Wagner's 'Communication and Structured Correlation':

Some Comments

I. Introduction

In his interesting and cogently argued paper, Wagner tries to analyse in more detail the conditions under which meaningful signalling can evolve in a group of organisms. His arguments are rich in insight and make for helpful starting blocks for further research in this area; however, as I try to show in this comment, there is also reason to think that the impact of these arguments is likely to be quite limited, both in a formal and in a philosophical context.

The comment is structured as follows. In section II, I summarise the key findings of Wagner's paper and relate them to previous work in this area. In section III, I raise some further issues and questions surrounding these findings. I conclude in section IV.

II. Wagner on Communication and Correlation

The background to Wagner's analysis is an evolutionary game theoretic model known as the 'Lewis Signalling Game' (after Lewis, 1969, chap. 4). This model concerns the evolution of signalling systems in a group of organisms; in its most basic form, it is structured as follows. There are two agents, two states of the world, two possible actions, and two possible signals; crucially, the fitness of the sender (who knows the state of the world) and the receiver (who does not) depends on whether the receiver chooses the appropriate action in the state of the world that actually obtains (see e.g. Wagner, p. 3). By making assumptions about the prevailing evolutionary process, this model can then be used to investigate the conditions under which signalling systems can emerge without a preordained plan. Four major results concerning this emergence have been established so far:

1. Assuming that (a) the states of the world are equiprobable, and that (b) the population evolves according to the classic model of the replicator dynamics, *stable signalling* evolves in all cases (see e.g. Skyrms, 1996).
2. Assuming that (a) the states of the world are equiprobable and that (b) the population evolves according a certain kind of neighbourhood interaction, *regional signalling* evolves (see e.g. Zollman, 2005).
3. Assuming that (a) there are more than two states of the world, and that (b) the population evolves according to the classic model of the replicator dynamics, *partial pooling equilibria* can evolve (see e.g. Huttegger, 2007).
4. Assuming that (a) the states of the world are not equiprobable, and that (b) the population evolves according to the classic model of the replicator dynamics, *babbling equilibria* can evolve (see e.g. Huttegger, 2007).

In his paper, Wagner tries to deepen and analyse some of these findings further. In particular, he tries to combine results 2, 3, and 4 by asking what happens when there are neighbourhood interactions with more than two states, and with states that are not equiprobable (see e.g. Wagner, p. 5). In order to do this, he puts forward three models / simulations. Consider these in turn.

Model 1: Interaction with Neighbours and More than Two States

Wagner's first model is based on the following five key assumptions:

(i) Neighbours interact with their Moore-8 neighbourhood.

(ii) Organisms change strategies according *Imitate the Best* (that is, agents choose the signalling rule that the fittest of their neighbours has adopted in the previous round).

(iii) Every organism is both a sender and a receiver.

(iv) The states of the world are equiprobable.

(v) There are n states, with $n > 2$.

Using these assumptions, Wagner shows that (regional) signalling systems evolve much more easily than has been found before (especially in result 3 above); moreover, he shows that the size of the lattice of agents has an impact on the likelihood of the evolution of regional signalling (see e.g. Wagner, p. 6). Further, he noticed that what drives this result is the fact that the evolution of non-signalling (partial pooling) equilibria relies on there being groups of organisms that are 'communicatively isolated' in the appropriate way: that is, there must be agents that do not border on too many successful signallers, and that completely miscommunicate with any signallers that they do border on (see e.g. Wagner, p. 8).

Model 2: Interaction with Neighbours and Non-Equiprobable States

The second model Wagner puts forward is based on the following assumptions:

(i)-(iii) See above.

(iv) The states of the world are non-equiprobable.

(v) There are only two states.

In this scenario, Wagner shows that signalling again evolves much more easily than has been supposed before (especially in relation to result 4 above). In particular, he shows that (a) unless the difference in the probabilities of the states of the world is large, signalling will always evolve; (b) if this difference *is* large, (half-) babbling occurs only in small regions of the lattice; (c) if the states of the world *are* equiprobable, only half-babbling (not full babbling) can evolve. On top of all of this, Wagner characterises in detail the 'knife-edge' at which the population switches from pure signalling to (half-) babbling equilibria.

Model 3: Correlation and Changes in the Lattice

In his last set of models, Wagner tries to determine what, exactly, the reason is for why his results come out the way they do. Here, he finds two things: firstly, it really seems to be the close interactions among neighbours that drive these results. In particular, he argues that the more densely connected the network of interacting agents is, the easier it is for signalling systems to evolve (see e.g. Wagner, pp. 18-19). Secondly, he notes that small changes in the structure of these networks can lead to drastic changes in the results – e.g. in the number of regional signalling communities that emerge (see e.g. Wagner, p. 20).

In this way, Wagner shows that many of the previous findings about when meaningful signalling can evolve change somewhat when the assumptions about the evolutionary process are altered.

In particular, he makes clear that by assuming that there is much interaction among neighbours, signalling systems are more likely to evolve than has been thought up to now.

III. Some Further Issues

There are two sets of further issues concerning Wagner's findings that it is useful to discuss here. The first of these is more technically oriented, the second of these is more philosophically oriented. Consider them in turn.

1. The Need for Further Formal Work

From a formal point of view, the basic idea behind Wagner's approach is to drop or alter several of the assumptions that earlier investigations of the evolution of signalling systems have relied on, and to see what happens to the previously established equilibria. In this regard, he is clearly to be commended, and we learn much of that is of interest from his efforts. However, it must also be acknowledged that, in many ways, his analysis here can only illuminate a small slice of the overall area to be explored. In the rest of this sub-section, I want to make this point clearer.

Begin by noting that, in his investigations, Wagner leaves many of the assumptions that earlier models have relied on intact. In particular, he continues to use *Imitate the Best* to model the evolutionary process, he continues to assume that all agents are both senders and receivers, and he continues to only consider an even, uniform lattice. This matters, as these assumptions can all be questioned as well – in fact, questioning them might well have more drastic consequences for the evolution of meaningful signalling than questioning the assumptions that Wagner has focused on.

To see this, consider, as a representative example, the different ways in which organisms can change their signalling strategies over time. Apart from *Imitate the Best*, this can be done using:

(a) *Imitate the Majority*: Adopt the signalling system that the (simple) majority of your neighbours employs; in case of ties, flip a coin.

(b) *Weighted Imitate the Best*: Throw a weighted 8-sided die to determine which rule to follow; assign the weights to the die in proportion to the fitnesses of the agents in the neighbourhood.[1]

(c) *Imitate the Neighbour on the Right*: Like *Imitate the Best*, only that the agent to imitate is fixed ahead of time.

Clearly, this is only a small sub-set of the possibilities here – there are many other such rules to explore (see also Barrett, 2006).

What matters for present purposes is just that, for each of these cases, it would be interesting to find out about how likely it is that signalling systems evolve, what other kinds of equilibria can evolve, how stable these are, and so on. This is especially important, as it is not at all clear what the results would be if one of these alternative rules were adopted: in particular, while it seems plausible that, sometimes, these results would not differ much from the ones derived by Wagner (see e.g. Berninghaus & Schwalbe, 1996), it is also plausible that, in other cases, they would differ greatly. In fact, for some rules – like *Imitate the Neighbour to the Right* or *Imitate the Majority* – it is quite plausible that meaningful signalling is much *less likely* to evolve than hitherto assumed.

[1] This is one particular way of assigning a weighting scheme to this rule; others are possible.

At this point, it may seem tempting to reply that, surely, not all of these rules are equally *biologically plausible*. In particular, it may seem that no organism would *want* to imitate only the neighbour on the right (say) – what would be the rationale for doing *that*? However, for two reasons, this reply is not very convincing.

Firstly, it is just not true that many of the above rules are biologically less plausible than *Imitate the Best.* For example, if adopting a signalling strategy depends on how often that strategy is encountered, then something like *Imitate the Majority* can be quite plausible. Equally, if organisms by and large follow the most successful individuals in their neighbourhood, but every once in a while make a mistake, a rule like *Weighted Imitate the Best* can be very plausible as well. Finally, if organisms adopt certain mentors (like their parents) as role models, then something like *Imitate the Neighbour on the Right* might well be plausible also.

Secondly, it seems that, to a large extent, the aim of Wagner's inquiry is purely *technical*: we are interested in the stability properties of certain equilibria. Given this, though, the *biological plausibility* of the assumptions that go into the above models is not greatly relevant: formally, determining whether signalling can evolve under *Imitate the Neighbour in the Right* is just as important as determining whether it can evolve under *Imitate the Best* (especially given the first point just mentioned).

In this way, it becomes clear that there is no good reason *not* to broaden the basis of Wagner's inquiry into the evolution of signalling. Moreover, this lesson extends directly to many other assumptions of the Lewis Signalling Game: for example, it seems equally important to investigate what happens to the evolution of signalling systems when one assigns probabilities to being a sender and to being a receiver (so that not all agents communicate in both directions – or at all – in any round), or when the lattice is heterogeneous in structure (see e.g. Crozier, 2008).

The upshot of all of this is that Wagner's simulations, while certainly a step in the right direction, merely scratch the surface of the kind work that is needed to determine if results 1-4 'transfer to models using other plausible evolutionary rules' (Wagner, p. 2). Much more research is needed before we can say with any confidence how easy it is for signalling systems to emerge naturally – and that is so even if we restrict ourselves to neighbourhood interactions of closely connected agents.

2. The Philosophical Contribution of Wagner's Models

From a philosophical point of view, the major worry surrounding Wagner's models and simulations is that it is not at all clear what debate they are trying to make a contribution to – and what, exactly, this contribution is meant to be.[2] In the rest of this sub-section, I want to make this point clearer.

In order to answer the question as to what the goal of his inquiry is, Wagner suggests that it is to 'explain how messages can acquire meaning' (see e.g. Wagner, p. 4). Before it is possible to assess whether his models really achieve this goal, though, it firstly needs to be noted that this goal is in fact consistent with two quite different interpretations. On the one hand, the goal may be read as an explanation of how, in general, 'messages' – i.e. purely physical occurrences like sound waves and bodily movements – can acquire the mysterious property of 'having a meaning'. On the other, the goal may be read as an explanation of how *particular* messages can acquire *particular* meanings. Unfortunately, on neither interpretation seem Wagner's models to be able to add much to the prevailing philosophical debate.

[2] Note that I use 'philosophical' in a broad sense here – the point is just to draw a contrast to the purely formal or technical considerations discussed in the previous sub-section.

To see this, note firstly that when it comes to the broader interpretation of the above goal, it seems clear that Wagner's approach can, at most, be used to show that signals can acquire content by reliably causing certain events to occur (e.g. for the receiver to do action A2 when the state of the world is S2). However, for all intents and purposes, this is just a restatement of the standard naturalist, causal account of meaning (see e.g. Dretske, 1981; Millikan, 1984; Stampe, 1986; Papineau, 1987; Fodor, 1990). The particular models that Wagner puts forward do not seem to add anything of substance to this account – they merely present a specific formalisation of it.

Secondly, note that when it comes to the narrower interpretation of the above goal, very similar issues arise. In particular, none of the major problems surrounding the assignment of particular meanings to particular message tokens are being addressed by Wagner's results. For example, Wagner's models do not make it easier to determine whether the content of a signal is an indicative or an imperative statement ('A predator is approaching from above' vs. 'Duck!'), and neither do they make it easier to tell what, *exactly*, the meaning of a signal is ('A predator is approaching from above' vs. 'An ambient black dot is on the upper right-hand corner of my retina' vs. 'My second least favourite event is occurring', etc.). However, since these are precisely the issues that need to be addressed by any fully-fledged theory of content, it seems that, once again, Wagner's findings do not add anything to the debate here.

For these reasons, it seems better to look for the goal of Wagner's work elsewhere. The most obvious suggestion for this is to see it in the attempt to develop a general philosophical account for when an *evolutionary process* (and not some higher authority) can lead organisms to transmit information about the state of the world. However, even here, it is not entirely clear what Wagner's contribution is meant to be.

To see this, note that while it would be nice if we could use his models to corroborate our intuition that signalling systems are more likely to evolve when people have much contact with each other than when they are communicatively isolated, it is not clear that we are *justified* in using them in this way. In the main, this is due to the fact that so many other assumptions are needed to get these models off the ground (and that small changes in the underlying networks can have major effects on the results); because of this, it is simply not clear what one is to conclude about the evolution of signalling that can carry some philosophical weight. In other words, since part of the goal of Wagner's analysis is to show that the classic results (1-4 above) do not necessarily carry over to models with slightly different starting assumptions, and since his own models do not seem to be immune from this problem either, one is left wondering what one has really learned here about when signalling systems can evolve on their own.

IV. Conclusion

In this comment, I have tried to present arguments for two conclusions. Firstly, I have tried to show that, from a formal point of view, Wagner's results are very interesting and informative, but also that they only present the starting points of the necessary research here. Secondly, I have tried to show that, from a philosophical point of view, it is not entirely clear which debates Wagner's models are meant to make a contribution to, or what exactly this contribution is meant to be. On the whole, therefore, Wagner's paper can be seen to present a useful intermediate report concerning the formal study of the evolution of signalling – nothing more, but also nothing less.

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