From complementarity to non-duality: Seeing objects and processes as pragmatic constructs

Reply to Comments on "Thoughts and thinkers: On the complementarity between objects and processes"

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We argued in [1] that "the distinction between objects and processes is always contrived, and always misleading, and that science would be better served by abandoning it entirely" (p. 256). The distinction misleads by suggesting that "objects" and "processes" are distinct ontological categories. **Prentner** refers to this ontological distinction as a "false premise" (p. 229). We agree.

We based our argument on the formal equivalence between factoring a state space and factoring a dynamics defined on that state space, as illustrated in Fig. 1 of [1]. Objects and processes, we argued, "are complementary ways of describing persistence through time, and hence the possibility of observation and manipulation" (p. 257); i.e. complementary ways of describing the possibility of doing science. Hence the core concept underlying science is that of persistence, or in cognitive language, memory. The Free Energy Principle (FEP) of Friston and colleagues [2,3] is, we argued, an operational definition of persistence. It is also a Rosetta Stone, as it provides a formal translation between the languages of statistical physics and Bayesian inference. Moving the methodological focus from disparately-described hierarchies of objects or processes to the formal consequences of requiring persistence, therefore, provides a foundation for a scale-free science that dissolves the conceptual boundaries that have traditionally divided "physical," "life," and "social" sciences. This move is empirically productive, opening up avenues of investigation that are foreclosed by conceptual schemes that disallow, for example, thinking of biological cells as economic or political actors [4-6]. We believe moving from ontological distinctions to a more relational outlook usefully deconstructs other related dualities, such as active machine vs. passive data it processes, or real being vs. mere thought patterns in its cognitive system.

We employed a quantum-theoretic formalism in [1] because it explicitly links persistence to separability, i.e. the absence of entanglement between whatever system is "of interest" and that system's environment. It also makes it clear that separability, and hence a meaningful distinction between a system and its environment, is a low-energy, short-time approximation. If system and environment interact strongly or for an extended period of time, they inevitably become entangled, and therefore indistinguishable.

Parr reminds us that talking about a *persistent* system is always talking about a path in some larger state space. He constructs a path-integral representation of persistence in the formalism of classical dynamical systems theory, the formalism in which the FEP was originally developed. Using this

representation, Parr shows how conditional independence and hence distinguishability between a generic system and its environment arises as the amplitudes of propagators connecting families of paths approach zero. A time-persistent Markov blanket between a system and its environment corresponds, in this case, to conditional independence between paths of the system and its environment in their joint state space.

Dodig-Crnkovic points out that persistent systems can also be thought of as time-stable informational structures, in which case their internal processes are computations that preserve these structures. This way of describing systems "decomposes anthropocentric cognitive phenomena into fundamental informational structures and computational processes" (p. 226). We agree; indeed, a major point of our paper, and of the "diverse intelligence" research program [6] that it exemplifies, is that there is not only no need to be anthropocentric about cognition, but that there are theoretical, methodological, and empirical reasons not to be. To assume all cognition is like human cognition is to close off potentially-productive research directions on the basis of prejudice alone [4]. This is also the core message of the FEP, which shows that Bayesian satisficing is just a way of describing the internal dynamics of systems that maintain their Markov blankets [2].

Prentner characterizes objects and processes as "non-dual" to emphasize their conceptual inseparability. Both, he argues, are time-stable informational structures – "icons'' in the language of [7] – encoded on the boundary of any system that observers them. He agrees with our statement in §4 that even the observer's "self" is an icon. An interesting consequence of associating both experience and action with boundaries or "interfaces" – one never stated explicitly in [1] – is that isolated systems, which have no environments are hence no boundaries, can neither have experiences nor execute actions. What we refer to as the "universe" U in [1], therefore, is not an active-inference agent.

In contrast to Prentner, **Banerjee** and **Lyon** argue that the object-process distinction "often serves genuine epistemic and organisational functions … [and] remain essential tools in biology, cognitive science, [and] artificial intelligence" and that "[A]bandoning them altogether risks losing valuable insight and clarity." (Banerjee, p. 79). Both argue from a pragmatic perspective; e.g. Banerjee argues that "[O]bjects as abstractions are not mystical essences; they are tools." (p. 80). We fully agree. So are processes. Our point is that while tools are useful, they can also be constraining; when one just has a hammer, one looks for nails. Both hammers and the object-process distinction are appropriate tools for some purposes, but in different settings, different ways of acting on or conceptualizing the world may work better. The key is to not let one tool or perspective rule out the use of others.

Both Banerjee and Lyon invoke Bohr's [8] notion of complementarity, and point to wave-particle duality in quantum mechanics as a productive, and indeed theoretically essential, example of the process-object distinction. For Bohr, "wave" and "particle" are distinct ways of talking about outcomes of measurements of quantum states. It is the interaction implementing measurement – i.e. observation – that is the central concept, not the particle or the wave. Indeed, both of these concepts, imported as they are from classical physics, introduce paradox – in the form of the "measurement problem'' [9] – as soon as one moves away from the bare mathematical formalism. Hence while "particle" and "wave" remain useful terms for informal discourse, the concepts they name cannot be considered fundamental. A similar fate has befallen the classical concept of spacetime, which is now widely viewed as a coarse-grained representation of underlying, purely-informational processes [10-12].

Lyon urges that "[W]hat we eliminate we are in danger of forgetting, and there is a price for forgetting" (p. 122). We are unlikely, however, to forget an intuitive distinction that we all learn, or as some argue

[13,14], empirically confirm, as infants. What we suggest is not forgetting these distinctions, but rather developing theoretical frameworks that do not rely on them. It is the reification of ontological presumptions as theoretical foundations with restrictive methodological consequences that we are arguing against.

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