it comes to physical computation by drawing the relation between the formal computational description and the physical implementing system: it tells us when some physical system implements the computational description. This is why theories of implementation are meant to extend to cognitive science. Thus, the implementation relation is directly related to **MR-MI.**

The other place "medium-independence" crops up is with the mechanistic account of physical computation (2015). This version takes the concept of medium independence from Garson (2003). Garson describes Adrian's 1928 theory of how we should understand information transmission in the electric activity of neurons. This conception is based on the generality of nervous transmission: basic principles of information transmission in neurons obtain among several types of sensory receptors, biological taxa, and among motor neurons. The ubiquity of the structure of the nervous impulse implies the ***medium independence*** of the sequence: that the temporal structure of the sequence can be instantiated across a wide range of physical mechanisms.

This idea is used to develop the mechanistic account of physical computation. According to this view, a process, such as performing a computation, is medium-independent if it can be realized by different kinds of physical mediums irrespective of the higher-level properties that they may interact with. However, medium independence in this sense *drops* the formal description (the abstracta), and instead, relies on the notion of a mechanism sketch rather than moving to a completely formal description of that mechanism, i.e., it relies on *abstraction* in terms of leaving out some details, rather than moving to a formal description.[1] Higher-level properties for this view, then are not, formal computational descriptions.

It's argued that medium independence *entails* multiple realizability: if a property or process is medium independent, then it can be realized in different physical media. However, the converse does not hold—for example, *a corkscrew* is multiply realizable, since corkscrews come in different varieties. But a corkscrew is not medium independent because *being a corkscrew* is a matter of interacting with a specific physical

[1] Sometimes the term "abstraction" is used when describing an abstract description of a physical system. I think this is a mistake because it gives the illusion that there is a seamless stepwise ladder from the mechanisms to the formal description. There is not ladder—if there were, we wouldn't need a theory of implementation!

medium, namely cork. The cork is the "higher-level" property in this theory. Call this version of medium independence '**MI**.' To recap:

> MI: Medium independence understood in terms of abstraction (i.e. mechanism sketch).
> MR-MI: Medium independence understood as multiple realizability.

MI and MR-MI cannot be used interchangeably and thus, the version of medium-independence that is being invoked must be specified. If the version is not specified, it becomes quite difficult to settle debates that center around questions such as: *is computation essentially medium-independent*? So, our first question should be: what do you mean by medium independence? It seems to me that our speakers each mean different things and they engage with various authors with their respective notions of medium-independence in mind. Because of this, it's possible that our speakers may *both* be correct in virtue of their arguments tracking different conceptions of medium independence across the dialectic.

MR-MI and the implementation relation

Zoe's view goes as follows:

> "there is no notion of physical computation which can be specified entirely in concrete terms… there is no such thing as 'concrete computation' which can be defined independently…. a concrete process only counts as a physical computation if it realizes or implements some mathematical computation."

Now that we've distinguished between MR-MI and MI, we can see that because Zoe is interested in the relation between a formal computational description and a physical system, that she is interested in preserving the MR-MI relation. She thinks that we can describe physical systems using formal, computational descriptions and that we identify physical computing systems when they meet certain implementation conditions. So, computation is essentially medium independent because we can describe a physical system as performing a computation without saying anything about the physical realizers and, if we want to know whether that system *literally* performs computations, that it is a computer, then we can draw the implementation relation.

Zoe organizes a series of arguments into three types: concreta, empirical, and analogicity. According to Zoe, each type of view provides a different way to argue for the idea that computation ***is*** essentially medium independent. I am going to focus on some of the views that Zoe mentions to draw out the difference between MR-MI and MI and how because of this difference, denying one does not also mean that we have to deny the other.

Polger and Shapiro (2023) are interested in computational descriptions of cognitive processes in the brain. In their paper, they aptly point out that the mechanistic account of physical computation's notion of medium independence relies on a conception of abstraction-as-subtraction rather than abstraction-as-abstracta. They go on to say that "subtracting details from a description of cognitive processes no more makes them multiply realizable than does subtracting details from a description of water make it multiply realizable. This argument targets the claim that medium independence in this sense entails multiple realizability. In other words, that the idea that computation is **MI,** does not entail that computation is **MR-MI**. This is just what we should expect as **MI** does not address the implementation relation. However, the idea that **MI** does not entail **MR-MI** does not mean that we no longer have a need for a theory of computational implementation—all that it means is that MI may not entail MR-MI.

One thing to keep in sight is that a theory of implementation is not meant to exclusively apply to brains. It's a question about which physical systems implement computations—perhaps the brain is one of them. Using the brain as a case study to deny that computation is multiply realizable *in general*, goes too far. Computation may very well be MR-MI even if the brain is not a computer. This is just a way to offer support for Zoe's conclusion against concreta arguments—so long as there are formal computational descriptions and physical systems that are said to perform those computational processes, then there is a still a need for a theory of implementation that draws the relation. In other words, just because MI does not entail MR-MI, does not mean that computation itself is not MR-MI.

Zoe also argues against various empirical arguments. These arguments have criticized the notion of MI specifically when it comes to neural computations. Chirimuuta especially has argued against the medium independence of neural computations because she thinks that there is more to neural computation than spike timing and frequency. She thinks that chemical transmission and other medium-dependent properties play a role in how the brain computes. But again, notice that this targets **MI.** It does not target what I'm calling MR-MI. So, even if neural computations are not MI, it does not mean that computation is not MR-MI. You can deny the mechanistic account of physical computation and all that comes with it and still accept that we need a theory of implementation that draws the relation between formal computations and physical systems.

One theory may help the other theory provide a more robust account of physical computation, but the success of one does not determine the success of the other—because they are addressing different questions about the nature of physical computation (Williams 2023). So again, against the empirical arguments, MR-MI still stands.

Analogicity arguments is where Corey comes in. He argues that because analog computation is not medium independent, then computation is not essentially medium independent. Corey's work targets **MI** specifically within the context of the mechanistic account of physical computation which is meant to capture analog computation. He thinks that because representational properties just are part of the system, that analog computations are not medium independent. And, if MI is meant to be the determining factor between which systems count as computers and which systems don't, and analog computing gets left off the table, then MI just isn't the way we should individuate computing systems. If we accept this, then we can say that computation is *not* essentially medium independent. Just as Corey does.

However, notice that because Corey is targeting MI, it does not also mean that computation is not MR-MI. In fact, both Zoe and Corey argue against MI! They both argue that in the MI sense, computation is not essentially medium independent. Where they differ is that Zoe thinks that computation is essentially MR-MI. Corey does express distrust in the implementation relation—a distrust that I share as well. But I think what's important to note here is that the difference between MI and MR-MI is worth paying attention to in the debate otherwise we might end up talking past eachother.

Citations:

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