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► **To cite this version:**

Arnaud Rey. Better not to yell “URA” too fast. Author’s response. *L’Année psychologique*, 2024, N° 142 (2), pp.263-273. 10.3917/anpsy1.242.0263 . hal-04678310

HAL Id: hal-04678310

<https://cnrs.hal.science/hal-04678310v1>

Submitted on 12 Nov 2024

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This article has been accepted for publication in "Topics in Cognitive Psychology" and will be published in a special issue in 2024

*Author's response to the commentaries on the target article
["Associations are all we need"](#)*

Better not to yell "URA" too fast

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Running Head: Reductionism

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Abstract

In this response to the comments made on my opinion article entitled "Associations are all we need", I underline three points that characterize the theoretical stance I propose to adopt. First of all, I will argue that brandishing the scarecrow of reductionism is inappropriate, as this criticism does not really reach the Hebbian project, which is rather to find an intermediate and functional position between mentalist psychology and radical reductionism. Secondly, I will emphasize that the Hebbian project provides interesting conceptual keys to improving our understanding of chunking mechanisms, a central notion in current models of statistical learning. Thirdly, I will argue that the Hebbian theoretical framework has the potential to provide a broader conceptual tool for unifying currently disjointed fields of psychology.

Keywords: Reductionism, chunking, unification

The proposal I have entitled "Unified Radical Associationism" (URA) aims to adopt a simple theoretical stance, which is to try to push as far as possible the associationist hypothesis according to which associations are all we have and all we need to account for our mental activities. And I'm very grateful to all my colleagues who have deigned to take the time to share their diverse, critical and stimulating ideas on this proposal. In replying to their judicious remarks and objections, I will focus on three points that seem the most important and answer most of their concerns.

1. Brandishing the scarecrow of reductionism

It is interesting to note that we have a fundamental problem with reductionism. Although it is becoming increasingly difficult to deny that we are organisms made up of billions of cells, that the organ that seems to carry our mental activity is the brain, and that this organ is made up of neural cells whose functioning we understand better every day, we seem fundamentally reluctant to admit that a human being does seem to be a remarkable aggregate of cells from which, what we call a *mind* emerges. Indeed, when put this way, nothing seems to distinguish us from a highly sophisticated biological robot, even though we find it unacceptable to reduce our human condition to that of a machine, as complex as it may be. To escape from this idea, which is certainly too distressing, some even go as far as to revive forms of neodualism (see notably **Thomas Rabeyron**'s interesting recent book, Rabeyron, 2023), in which our biological materiality could not get rid of the hypothesis of a non-material spirituality (a notion that seems just as

problematic as the notion of *force* or *gravitation* in physics, as **Pierre Perruchet** and **Annie Vinter** rightly point out).

But what I take the liberty to call "the Hebbian project" really has nothing to do with reductionism, just as most connectionist projects have nothing to do with a form of radical reductionism either. Even if the neural substrate is invoked in both cases, there's no question - for the moment at least - of accounting for our mental activity by providing a detailed description of the billions of interactions that govern our brains (e.g., Herculano-Houzel, 2009). In both cases (the Hebbian and connectionist projects), the idea is to inject some of the properties of our nervous system into our conceptualizations and mimic its global dynamics to achieve more realistic descriptions of our mental functioning. So there's no such thing as a reductionist pitfall, because that's simply not the point. The project is to enrich our descriptions of our mental activities by framing our psychological concepts more closely with what we know of the neurobiological tissue. Such an approach also makes it possible to build computational architectures and test their predictions using computer simulations, a major advance brought about by connectionism, which makes it possible to compare the behavior of such complex dynamical systems to the one of humans.

For example, the notion of *assemblies of neurons* is by no means a form of radical reductionism. It should probably be understood more as a way of connecting our psychological notion of *representation* to an attempt to better describe its implementation in the brain and to better grasp its nature and dynamics, and thus to arrive at better and more precise descriptions of

these mentalist notions. The unified radical associationism (URA) I envision is therefore not a form of radical reductionism. More simply, it's a heuristic to get us closer to a better description of the nature and dynamics of our mental activities. So I'm just sharing here the conviction that we should reconsider such Hebbian notions as *assemblies of neurons* that encode certain events processed by our brains as transitory conceptual tools that will enable us to progress in our understanding of our mental activities. This in no way undermines the remarkable and inspiring theoretical work from the self-organizing consciousness theory (Perruchet & Vinter, 2002), which in fact seems to be perfectly compatible, in essence, with the Hebbian theoretical proposition.

Frédéric Lavigne's commentary and much of his recent computational modeling work illustrate this point (Ersöz et al., 2020; Köksal Ersöz et al., 2022; Lavigne et al., 2014, 2016), as well as the value of trying to implement Hebbian propositions. He also shows that while these ideas may seem appealing at first glance, they quickly raise a host of difficulties if we try to implement them in a computational format. Note that the challenge here is not only to propose precise computational solutions, but also to ensure that these solutions are accessible to the vast majority of psychologists, so that they are not only conceptually relevant, but also easy to grasp, use and communicate. The transitory concepts proposed by Hebb (1949) seem to have that simplicity that makes them easy to understand, as well as having a certain explanatory power.

From this point of view, the approaches developed by **Ángel Tovar** and **Gert Westermann** (e.g., Tovar et al., 2018; Tovar & Westermann, 2023), which are based on the Hebbian theoretical framework without resorting in particular to the complex notion of neural assemblies, offer an interesting and much simpler alternative. In their comments, they suggest supplementing the 10 points I have proposed to characterize the associationist hypothesis with two additional points.

Point 11 seems essential, as it states that the network of neurons on which our mental activity is based follows a certain organization from birth, and that throughout development, the structure of this network evolves according to a process that is largely genetically guided and partly dependent on the organism's interactions with its environment. Brain connectivity is therefore not a matter of chance, and the genetic material of each species seems to largely determine its initial organization and connectivity in adulthood (Ardesch et al., 2022; Barrett et al., 2020; Reid et al., 2016; Rilling et al., 2008). I would therefore propose to slightly reword Point 11 in perhaps more general terms, as follows: The neural network of each species follows a genetically determined organization that imposes a certain neural connectivity and thus certain limits on what can be learned.

On the other hand, I'm not sure I'm ready to adopt their Point 12: "Learners choose their input, arguably to optimize their in-the-moment learning". Unless I've misunderstood their proposal, it seems complicated to conceive within an associationist framework how learners choose their inputs in order to optimize their learning. That there are, for example, reinforcement

loops that enable certain information to be selected and processed rather than others, and that this selection optimizes learning, seems possible. But these loops must be part of the associative structure and of what guides the organism to process this or that information. Just as in the example of ants provided in **Pierre Perruchet** and **Annie Vinter**'s commentary, ants have no intention of optimizing the route that takes them from nest to food. This optimization is a by-product of elementary mechanisms, not of any intention to optimize the route. So I would rather suggest that if learning is ultimately optimal, it can only be an emergent property of an associationist system, not a constitutive element of the system.

2. Better understanding and describing the central notion of chunking

Chunking refers to the processing of consolidating and organizing repeated sequences of items into unified processing units known as *chunks* (Gobet et al., 2001, 2016; Pinto Arata et al., in press). This psychological notion currently occupies a central place in the field of implicit statistical learning (e.g., Isbilen et al., 2020, 2022; Isbilen & Christiansen, 2020; McCauley & Christiansen, 2019; Perruchet & Vinter, 1998). Commentaries by **Fernand Gobet** and **Vsevolod Kapatsinski** both stress the role of this essential notion in accounting for our mental activity.

I certainly agree with **Fernand Gobet** to say that “LUV” is all. However, if I have implied that statistical learning is limited to the learning of sequential patterns, this is a mistake. The studies quoted by Fernand Gobet and many others show that the principles of statistical learning apply just as well to the

processing of repeated visual information (e.g., Fiser & Lengyel, 2022; Orbán et al., 2008). Similarly, while I find the latest theoretical proposals made by **Fernand Gobet's** group particularly remarkable (e.g., Jessop et al., 2023), it seems that they are not incompatible with a Hebbian theoretical framework and would perhaps even benefit from being brought closer to it. Indeed, if the notion of chunk seems central and rather functional in the context of a psychological description, it would certainly benefit from being implemented in a Hebbian-compatible format.

Vsevolod Kapatsinski's commentary also puts forward a set of fundamental questions that theories referring to the notion of chunk will have to answer. One of them, and not the least, concerns what Plaut and Vande Velde (2017) have recently called the *parts and wholes problem*, which we also raised in Giroux and Rey (2009). In that study, we started from the observation that **Pierre Perruchet** and **Annie Vinter's** PARSER model (which gives a crucial place to the notion of chunk) predicts that as a chunk including several elements develops, such as the ABC chunk (A, B, and C, corresponding to three syllables from an artificial language), the units (or sub-chunks) included in this ABC chunk, such as AB or BC, would tend to decline and disappear from perceptual memory. Just when we thought we'd falsified this strange prediction, the data proved us wrong and actually falsified the predictions of the alternative model (i.e. the SRN model, Elman, 1990; but see Plaut & Vande Velde, 2017). However, while PARSER's explanation seems valid, the description of the mechanisms that produce and define a chunk seems insufficient. Even if this is nothing more than wishful thinking for the time

being, it nevertheless seems that the adoption of the Hebbian theoretical framework should make it possible to arrive at more precise descriptions of the nature and dynamics of these fundamental chunking processes.

In his commentary, **Thomas Chartier** points out that while Hebbian learning probably accounts for the emergence of chunks, encoded by dedicated assemblies of neurons, it seems that these learning mechanisms, which imply the existence of multiple repetitions for the chunk to develop in memory, are unable to account for the phenomenon of one-shot learning. In this case, the essential ingredient of Hebbian learning - repetition - seems totally absent. However, an essential feature of this apparent one-shot learning is the emotionality of the information so memorized. Of course, it would be necessary to study each situation in detail, but it appears that this so-called one-shot learning is in fact the product of internal loops generated by the emotional dimension of this information, which acts as a motor for internal repetitions.

However, there are examples of memorization without apparent repetition, which we can all experience every day. For example, we can remember what we had for dinner yesterday, even though we had no intention of memorizing this information, and even though we didn't rehearse yesterday's menu all night long (even though we repeatedly processed all the elements that made up the menu for many minutes as we ate it). Here, the emotional dimension can obviously accentuate the memory, but it doesn't seem essential. On the other hand, in this type of example, it is clear that if we have implicitly memorized this information, it has generally completely

disappeared from our memory after a week. Only repetition can transform them into more stable memories that can survive over the longer term. Repetition, a central ingredient of Hebbian learning, therefore seems inescapable.

As **Thomas Chartier** also points out, another major feature of the nervous system that is absent from recent high-performance deep neural network models is the presence of feedback loops. Although it has long been shown that these feedback loops play an essential role in our visual perception (Bullier, 2001; Bullier et al., 2001), apart from symbolic connectionist models such as McClelland and Rumelhart's model (1981; see also Ziegler et al., 1998), few models incorporate this architectural constraint, which nevertheless seems central and should undoubtedly figure among the list of points that characterize the associationist hypothesis. However, the addition of such a constraint makes this dynamic system even more complex, which certainly explains why few models are venturing in this direction at present.

3. Paving the way for a unified psychological science

The commentary by **Krzysztof Dołęga**, **Arnaud Destrebecqz** and **Axel Cleeremans**, with its reference to the Perruchet effect, underlines the difficulty, for the human species, of a strictly associative general theory. Our own comparative psychology work, in which we compare the performance of human and non-human primates in relatively simple serial pointing tasks, shows that even in such simple protocols, performance between species differs due to the presence of verbal recoding in humans that induces explicit forms of

processing, which interact with associative learning generally considered to be implicit (e.g., Rey et al., 2019; Tosatto et al., 2023). This is why it is particularly interesting to study elementary associative mechanisms with non-human primates, as we can assume that they lack the verbal recoding provided by language (e.g., Rey et al., 2022; Tosatto et al., 2022). We can therefore assume that we have a unique window for studying these fundamental associative mechanisms, which is biased in humans due to the presence of language and our capacity for explicit recoding (but see Smith & Church, 2018, for a different point of view).

Naturally, this is not to deny the co-existence in humans of implicit associative processing and explicit language processing. But the challenge for the coming years, as far as the hypothesis of unified radical associationism is concerned, is certainly to understand how language develops on the basis of implicit associative learning. The ever-increasing number of studies focusing on the early phases of language development should soon provide the first computational models of language development to account for the emergence of this major cognitive ability within our species (e.g., Casey et al., 2023; Rane et al., 2023). Our growing ability to record large databases of children in their natural environment, and to analyze these databases using powerful automatic processing tools, should enable us to better understand the gradual, and certainly associative, emergence of language in every human child (e.g., Bonafos et al., 2023; Roy et al., 2015). The question of the dynamic coexistence of explicit and implicit processes in the human species should then gradually become clearer.

To conclude with **Thomas Rabeyron's** commentary, it does indeed seem that the associationist hypothesis may have the ambition to reunify fields of psychology that have developed too far apart until now. Clearly, the Freudian psychoanalytical project is fundamentally associationist, even if it is not yet Hebbian. We know from his "Project for a scientific psychology" (1895) that the neurologist Freud would have dreamed of anchoring his theory more firmly in its neurobiological dimension. In his visionary neuropsychological book on aphasia (1891), Freud developed an avant-garde critique of localizationist theories, and although he was not yet Hebbian, he was already developing a dynamic, distributed view of brain function. There is therefore little doubt that he would have become Hebbian.

But conversely, while Hebb (1949) seemed to be sympathetic to Freud's work, he felt that his theoretical proposals deserved further work and development. In any case, both Freud and Hebb had the ambition to move towards a unified theory of human mental functioning, and it's certainly a fair bet that the associationist hypothesis will one day achieve this (see notably, Flatot-Blin et al., 2023).

Acknowledgments

I am grateful to Thomas Chartier, Axel Cleeremans, Arnaud Destrebecqz, Krystof Dolega, Fernand Gobet, Vsevolod Kapatsinski, Frédéric Lavigne, Pierre Perruchet, Thomas Rabeyron, Ángel Eugenio Tovar, Annie Vinter, and Gert Westermann for their critical and elegant commentaries. This work was supported by the Convergence Institute ILCB (ANR-16-CONV-0002), the Hebbian ANR-project (#ANR-23-CE28-0008) and the Compo ANR project (#ANR-23-CE23-0031).

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