PhD Dissertation

Epidemiology of Representations:
An Empirical Approach
—original title may change—

Sébastien Lerique[1]

Supervisor: Jean-Pierre Nadal[2]
Co-supervisor: Camille Roth[3]

[1]Centre d'Analyse et de Mathématique Sociales (CAMS, UMR 8557, CNRS-EHESS, Paris). Email: sebastien.lerique@normalesup.org.

[2]CAMS, and Laboratoire de Physique Statistique (LPS, UMR 8550, CNRS-ENS-UPMC-Univ. Paris Diderot, Paris). Email: nadal@lps.ens.fr

[3]CAMS, Centre Marc Bloch (CMB, UMIFRE 14, CNRS-MAEE-HU, Berlin), and Sciences Po, médialab (Paris). Email: camille.roth@sciencespo.fr

Contents

General introduction

Chapter 1

Introduction

Current scientific knowledge describes the complexity of life, and of human life in particular, through a wide array of theoretical and empirical approaches. Given the heterogeneity of the phenomena we aim to understand, we consider it no surprise that biology, psychology, cognitive science, linguistics, anthropology, sociology, or philosophy claim such varied problems and explanatory programmes. But diversity also begs for questions: how can we bring together programmes which, at times, seem to talk past one another in spite of taking humanity as the same core object? Do different programmes always correspond to different explanatory levels, or should we rather combine them as interlocking aspects of the same unique level? Which of those programmes build on incompatible ontologies or world views, making their perspectives on life irreconcilable? These questions have interested a great number of researchers throughout the 20th century and up to now. Indeed, if we aim to carve life at its joints, the way we combine the diverse theoretical and empirical programmes that describe it will constrain the resulting bones and muscles carved out. In other words, choosing an assembly of fields goes hand in hand with a view of what it means to be human, of what exactly nature and culture correspond to, and of how we can best approach the emergence, complexity, and evolution of human life through time.

LOCATE

Over the last 40 years the field of cognitive anthropology, along with the approach to cultural evolution it suggests, has emerged as the strongest view of how science could combine the findings of anthropology, cognitive science, and biology. This approach, now "a booming cottage industry on the borders of evolutionary biology, archaeology, and biological anthropology" (following Sterelny 2017, and the labels he suggests), has two central traditions: the Californian, initiated by parallel works of Cavalli-Sforza and Feldman (1981) and Boyd and Richerson (1985), and the Parisian, federated around the seminal work of Sperber (1996). The two traditions agree on the combination of fields they defend.

- it has a number of variants, of which SCE and CAT, which seem to agree on the philosophical framing of things, but have open debates and differing focuses

- it also has stark critiques

- at stake in those debates is the overarching vision/paradigm of how facets fit together, which

defines the set of obvious and difficult things, guides the design of new questions, experiments, and implementations.

- recently new generations have developed in several fields: cognitive science is at a crossroads, evolutionary biology also. 4E / DST / Eco-evo-devo

- the particular question here is: observe actual phenomena, explain them. From there, what are the ways of accounting for all these phenomena in a unique framework, i.e. with a small number of guiding principles, that will give intelligibility at high level, and guide further questions. What are the differences between the various approaches, and which approaches are viable. Oyama 2001: "We believe that the heuristic value of the idea of developmental information in certain contexts is more than outweighed by its misleading connotations". (This problem, the cog-soc link, is also sometimes viewed as the question of what human nature is, because an answer to that question would define the unit of analysis for culture and everything else.)

- How could there be any problems, and how is this a real question, since it's all a matter of empiricism? How is this a scientific question? Well it's a question at the level of scientific programmes

- First, the breadth of things you can look at is such that a theory will let you define what things are worth looking at. It also makes some cases more natural to explain than others. So a first question is, how much of the phenomena does it capture easily.

- Inside those things, some phenomena are not explained and we have a good idea of what could be the explanation

- Some other phenomena are not explained, and we have no idea how to tackle them, like the hard problem of content

- And the approach you take on those unsolved problems can be somewhat foundational for the rest of your theory, and makes other phenomena more or less natural to account for

- I don't claim to help with anything in the HPC. But I do think that existing theories can be moved forward by improving current empirical methods, to try and see how they pan out in relation to these hard problems.

FOCUS

- I will focus on CAT

- CAT, or ER, was developed by Sperber in the 90's, in a series of innovative articles

- explicitly not a reductionism, and not a Grand Unified Theory

- he proposes a general ontology where we think of things as representations, public/private that circulate, and that global dynamical system has attractors (that are more or less contingent on a situation in space and time)

- that lets us give an ontology for a framework, where we can rephrase long-standing anthropological questions in terms of spread of representations

- the hypothesis of attractors is the main added value of the theory: it claims that because of the interaction of biology, cognition, environment, and current cultural state, the space of how things evolve is somewhat skewed

- as can be understood by the recent name change, it's not clear that representations are the focus (e.g. distance when talking, or even the Claidière & Sperber 2007 example of smoking). I believe the central intuition was that psychology, in the form of at-the-time-emerging cognitive science, has a rich part to play in any synthesis, and is a core ingredient in the appearance of attractors.

- indeed, that is what is emphasised in debates with SCE

- also, it is not an explanatory theory in the sense of quantum physics (as it's not a GUT): Sperber reminds us that finding an attractor is only a cue to looking for its underlying causes. Instead it's a way of thinking at a high level, like a philosophy maybe

- so in a way, it can't be proved or disproved. But it can be more or less fruitful in generating situations and ideas, and providing a global assembly of facts

ARGUE/EXPAND

- up to now, empirical approaches fall into three categories: experimental transmission chains on simple content, compilation of historical works or data, social network data analysis

- each has its problems: transmission chains are on excessively simple content, historical compilations miss the variety of situations (lose detail) and are hard-put to distinguish explanations, social network analysis doesn't look at cognitive factors

- my focus will be on short utterances, bringing case studies of two types, one of each

- in-vivo, where there is huge complexity, but it's ecological

- in-vitro, where one can control the complexity a little, but you have to set a task and anything you do is subject to that choice

- I choose this for two main reasons: first, the availability of data, or relative ease in collecting it (though we'll discuss that). Second, language is at the core of the criticisms on CAT, so it's a good way to go to tease approaches apart.

- discuss the usefulness of those cases for CAT (and vice versa): does it help capture and account for the phenomena? And above all, do we observe attraction/convergence in these case studies? If not why not? Do we transform meaning in a particular fashion given a particular situation, and if such effects are observed can they be somehow generalised?

- show how developing these experiments helps:

- (1) formulate existing questions in more detail, and possibly ask new questions: convergence becomes a concrete question with real measures in these experiments, obstacles to or inappropriateness of convergence can become evident also

- (2) show the pain-points and problems in CAT. Notably:

  - the question of what information is, i.e. the information dualism of representations
  - -> level of description for convergence/transformation (can't decide on a principled level)
  - -> interpretation and meaning
  - taking context & environment into account, which is tackled by RT and Niche Construction, although that may not be enough, as it can maintain the dualism of nature/culture (might follow from the information dualism), even if you believe that it started early in biological evolution

OUTLINE

- I start with a detailed review of the literature on current approaches to cultural evolution, neighbouring areas, and parallels, alternatives, or downright criticisms
- I go on to detail the open problems of the field, seen both from its advocates and from its critiques
- I then explain how I contribute to those problems
- The second part details the first case study, an in-vivo "experiment" led on quotes on the internet
- The third part details the second case study, an in-vitro transmission chain experiment of short utterances of various types
- The final part revisits the contributions such experiments can bring to highlight (1) what has been unexplored, (2) the main challenge further case studies in this area are faced with and how it relates to criticisms, (3) how it would be possible to move forward.

1.1   Relevant works

1.1.1   20th social science

Social science has concerned itself with the stability, temporal evolution, and spatial variations and regularities of cultures since the start of its discipline. Émile Durkheim already, in his seminal study (2012), was looking at the regularities of suicide rates over the years, and the correlation of those rates with a partition of society into religion-related groups. The continuity of suicide over time, and the links between suicide rate and social group, he argued, suggest we should study suicide as a *social fact*: a phenomenon which, in spite of manifesting itself individually, has emerging properties in large groups, with a causal life at the level of other emergent social phenomena. In particular, this emergent level has effects on individual psychology (one of Durkheim's aims was to establish the autonomy of sociology as a natural science of society). By what mechanisms does such an effect operate, and what role does it play in shaping the stability and evolution of cultures? Contemporaries of Durkheim, as well as later researchers, made this matter one of their central preoccupations.

But as those works also acknowledged, such a question raises issues in need of prior clarification: what is the exact status of culture in relation to psychology, or even biology, and how separable are they? Correspondingly, the question of how culture and psychology are part of one another and, if at all separable, how are the two related, or how best to describe the intermingling of these possible levels, has generated much debate throughout the 20th century.

Mauss (1936), in his studies of the ways in which people of different societies and throughout history use their bodies differently, represents one approach to that question. He noticed and began documenting the resting postures, the attitudes, the ways of walking, of swimming, or of sleeping, that different communities adopt, pass on to their offspring, and evolve through time. His endeavour focused precisely on describing (parts of) culture as an embodied and physical property of life, incorporated through the everyday practices of a community, into which children grow by imitation, teaching, or other kinds of learning. In this sense, he argued, there is no normal way of walking, there are only *ways* of walking: by living with different bodily practices, different communities develop different bodies, none of which is standard. Indeed most of these *techniques of the body* documented by Mauss play a role in the physiological development of people growing into them, with noticeable effects: they will make one able to crouch for long periods of time or sleep while standing or horse-riding, and will also, Mauss argued for instance, change the silhouette of

an adult body by influencing the way bones develop. While such practices are undeniably linked to the physiology and to the history of communities, and in that sense are both biological and social, Mauss also asked what part psychology plays in their development, and what influence they have in turn on psychology: he considered these practices complete *physio-psycho-sociological* phenomena.

The question of the incorporation of culture, and behind it the inseparability of culture, physiology, and psychology, has remained central in social science. Works closer to us have contributed to the matter: for Bourdieu (1980), societal norms are also incorporated in perception, and shape our every-day unreflective interpretation of events, our way of navigating life (our *sens pratique*). According to him, norms become embedded in the fullest sense, through life, into our low-level perception and exploration of the environment. Together, incorporated norms form what he calls a person's *habitus*, a concept he puts at the centre of his theory of social reproduction, building on the idea that members of a society grow into a *habitus* leading them to perceive events in ways that reinforce existing power structures.

Social scientists often criticise Bourdieu's approach for not providing a satisfactory account of individual agency, as in this view it still seems opposed to structure acting as a constraint on action. Another prominent approach, the *Theory of Structuration* developed by Giddens (1984), offers a more balanced way out of the tension between agency and structure (or norms), and in doing so reflects yet a different view of the relation between psychology and culture. Acknowledging that approaches that conceive of structure as an external constraint on individual agency cannot resolve that opposition, Giddens (closer to the notion used in structuralist works) sees structure itself as a set of properties of social systems that bear an inherent duality, and cannot be meaningfully isolated from agency: on one side, action arises by using existing structured resources, and its reliance on structure, or referring to it, is what makes it action and not noise; on the other side, the production of action is a new reinforcement of the structure on which it relies. This notion of structure is akin to Saussure's notion of linguistic structure, which in turn inspired the structuralist tradition in social science: on one side, Giddens recalls, in producing an utterance we rely on incorporated syntactic rules; on the other side, the production of a meaningful utterance contributes to maintaining language as a structured totality.

ADD: steiner-autonomy-2009, who connects Giddens (and others) with the questions of social cognition

Anthropology and sociology have produced considerable amounts of work concerned with the nature of culture in relation to psychology, the most prominent parts of which are reviewed by Risjord (2012). The sample I exposed here represents the approaches which have most influenced the initial questions of the present thesis. Common behind the works of Mauss, Bourdieu, Giddens, and authors contemporary to each of them, lies a certain interest in eliminating biology-culture, nature-nurture, or substance-form dualisms which we routinely rely on in our conception of life. This concern has remained central in contemporary social anthropology, and is worth keeping in mind when studying the cultural evolution approach that I will focus on in what follows.

While current writings often argue that such a separation is not "sharp" (Acerbi 2016, 2; relying on Morin 2016), the dualism it comes from permeates most of our theories about non-human animals, human beings, and life in general. This thesis is no exception, as I am myself an apprentice of the traditions I present and discuss here. However I see no reason to believe it is the best conceptual dicing one could achieve, and am (for now) agnostic about whether or not it should be maintained; whenever such distinctions appear in what follows, for instance between cultural and biological evolution, I will thus be referring to the conception of the works discussed, and will attempt to clarify when otherwise. I will come back to the consequences of this dualism in Section 1.1.5, and

will propose a more detailed discussion in Chapter 4.

1.1.2   Evolution of culture

Today's discussion of the ties between culture and psychology is more influenced by proponents from cognitive science. Inspired by the generality of the populational approach underlying contemporary evolutionary theory, a new wave of analyses developed throughout the eighties and nineties by proposing a blend of (a) the gene-centred level of evolutionary theory, (b) insights that the application of generalised evolutionary principles may, or may not, bring to the study of cultural change, and (c) a construal of the two processes of change, genetic and cultural, as parallel evolutions that actively interact, notably through psychology, learning, and environmental engineering. The combination of (a) and (b) is not new, as a similar inspiration underlay the development of memetics. Tim Lewens clarifies the position of this new wave regarding previous evolutionary approaches to culture:

> "Cultural evolutionists frequently begin their theorizing from a starting point that does not invite use of the meme concept, and may therefore appear neutral regarding its propriety. Their project is to integrate various forms of learning into evolutionary theory, in a way that leaves open the degree to which learning has anything in common with genetic inheritance." (Lewens 2012, 466)

(c), which differentiates current cultural evolutionists from previous approaches, has been developed into two parallel approaches, which Sterelny (2017) terms the Californian and the Parisian traditions.

\# ADD: scott-phillips-simple-2017, mesoudi-cultural-2016

Californian

Cavalli-Sforza and Feldman (1981) first articulated the combination of these three ideas in detail, by building on the fact that an evolutionary process need not be mediated by genetic transmission to take place. Indeed, following the synthesis provided by Lewontin (1982): for any type of item, the combination of (a) a transmission process leading to nonrandom dependence of subsequent instances on preceding instances (e.g. offspring and parent phenotype), (b) at least some variation of the properties of items (against which to select), and (c) some level of differential survival and spread depending on those properties, will lead to evolution by natural selection. By looking at genetic models of evolution as a special case of those general principles of evolution, Cavalli-Sforza and Feldman (1981) developed the mathematical analysis of purely phenotypic transmission, which can take different paths in a given population: vertical (from parent to offspring), oblique (from a non-parent member of the previous generation, to member of the next generation), horizontal (inside one generation), or any combination thereof. Boyd and Richerson (1985; 2005) further developed this line, leading to the formulation of *Standard Cultural Evolution* (hereafter SCE) which offers a systematic analysis of part of the interactions between cultural and genetic evolution, an approach which is now vibrant with empirical work (see Acerbi and Mesoudi 2015 for a review of recent studies). A notable feature of this programme is that it does not constrain itself into a particular view of what culture is. While the main authors do define culture as "information that people acquire from others by teaching, imitation, and other forms of social learning" (Boyd and Richerson 2005, 3), a definition which at first sight might prove difficult to reconcile with a non-informational view of culture (such as the incorporated views from Section 1.1.1), the mathematical models do not constrain the

concept of culture as much. The approach also has deep links with the analysis of *Niche Construction* (e.g. Odling-Smee, Laland, and Feldman 2003), which offers promising steps towards a reconciliation with non-informational views of culture stressing the importance of the development process in evolution. I return to this subject in more detail in Section 1.1.4.

ADD: mesoudi-cultural-2011?

Parisian

In the mid-nineties Dan Sperber formalised a second influential approach to the question of the evolution of culture: in a series of innovative articles gathered in Sperber (1996), the author puts forward a research programme called *Epidemiology of Representations* (better known today as *Cultural Attraction Theory*, hereafter noted CAT), and seeks to provide the cognitive and social sciences with a common framework with which to address interdisciplinary questions. One of the guiding questions of Sperber's work is the following: how can we explain both the diversity of culture across regions, and its relative stability through time, knowing that all human beings are more or less made of the same ingredients? In developing an answer, Sperber commits himself to presenting a coherent ontology where the status of each object he refers to is well defined, while at the same time connecting with the many ontologies he identifies in anthropology.

The framework he suggests then starts from an ontology made of "mental representations", which correspond to those defined and studied by classical cognitive science, and "public representations", which are the expressions of mental representations in diverse cultural artefacts such as pieces of text, utterances, pictures, myths, built structures, etc.. New mental representations are constantly formed in people's minds whenever they perceive or interpret public representations. For instance, say I am thinking of a tune (mental representation), and I whistle it (public representation); someone else hears it, and forms their own mental representation. Most of the time, the new representation in that person's head is different from my original representation. This last point is a defining feature of the theory Sperber proposes, in contrast to not only memetics, but also to SCE as outlined above (Sperber 1996, 25–26, 31).

On this basis, Sperber proposes to model human societies as large dynamical systems of people continuously interpreting public representations into mental representations, and producing new public representations through their situated actions (in which mental representations play a role). To explain culture then, in this framework, is to analyse the processes by which representations circulate through a society, with different levels of change along the way. Those processes are many and heterogeneous, which corresponds to the diversity of cultural domains that exist in societies, but the basic ontology remains grounded in the same notion of mental representations from cognitive science.

By developing such an ontology to connect disciplines, Sperber proposes a credible bridge between the notions of representation in social science and that of mental representation in cognitive science, without reducing one area to the other or making simplistic assumptions about the phenomena encountered. In this sense, his proposal is that of a naturalistic ontology for the study of culture which builds on cognitive science principles. It is amenable to anthropology, and encourages the combination of the two bodies of knowledge in a well defined way. Sperber can then rephrase interdisciplinary questions in terms of spread and transformation of representations. For instance: what types of representations are less transformed than others as people integrate them or perceive them, and produce them anew, making them circulate in a society? Such representations, spreading wider than others, become *cultural representations* and will characterise a given society (for instance

the habit of clothing, eating customs or values, or technological knowledge).

Why are those representations so stable, and how do they evolve? Sperber introduces an additional concept to analyse this evolution: the dynamical system of representations which models a society's culture exhibits attractors, called *cultural attractors*, that depend on the complex interaction of psychological and ecological factors, and on the distribution of representations at a given moment in time (Sperber 1996, 106–18). Cultural attractors are one of the core concepts in CAT providing intelligibility to the evolution of culture and to the reciprocal influence of psychology, culture, and environment. As such, a central goal in the CAT research stream has been to identify existing attractors, and explain their emergence based on the interaction of psychological and ecological factors.

The most important intuition in Sperber's proposal, and what differentiates it from previous works, is the centrality of psychology for the evolution of culture (Sperber 1996, 31) and its role in the emergence of attractors. He substantiates this by relying heavily on contemporary cognitive science, and in particular by adopting and extending the view of the modularity of mind initially defended by Fodor (1983) (his view goes further than Fodor's, as he argues for a *massive modularity of mind* applying not only to perception but also to conceptual processes). Combining this view with epidemiology of representations, Sperber argues, results in a theory avoiding both the blank slate approach to psychology (Sperber 1996, 63–66) and a naive application of neo-darwinist formalism to the specific case of culture (Sperber 1996, 101), while still being able to account for the diversity of cultures (Sperber 1996, 120). This specificity of CAT is often highlighted as one of the main differences with SCE (Sterelny 2017, 47); CAT is nonetheless compatible with the framework of gene-culture co-evolution developed by SCE (Sperber 1996, 114), and most authors consider that both theories are compatible but focus on slightly different questions (Sterelny 2017; Acerbi and Mesoudi 2015).

The space opened by the development of SCE and CAT has generated much debate (see e.g. the peer commentary to Mesoudi, Whiten, and Laland 2006) and some heated criticisms (Ingold 2007; answered in Mesoudi, Whiten, and Laland 2007; Lewens 2012, 461–2 provides further discussion and context). Sections 1.1.4 and 1.1.5 come back to these debates and criticisms, which I group into two broad categories. The first concerns the specifics of the evolutionary approach adopted by SCE and CAT: what evolutionary mechanisms should they take into account (for instance niche construction, or epigenetic or extended inheritance) and, correspondingly, how long the restriction of inheritance to two isolated and parallel channels will remain the best approximation. The second critique concerns what Thompson (2007) has termed the "informational dualism" of the notion of representation in cognitive science: at the concrete level, it questions whether a representationalist approach can naturalise meaning, a core aspect in the analysis of culture and life; at the programmatic level it suggests that, compared to the focus on dynamic couplings that Thompson and his colleagues develop under the "enactive approach" banner, a focus on representations in cognitive science has less heuristic value in guiding the exploration of the interactions between culture and psychology. Regardless of whether proponents can reconcile SCE and CAT with the second critique, I believe both approaches can benefit greatly from these debates, and that empirical study has a crucial role to play in exploring the implications of each side.

The empirical exploration of CAT has proven a difficult task, for two main reasons. First, Sperber clarifies that CAT is not, and should not be, a "grand unitary theory":

> "An epidemiological approach … should not hope for one grand unitary theory. It should, rather, try to provide interesting questions and useful conceptual tools, and to develop the different models needed to explain the existence and fate of the various families of cultural representations." (Sperber 1996, 83)

Indeed, CAT accomplishes this:

> "What the epidemiological analogy suggests is a general approach, types of questions
> to ask, ways of constructing concepts, and a plurality of not too grand theoretical aims."
> (Sperber 1996, 61)

As a consequence, testing CAT means evaluating the fruitfulness of its paradigm. No single study, or collection of studies for that matter, will reach a yes or no answer to the validity of CAT. But we can reach a collective consensus about the usefulness of approaching the psychology-culture link with the tools and questions developed by that theory.

As the name CAT indicates, an important part of that toolbox is the notion of cultural attractor, which is amenable to empirical study: the presence or absence of a well-defined attractor in a given situation can be turned into a testable hypothesis. In addition at the meta-analytical level, one can readily evaluate the usefulness of a cultural attraction approach in concrete domains, by analysing whether or not the questions it encourages result in fruitful studies, on average, for that domain. So while testing CAT empirically is not a simple matter of yes or no, the theory provides a clear set of tools and lines of thought that are well worth evaluating in a wider, programmatic appraisal.

The second challenge to empirical exploration resides in the fact that quantitative data on out-of-laboratory cultural artefacts is not easy to collect. Although theoretical models to guide that exploration are gradually appearing (Claidière and Sperber 2007; Claidière, Scott-Phillips, and Sperber 2014), developing methods for the quantitative study of attractors is still an open problem. The literature on CAT shows at least two important methods that have been used up to now. First, the meta-analysis of large numbers of anthropological or historical works, which has uncovered several relevant effects. The way portraits are painted over the centuries, for instance, has been show to increasingly favour direct- versus oblique-gaze portraying (Morin 2013). Miton, Claidière, and Mercier (2015) also used this technique to propose an explanation for the historical stability of the bloodletting practice, in spite of its medical ineffectiveness. Exploiting similar records, Baumard et al. (2015) showed a link between the evolution of religious values and the affluence of societies in which they develop. Morin and Miton (EHBEA 2017? [Citation needed]), using the same approach, model the evolution of heraldic coats of arms to test which hypotheses account best for the distribution of patterns and colours through time.

A second approach is to reproduce the evolution of content with human or animal participants in the laboratory, where subjects repeatedly transmit or interact around pieces of content initially chosen by the experimenters. The resulting data is an approximation of the rapid evolution of artefacts in real life, yet in a controlled situation that can then be statistically analysed with access to all the parameters. This technique has been used in studies ranging from the evolution of visual patterns transmitted in a group of apes (Claidière et al. 2014), to the role of argumentation in the transmission of solutions to simple but counter-intuitive reasoning problems (Claidière, Trouche, and Mercier 2017). # ADD: baumard-mutualistic-2013. A number of other disciplines have developed methods that can be relevant to the study of CAT and SCE, and I review these in Section 1.1.3.

While authors have acknowledged that there is no core incompatibility between CAT and SCE (Acerbi and Mesoudi 2015; Sterelny 2017) and a growing number of social scientists is discussing both approaches positively (see the comments to Mesoudi, Whiten, and Laland 2006; and Slingerland 2008), the work I present in this thesis is mainly focused on CAT itself, and less so SCE. While the prevalence of the cultural attraction approach in the French academic landscape naturally had an impact on this choice, I see three other arguments for focusing on CAT. First, it puts cognitive science squarely in the middle of the problem because of the importance of psychology for the study culture. I admit to sharing that opinion (and given current evidence, it is not more than an opinion). Second, its initial goal is not so much to develop a mathematical theory of culture (which

will surely flourish in due time), but to interest all disciplines studying human life in a common framework by using *principled philosophical arguments*. Third, this approach in turn leads to a clear articulation of the philosophical principles defended, discussed, and tested by the theory at the cultural and cognitive levels.[1] # ADD: smaldino-let-2014. As such, it seems that CAT is in a good position to generate productive debate between alternative approaches (such as the propositions coming from social anthropology, and those discussed in Section 1.1.5) which, at the moment, are still competing on the principled level. In particular, the challenges that arise when attempting to study CAT experimentally, as will be the case here for linguistic utterances, should prove helpful in developing a path to the resolution of the critiques faced by both CAT and SCE.

1.1.3   Neighbouring empirical areas

A number of adjacent disciplines have developed interest in and contributed to CAT. Simulations and experimental studies of the evolution of morality (Baumard, André, and Sperber 2013), religion (Boyer 2001), or reasoning (Claidière, Trouche, and Mercier 2017; Mercier and Sperber 2011) have applied the theory; studies on the evolution of language, and of online content through digital media, are also part of this cluster. The latter two areas are particularly relevant for applying CAT to the evolution of linguistic material, as they have already explored factors in this process for a variety of domains, as well as conditions under which gradual changes can build up cumulatively, and the role that such accumulation plays in long term evolution. Essential to these studies are the serial reproduction paradigm and its derivatives, better known today as transmission chains and micro-societies, which have all been used extensively in recent works.

The versatile serial reproduction paradigm

The serial reproduction paradigm was first applied in a series of influential studies on memorisation and recall by Bartlett (1995), who was experimenting with ways of reproducing the evolution of content through its iterated production by and transmission to different people, under somewhat more controlled conditions than what can be achieved in field work. The paradigm was only one among several other techniques introduced by Bartlett, but it came to have a lasting impact on later studies linking memory to culture. Similar to a game of Chinese Whispers, people participate in a chain along which content is transmitted; the experimenter gives a first participant initial material, typically a picture or a short piece of text, with instructions to read or memorise it; that participant is later asked to recall or reproduce the material, and the experimenter uses their output as input for the next participant, thus constructing a chain of successive memorisation (or perception) and recollection (or reproduction) of the initial material. Participants may or may not know that they are part of a chain. The setup approximates the transmission and change process that happens in everyday life, and while it is quite idealised and imperfect it allows experimenters to explore effects of different factors on the process, and examine the evolution of the artefacts produced as a trace or signal of the overall phenomenon at work.

Important independent variables that may vary include the chain structure (e.g. the number and sources of preceding recollections a participant is exposed to), the reading or memorising instructions and context, the interval between exposition and recall, the possible task given during that interval (or, conversely, a possible overlap of exposition and recall, turning the task into copying, or

---

[1]In the words of Tim Ingold, an outspoken critic of both CAT and SCE: "[Sperber's work] has the virtue of rendering unusually explicit the assumptions built into much contemporary theorising about culture and cognition, and of driving them through to their logical conclusions" (Ingold 2001, 113).

online interaction between participants), the recall instructions and context, the ordering and organisation of participants in the chain, or the ordering of the content itself in the chain (e.g. is a given participant exposed to material from a single generation all in one go, or to material successively sampled from random generations). Typical studies will then analyse the trends in the transformation of artefacts that were produced, possibly comparing the behaviour across different chains. When faced with the complexities of quantitatively analysing the content itself, studies often opt to contrast a simpler measure (such as rate of change) across two different populations, two conditions in the independent variables mentioned above, or two minimally different types of content. In CAT parlance, this method corresponds to the simplest instantiation of the causal chains of public representation to mental representation to public representation (and so on) described by Sperber (1996, 99), and has thus garnered much attention in the literature related to cultural attraction.

Early work contemporary to Bartlett's applied the technique in a variety of settings. A first stream of research explored ways in which verbal memory and social or cultural background can interact. Maxwell (1936), for instance, contrasted the evolution of a story containing deliberate inconsistencies in groups of different social status and age such as soldiers, priests, educated men or women, students, or boy scouts. He found indications that different groups shortened the story at different rates, and conserved or transformed different pieces of the initial story. Northway (1936) also contrasted the conservation of story parts across groups of children from schools with different social backgrounds, relating the proportion of good recollections of a given item to the everyday activities of the children, or the types of transformations (addition, recasting, modification) to the different age groups and to the diversity of backgrounds in a given group. A later stream of research focused more on pictorial content, such as Ward (1949) who related a record of European coin types from 4th to 1st century B.C. to the trends obtained by Bartlett in serial reproduction of pictures. He confirmed that what Bartlett called "representative detached details", that is parts of a picture that represent a distinctive pattern or object even when isolated from the whole, are well preserved both in artificial and historical serial reproductions. Ward thus suggested that comparing historical data to results of serial reproduction experiments can be a useful method to investigate the influence of universal-psychological versus local-cultural factors in theories of historical evolution of artefacts. Hall (1950) further explored hypotheses made by Bartlett on the effect of titles for pictorial and verbal serial reproduction: in those new experiments, it appeared that titles had a considerable influence on the reproduction of both pictures and texts, by acting as an interpretive frame that guides (or confuses) the participants in interpreting the material.[2] More recently the reliability of Bartlett's studies has been discussed, shifting the focus towards a better control of experimental conditions: Gauld and Stephenson (1967), while still praising Bartlett for the progress that his work represented compared to that of his predecessors, showed that changing the exposition instructions, for instance by giving strict memorisation instructions, or by adding a simple sentence asking participants to be "accurate", would considerably reduce the transformation rate in the resulting chains, a fact that should question the effects measured by a setup that lacks explicit memorisation instructions. The authors also examined the level of conscientiousness of participants in accomplishing their task, showing that the measure correlated negatively to the participants' transformation rate. Noting that the effect was not explained away by a measure of intelligence of participants, they finally suggested that "errors could, it seemed, be avoided, if the subject was so inclined" (1967, 45). Today, one overcomes such an issue by designing experiments that create an intrinsic motivation for participants to adopt the behaviour under study (see Claidière, Trouche, and Mercier 2017 for an example). In contemporary work, Kashima (2000b) offered a reappraisal of the social aspect of Bartlett's contri-

---

[2]Hall, noting that "the function of the headline or title to some story or article is that of giving a particular emphasis to certain aspects of the text, and is one of the main methods of distorting and biasing what is remembered" (Hall 1950, 120), later reflects on the fact that such results have crucial political implications given the development of mass media.

butions. Kashima argues that while Bartlett's legacy is mostly seen in psychological studies that adopt methodological individualism, Bartlett fiercely opposed that approach; indeed, his view of the interaction of culture and psychology had much in common with views from social science such as those evoked in Section 1.1.1, and with today's social psychology view of a deeper integration between culture and biology.

One recurrent problem, found across most of the above studies, is the difficulty of quantitatively analysing meaning in the material transmitted along chains. Northway (1936), through her focus on meaningfulness, Hall (1950, 120) and Gauld and Stephenson (1967, 42) all indicate that analysing content itself is a laudable but yet unreachable goal. In facing that difficulty, studies recur to analyses of form, survival, or other measurable aspects of the participants' productions. For linguistic material for instance: the length of a recollection, the number of words, concepts, or propositions accurately recalled, or a contrast of the concepts conserved at the end of the chains. Today the problem remains, and contemporary studies of meaningful material use the same techniques to index or approximate changes in the content of artefacts produced (indeed, the work presented in this thesis will be no exception). While much progress can be made by using these approaches to quantifying aspects of the material, or by instead focusing on artefacts that bear no content, it seems a consensual account of meaning, and a corresponding means of analysis, will be necessary for a full-fledged theory of cultural change to establish itself. I will return to this issue in Section 1.2.

Contemporary revival

Owing to the development of SCE and CAT, the last two decades have seen a regain of interest for the serial reproduction paradigm (now known as a transmission chain) and its derivatives (generally known as cultural transmission experiments), resulting in the development of new case studies and methodologies. A number of effects have been catalogued by recent works. Bangerter (2000), for instance, showed that in transmitting a scientifically styled account of human sexual reproduction, participants tended to personify ovum and sperm, and attribute stereotypical gender roles to them. Mesoudi and Whiten (2004) have argued that the loss of detail that is repeatedly observed in transmission chains, and in particular in the transmission of reports of everyday events, is due to a hierarchical encoding of memories that biases participants' recollections in favour of higher-level descriptions. Works studying the evolution of religion have focused on the effect of counter-intuitive information: by studying transmission chains of stories made of elements with varying degrees of counter-intuitiveness, Barrett and Nyhof (2001) and Norenzayan et al. (2006) observed a conservation advantage for minimally counter-intuitive elements which supports the eponymous Minimal Counter-Intuitiveness account of religion (Boyer 2001; and see Purzycki and Willard 2016 for a critical discussion). Other similar transmission advantages have been identified in relation to stereotypes: for instance, elements of a story that are consistent with gender stereotypes are less degraded than elements that are inconsistent with such stereotypes, but only when relevant to the story plot (Kashima 2000a); stories made of social information, that is featuring human interactions and plots, are also better transmitted than stories involving non-interacting people or than stories about physical nonhuman elements alone (Mesoudi, Whiten, and Dunbar 2006). The extensive reviews provided by Mesoudi and Whiten (2008) and Whiten, Caldwell, and Mesoudi (2016) give a broader idea of the effects studied and methods used in the literature.

ADD: bebbington-sky-2017, stubbersfield-serial-2015

A more recent stream of research explicitly focuses on the individual transmission step in a chain. For instance, setups with two parallel chains that cross-fertilise each other have been shown to improve transmission rates (Eriksson and Coultas 2012): if at each generation, the participants of two parallel

chains both receive two inputs, one from each chain at the previous generation, information loss is decreased compared to a single chain where participants read twice the same piece of content (of the previous generation). Acerbi and Tennie (2016) further modelled such error-correcting redundancy, simulating minimal scenarios that could favour its evolution given fixed cost-reward constraints. Eriksson and Coultas (2014) also decomposed real world transmission into three phases: choose-to-receive, encode-and-retrieve, and choose-to-transmit. Focusing on emotional selection studies showing that participants are more willing to pass on stimuli that elicit disgust (Heath, Bell, and Sternberg 2001), the authors showed that any of those phases can be the target of a selection pressure. Such pressures can additionally counteract each other, showing that the transmission process is more complex than was initially assumed. Studies of digital media have adopted the increased level of detail, as digital communication lets users copy-paste and bypass the encode-and-retrieve phase of transmission (Acerbi 2016).

Methodological exploration has also led to more free-form interaction setups: in a study of the transmission of risk perception, Moussaïd, Brighton, and Gaissmaier (2015) chose to make the interaction and underlying transmission of information an open-ended process. After initiating a chain by providing the first participant with a set of documents to read on their own, later participants were left to talk freely in successive dyads, and the whole session was recorded on film for subsequent analysis. An analogous change of setup was operated by C. A. Caldwell and Millen (2008b; 2008a) who investigated the cumulative aspect of the evolution of building techniques in a series of experiments asking participants to construct spaghetti towers or paper planes, later evaluated by their height and flight distance. A crucial point in those setups, Sterelny notes (2017, n. 12), is that participants could observe the preceding generation during their experimenting and building, meaning they had access to rich context for the learning phase of transmission. Taking another step to embrace interaction with a setup where participants had to repeatedly build Lego cars in pairs (though without transmission), McGraw et al. (2014) take the complete joint interaction to be their object of study and propose to use the constructions resulting from interacting dyads as a trace of the processes that took place in the interaction. By looking at the characteristics of the cars built by participants, the authors claim to present "methods for discerning, and quantifying, schema-like intersubjective understandings in material form" (McGraw et al. 2014, 4; see also Mitkidis et al. 2015; and Wallot et al. 2016), effectively integrating critiques that I discuss below in Section 1.1.5.

The works reviewed here show that there is much room for exploration, on one side, of the methodological choices in transmission chain experiments (some of which will turn out to be more important than others in the trends observed), and on the other, of the theoretical background that sustains a given study. Such experiments have therefore much to bring to underlying theoretical debates.

Language change: Experimental semiotics and Iterated learning

ADD: tamariz-experimental-2017

A related strand of research has developed similar methods to study the emergence and evolution of language. A central experimental paradigm is that of iterated learning, which resembles a transmission chain for artificial languages where participants learn a communication system at each step: a first group of participants must learn to use a simple artificial language (e.g. an artificial vocabulary for naming a range of objects), after which a second group of participants must learn that language through some interaction with or transmission from the first group. The process is then iterated over successive generations, leading to the evolution of the artificial language initially introduced. A related setup used in experimental semiotics surfaces the evolution of interaction without transmission across generations. It consists in pairing participants and assigning them a task that

they must cooperatively solve over repeated iterations, without changing partners. Most often, participants can use a communication channel (or must create it) to help in coordination, such that the setup exposes the way participants iteratively develop conventions over the channel. Studies using these two paradigms have shown that simple biases in participants' interactions and learning capabilities can lead the final evolved communication system to exhibit non-trivial structure. Several factors have been shown to influence the process, including the structure of the objects referred to by the artificial language, the transmission or interaction task (and its surrounding context) for iterated learning, and the reinforcement rules favouring expressivity of the language that will interact with learnability pressures.

A first major goal in this stream is to provide an non-nativist account of the emergence an structure of communication systems (Kirby, Dowman, and Griffiths 2007). Galantucci (2005), for instance, studied pairs of participants facing a cooperative task that required them to develop ad hoc communication conventions. The communication channel, a form of shared whiteboard, distorted participants' input by a constant drift such that they could not enter letters or pictorial drawings. The study highlighted the variety of strategies used by participants to develop conventional sign systems, and in particular the way those systems were adapted to the interaction history of dyads. The authors showed that sign systems were deeply meshed with the situated and time-dependent information that was available, allowing the participants to solve their task by dynamically coordinating (Galantucci 2005, 748–49). Further stripping down the set of assumptions built into the experimental setup, Scott-Phillips, Kirby, and Ritchie (2009) created a cooperative task without providing any communication channel parallel to the task itself. To solve the challenge, participants had to develop a communication system where their own behaviour in the task could become an embodied communicative signal, aside from accomplishing their action for the task either simultaneously or at other times. Here too, the authors underline the importance of developing a dialogue, based on common ground provided by the history of interactions, to bootstrap the creation of a general communication system that can solve the task in all situations. These studies show that communication systems are inherently embodied and situated, but still involve some degree of intentional design by the participants.

Iterated learning setups, on the other side, have focused on the unintentional emergence of structure. Kirby, Cornish, and Smith (2008), for instance, studied the evolution of an initially random artificial vocabulary set which participants had to learn, use, and extrapolate to name events (events were a combination of a shape, a colour, and a movement). By filtering ambiguities in the output vocabulary produced by one participant and given to the next, the authors were able to create a pressure for expressivity of the complete vocabulary; combined with the learnability pressure inherent to the task, and the fact that participants had to extrapolate to unknown events, the vocabulary gradually evolved to regularise variation with the emergence of compositionality corresponding to the three dimensions of the events to name. Crucially, the participants were not aware of the goals of the experiment, nor that they were part of a chain: the emergent structure in the vocabulary thus appeared without intentional design. Using a comparable setup where participants had to extrapolate a colour-naming vocabulary, a subset of which was then transmitted to the next generation, Xu, Dowman, and Griffiths (2013) observed that (probably culture-specific) biases in colour grouping played an important role in the convergence of vocabulary terms. Combinatorial structure and distinctiveness has also been shown to emerge in a set of acoustic signals devoid of meaning that participants had to learn and reproduce (Verhoef, Kirby, and Boer 2014). Cornish, Smith, and Kirby (2013) encountered similar results for sequences of categorical items that had no inherent meaning: since participants must reproduce a whole set of sequences, or acoustic signals, at each generation, the set behaves as a interconnected system for which learning pressures gradually increase the combinatorial structure.

Experimental semiotics and iterated learning also cross-fertilise each other: after Garrod et al. (2007) used a Pictionary-like collaborative task, without transmission, to study the emergence of symbolism in a lexicon, a process they called "interactive grounding", Fay et al. (2010) extended the findings to a micro-society. Fay and colleagues showed that globally shared symbols can emerge through the gradual alignment of such interactive groundings, leading to an increasingly refined and streamlined symbol system. The authors thus proposed "symbolisation" as an additional mechanism in the emergence of communication systems, based on intra-generational collaborative coordination through interaction, and parallel to the inter-generational learning biases and bottlenecks studied by iterated learning studies. Taking another leaf from experimental semiotics, Winters, Kirby, and Smith (2015) exploited the observation that a large part of the meaning of an utterance comes from its situational context: they studied the influence of the situations in which participants use vocabulary items on the structure of the language that evolves from interaction and iterated learning (thus extending Silvey, Kirby, and Smith 2015). The authors show that, if the situations in which participants communicate do not contrast items on all the dimensions on which they differ, then the vocabulary set often evolves to not encode those dimensions. In other words, if the usage situations shield the participants from certain contrasts between items, the final vocabulary is often under-specified with respect to the full item space: it does not encode the dimensions that discriminate the unobserved contrasts, instead adapting to be useful only for the contrasts that users observed. This stream of research is active and gradually relaxing the constraining hypotheses made by initial studies. Carr et al. (2017), for instance, recently made the space of items more realistic by exploring the emergence of vocabulary sets where participants communicate about a continuous unbounded set of items.

A second, closely related question concerns how an already structured communication system evolves given a set of external, learning, or interaction pressures. Croft (2013) provides a general framework for this question, inspired by principles from biological evolution and by recent debates on the nature of the evolutionary process, and crucially focused on identifying an adequate unit of analysis for the evolutionary study of language change. Indeed the author combines two key insights. On one side, Hull's General Analysis of Selection (Croft 2013, 16) lets him abstract out the principles of evolutionary processes and distinguish between replicator, interactor, and selection, three core components that provide "a model for disentangling different cultural evolutionary processes and identifying their interconnections" (Croft 2013, 18). On the other side, he draws on the critique that Developmental Systems Theory opposes to a gene-centred view of biological evolution (Oyama, Griffiths, and Gray 2001), and insists that a theory of language change should consider utterances to be full life cycles made of pronunciation, meaning, and interpretation in context. He thus proposes the Theory of Utterance Selection, which takes linguemes (i.e. the linguistic structure of sounds, words, constructions and utterances) to be replicators, but always part of a larger cycle; language speakers are the interactors (2013, 16), and the theory defines language as the "population of utterances in a speech community" (2013, 35).

A number of existing studies fit well in this framework. Tamariz et al. (2014), for instance, used a common setup requiring participants to develop a pictorial vocabulary for a pre-given set of words, and modelled the trends participants exhibit in adopting new signs as they go through the interactions of the experiment. The authors found that participants do not select new signs neutrally; rather, they tend to favour signs they have used in the past, even if their partners use different ones, unless they encounter a sign they find obviously superior in representative power. Similarly, in a picture-description transmission chain using an artificial minimal language, Smith and Wonnacott (2010) showed that the accumulation of individual participant biases will regularise the marking of plurals in the evolved language. Kirby et al. (2015), while studying the emergence of structure as the result of combined pressures of expressivity and compressibility (the latter often attributed to learning, Tamariz and Kirby 2015), hint to the fact that the way structure emerges and evolves is

highly dependent on the combination of such pressures. They note, in particular, that "there is some suggestive evidence that structure in language can be modulated by the composition of populations" (Kirby et al. 2015, 99): different communication patterns at the population level, or a different fabric in the population responsible for the transmission and evolution of a language (e.g. more second-language learners, or more children learners), should lead to differences in the evolution of language structure. Regarding symbolism, Caldwell and Smith (2012) extended the micro-society Pictionary-like task studied by Fay et al. (2010) to one where participants were gradually replaced, inducing increased symbolism and successful transmission of the evolved symbols at the same time. Initial members of the micro-society constructed highly iconic representations of the meanings to convey, but as the experiment introduced newcomers to those signs through observation and consequent use, the drawings gradually lost the iconic link to their referent and became simpler.

Large portions of the iterated learning literature draws on and contributes to a parallel theoretical track which laid down the first analytical predictions for models of Bayesian agents learning and producing languages in chains. Griffiths and Kalish (2007) were the first to show that the analytical structure of iterated learning with uniform Bayesian agents can correspond, depending on the way the agents produce new iterations, to well-known statistical inference methods (Gibbs sampling and a flavour of the EM algorithm). In such a setup, iterated learning predictably converges towards distributions determined by the internal prior distributions of agents (i.e. their inference bias). As a consequence, in those analytically derived situations one can straightforwardly predict the final distributions that should evolve under iterated learning, a fact that Kalish, Griffiths, and Lewandowsky (2007) verified with humans in a function learning task. Griffiths, Christian, and Kalish (2008) further exploit this result by using it in the reverse direction: since the outcome of iterated learning, for specific setups, is predictable on the basis of participants' priors, one can use such experiments to investigate the inductive biases of participants. The authors confirmed this, showing that the method infers well-known participant biases in category learning tasks. Griffiths, Kalish, and Lewandowsky (2008) then explored the relevance of these findings for the study of cultural evolution, showing in particular that individual cognitive biases can have significant effects on long-term cultural evolution. Reali and Griffiths (2009) further related those results to the evolution of vocabulary, showing that they are consistent with experimental cases of word-meaning mapping regularisation. Finally Perfors and Navarro (2014), through analytical derivation and experimental confirmation, reintroduced the impact of the external world in those results; the authors showed that the structure of referents (i.e., the external world) will also play a role in the final evolved language, provided it has an effect on the choice of items people actually talk about (versus, the choice of items talked about only depends on the language itself).

Scott-Phillips and Kirby (2010) and Tamariz and Kirby (2016) provide further reviews of the iterated learning literature, and Galantucci, Garrod, and Roberts (2012) and Roberts and Galantucci (2017) offer reviews of experimental semiotics. An interesting and important development in recent works is the reintroduction of pragmatics into theoretical questions. Scott-Phillips (2017), in particular, reaffirms the central role of pragmatics in the creation and understanding of meaning in context, and argues for a much stronger focus on the evolution of pragmatics itself, that is, as he envisions it, on the evolution of *ostensive communication*. Let me close this review by noting that there is an increasing convergence both in the literature and in empirical questions, of the cultural evolution and language evolution fields; the intersection of questions from the two fields is likely to push theoretical issues forward.

ADD: sperber-beyond-2015

Digital media

Acerbi (2016) defines digital media as "media encoded in digital format, typically to be transmitted and consumed on electronic devices, such as computers and smartphones". The ubiquity of this medium, which created the ongoing avalanche of available digital traces, has opened both questions and possibilities for the study of cultural evolution over the past 15 years. Indeed digital media is both a measurement tool and an object of study, as it has become embedded in everyday life in many societies, with its own practices of interaction, mediation, or transmission, possibly impacting cultural evolution. While digital practices are different from those in physical encounters, the digital transition remains an addition to the possible range of interaction media, and the cultural evolution framework can study it as such, with increased access to the artefacts those interactions produce. Acerbi (2016) argues precisely for such an approach to digital media, and reviews relevant works that have explored that space. In what follows I present three areas of focus that have received particular attention in the literature.

A core—and somewhat canonical—challenge for digital media has been to describe the behaviours of diffusion and change of artefacts in social networks, and if possible predict their macroscopic spread and evolution. The question is far from new (see Rogers 2005) and works have historically tackled this question through analytical models, simulations and empirical studies, but the recent increase in access to digital traces and computing power to make sense of such data has boosted empirical developments. Gathering data from blogspace, for instance, has allowed studying the propagation of information topics, as Gruhl et al. (2004) did by separating topics into "chatter" and externally-triggered ("spike") subjects to model their spread over the social network formed by users. The email network is another source of digital traces, with patterns specific to it; indeed Liben-Nowell and Kleinberg (2008) showed that information diffusion along email chains has an unexpected deep tree-like structure, which they suggest is because of the asynchronous nature of email. Such studies focus on *socio-semantic systems*, that is systems made of, on one side, a collection of users whose interactions or links form a social network, and on the other side, a set of topics or subjects around which the users interact, which also features a network-like structure. The two levels of structure reciprocally influence each other, as Cointet and Roth (2009) show for blogspace (see also Cointet and Roth 2007 who explore the relative roles of social network topology and transmission rules, related to the structure of topics in the spread of information).

The scale of the study of social networks has grown considerably over the past decade, and linguistic memes in particular have received much attention. In a landmark endeavour, Leskovec, Backstrom, and Kleinberg (2009) gathered and published a data set of quotes extracted from a million blogs and news outlets over a nine month period, and developed a method to group minimally different occurrences into quotation families in order to quantify the popularity of news topics over time. The technique allowed the authors to study the evolution of the online news cycle, measuring differences in publication timings across blogs and news outlets. Simmons, Adamic, and Adar (2011) further analysed that data set, showing that transformations of quotes upon copy are frequent (contrary to what one would expect for such memes), work that Omodei, Poibeau, and Cointet (2012) then extended with a more accurate multi-level transformation model. Adamic et al. (2016) developed a similar study for the evolution of explicit memes (that include instructions asking the reader to copy and pass on the contents of the meme) in a Facebook data set of hundreds of millions of occurrences; by using a biological evolutionary model of mutation and replication where genotype corresponds to the meme's content and phenotype to the copying instructions, the authors explore the implications of pushing the biological analogy to its limits in such a paradigmatic case. The range of empirical questions, and the technical challenges involved in tackling them, are such, that the focus has moved towards developing methods for the collection and study of similar data sets. For instance, the

MemeTracker project initiated by Leskovec, Backstrom, and Kleinberg (2009) has now evolved into a fully-fledged network collection and analysis platform (Leskovec and Krevl 2014) with associated data sets (Leskovec and Sosǐc 2016). Another noteworthy example of this is the development by Moritz et al. (2016) of text re-use detection methods for historical works, a technique that could open the application of the above studies to digitised historical corpora.

A second research stream isolates the different processes involved in the spread and change of artefacts. In particular for transformation, separating effects of content from effects of context is a necessary step to understand the processes responsible for the changes of artefacts. Danescu-Niculescu-Mizil et al. (2012) thus studied the memorability of movie quotes by identifying features that can predict quotes marked as memorable by users of the Internet Movie Database (call these IMDb-memorable): from about 1000 movie scripts, the authors extracted around 2200 pairs of quotes, each consisting of one IMDb-memorable quote paired with the closest quote in the movie script that has the same length, is spoken by the same character, and is not IMDb-memorable. By contrasting these pairs, the authors surface the content-related features of a quote that make it memorable, and factor out the context in which the quotes appear, context which otherwise plays an important role in the memorability rating. After checking that human subjects can identify which quote in the pair is memorable (they do so with an average 78% success rate), the authors show that memorable quotes, on average, use less frequent vocabulary, more frequent grammatical categories (POS tags), and more general constructions (fewer 3rd person pronouns, more indefinite articles, etc.) that make them more adaptable to changing contexts (each of these measures, taken individually, partitions the quote pairs into two subsets containing about 40% vs. 60% of the whole set). Cancelling out context effects to develop content-related features has become a widely used approach, with adaptations ranging from the identification of linguistic markers of politeness in online content (Danescu-Niculescu-Mizil et al. 2013) to the measurement of attractiveness of famous quotes (Acerbi and Tehrani 2017). In a study reminiscent of Hall (1950), Acerbi and Tehrani (2017) compared the relative strength of content and presentational context in a sample of famous quotes that participants had to rate for attractiveness. The authors compared conditions where quotes were presented alone, versus presented with random attribution to more or less famous personalities, or versus presented with a random popularity score. They found that such minimal context has little effect if any at all: attribution, famous or not, bears no effect on the attractiveness of a quote, and popularity has little. Althoff, Danescu-Niculescu-Mizil, and Jurafsky (2014) also opened the study of context versus content to relational variables, by showing how social status and presentational features (such as showing a strong need) can affect the success of requests on Reddit.

A third related stream of research focuses more specifically on influence in social networks, and its links with attention: what network effects trigger the diffusion of a particular meme or piece of information? Among the micro-processes involved in the spread of information in networks, what is the role of influence across connected nodes? Bakshy, Karrer, and Adamic (2009) investigated the question of social influence by examining information cascades in Second Life. Information cascades, where a comparatively small initial event triggers large scale diffusion, are a well-known phenomenon in social networks, and their size distribution is well modelled by peer-pressure threshold models which link the cascade behaviours to the topology of the network in which they occur (Watts 2002; Ruan et al. 2015). Bakshy, Karrer, and Adamic (2009) thus tracked the spread of *assets* in the virtual world provided by Second Life (that is pieces of content introduced and copied by players in the game); they find that a significant part of contagion happens along the friend network, instead of in avatar-to-avatar interactions, indicating that the adoption rate of (in-game) social circles has a strong impact on a person's adoption of an asset in Second Life (see Bakshy et al. 2011 for another example study, on Twitter, separating the strength of content from the strength of social influence).

Attention in social networks is another related factor. Considering the amount and constant flow of information available, filtering and attention management is a necessary component of the diffusion of artefacts; it is usually accounted for through competition among pieces of information. Weng et al. (2012), for instance, model the spread of Twitter hashtags through agents with bounded memory and attention, and show that such simple assumptions account well for the distribution of hashtag diffusion along the social network. The relationship between attention and strength of ties has also been explored by Weng et al. (2015) in data gathered from Twitter, cell phone, and email networks. In these data sets, the authors confirm that while strong ties transport the majority of events, users devote comparable attention levels to both strong and weak ties; they suggest that strong ties play a social communication role, while users use weak ties for seeking novel information, a distinction which could explain the different attentional patterns they measure across the different media.

The empirical study of information diffusion and spread has steadily grown since the advent of digital traces; the number of factors included in analyses is growing, and the influence of core processes such as attention is gradually becoming clearer (an interesting addition would be the role of power relationships, which are also detectable through markers of interactive behaviour, Danescu-Niculescu-Mizil et al. 2011). As mentioned above, Acerbi (2016) provides a useful overview of other works that are relevant for current questions of cultural evolution.

Conclusion

As I discuss in Chapter 2, the development of data set collection and analysis methods can bring insight, as well as refined questions, to the study of the reciprocal influences between cognition and culture. # TODO: "I" or "we", for BCP? Other empirical fields in psychology and linguistics are useful to the study of CAT as a framework for cognition-culture interactions: I further introduce works in psycholinguistics relevant to the study of quotes online in Chapter 2, and Chapter 4 will return to how future works could make deeper use of "Smartphone Psychology" to contribute to the more contentious issues. # TODO: actually do that. Let me now move on to the most debated developments of cultural evolution, the criticisms opposed to the approach, the alternatives emerging from these critiques, and the possibilities of reconciliation.

1.1.4 Developments

The exact nature of evolution is subject to debate in biology and philosophy of biology, and some of the recent developments have made their way into the core of cultural evolution theory. In a parallel movement, the nature of cognition is itself debated inside philosophy of cognitive science. The aim of the next two sections is to briefly discuss the relevant parts of those debates for the cultural evolution approach, delineating first the elements that could be—or are already partly—integrated into mainstream CAT, and second the critiques which, at least in current writings, seem to call for a partial rethink of the paradigm. The questions here are more theoretical than above, as they explore both the way different disciplines studying life are best meshed together, and what core components should be at the root of such a convergence. This is not to say the debates in biology and cognitive science concern theory alone, as each debated position is well supported by empirical work; rather, up to now those works have not translated to actionable contradictory predictions in the study of cultural evolution proper. Nonetheless, I will argue in Chapter 4 that these debates provide crucial context to understand a particular practical challenge in the empirical study of CAT, namely the definition of the meaning of representations and its impact on the dimensions of attraction. I begin with developments then, that is the elements that seem possible to integrate into CAT. These also

lay some of the groundwork for the subsequent criticisms, which I believe challenge CAT closer to its foundations.

Niche construction theory

A central question in the study of evolution is the definition of what counts as heritable material, for which two broad views are competing. The debate, agreements and disagreements between both views are well documented, and I base the following discussion on the recent reviews provided by Laland et al. (2014) and Scott-Phillips et al. (2014). The standard account of biological evolution, or Standard Evolutionary Theory (SET) as termed by Scott-Phillips et al. (2014), defines evolution as "change in the frequency of DNA sequences (i.e., genes and associated regulatory regions) in a population, from one generation to the next" (Scott-Phillips et al. 2014, 1232; referring to Futuyma 2005). Such change occurs through what is known as an evolutionary process:

> "Evolutionary processes are generally thought of as processes by which these changes occur. Four such processes are widely recognized: natural selection (in the broad sense, to include sexual selection), genetic drift, mutation, and migration (Fisher 1930; Haldane 1932). The latter two generate variation; the first two sort it." (Scott-Phillips et al. 2014, 1232)

In this view, DNA sequences constitute the principle heritable material transmitted from parent to offspring across generations, and their distribution and change should be the main focus of evolutionary theory. Furthermore:

> "There are many factors that can cause these four evolutionary processes to occur, and for the skeptics [of Niche Construction Theory], niche construction is one such factor." (Scott-Phillips et al. 2014, 1233)

Niche construction is the process by which organisms engineer their own and other organisms' environment in ways that are often beneficial to them. A classic example of such niches are the dams built by beavers along the rivers they inhabit; a beaver-built dam creates a local lake, and its presence actively changes the environment in which future generations of beavers—as well as neighbouring organisms—develop. The constructed niche is inherited across generations such that it can have a lasting impact on the selection pressures under which later generations evolve. SET recognises this phenomenon and defenders of the classical account are among those who actively study it (Laland et al. 2014). Niche Construction Theory (NCT, Odling-Smee, Laland, and Feldman 2003), however, contends that increasing amounts of evidence are unsatisfactorily accounted for by SET (though not in contradiction with it), and proposes "a broadened concept of inheritance, including 'ecological inheritance,' the modified environmental states that niche-constructing organisms bequeath to their descendants" (Scott-Phillips et al. 2014, 1233). Those constructed environmental states bias the natural selection of later generations (so-called "selective niche"), and also affect the social and ecological environment in which offspring develop (so-called "ontogenetic niche"), both being processes that can lead to evolutionary feedback loops. The evolution of dairying, as analysed by O'Brien and Laland (2012), is claimed as a paradigmatic case that is well accounted for by NCT.

ADD: gilbert-eco-evo-devo:-2015 if clearly aligned

NCT is part of a broader movement in evolutionary biology that seeks to integrate a strong view of such feedback dynamics into evolutionary theory, by combining evolutionary developmental biology ("Evo-Devo") with the evolution of the environment in which development take place. These

works argue for an Extended Evolutionary Synthesis (EES, also presented as Eco-Evo-Devo by Gilbert, Bosch, and Ledón-Rettig 2015), conceiving of evolution as the co-evolution of organism and environment, a system that inherits genetic material, but also constructed selective and ontogenetic niches. The crux of the disagreement with SET lies in the importance of the dynamics that this feedback generates: SET considers it more parsimonious to define evolution as change in frequency of DNA sequences, and thus frames niche construction and other ecological inheritance processes as a cause for changes in DNA. Conversely, EES considers it more *fruitful* to define evolution as change in the whole organism-environment system, for which niche construction is a core evolutionary process, like genetic mutation or natural selection. According to Scott-Phillips et al. (2014), the current evidence does not tease the two perspectives apart unequivocally: all known phenomena can still be explained by both approaches with varying degrees of shoehorning, and predictions from each theory can be rephrased into the other one (although such inseparability might not last). However, proponents of EES argue that the study of ecological processes in evolution, while present in SET, has become systematic only thanks to the change of focus brought by the development of NCT.

The Extended Evolutionary Synthesis offers a natural framework for the study of all aspects of evolution, be they cultural or biological, and indeed the gene-culture co-evolution framework fits well with this synthesis. The communities developing those approaches overlap partially (Marcus Feldman, notably, is a core contributor to both research streams), and Sterelny (2017) argues that NCT is a core—if sometimes implicit—component of both Californian and Parisian cultural evolution. Indeed, EES is capable of integrating a non-opinionated notion of culture as part of the organism-environment system under study, and the task at hand then joins up with that of dual inheritance theory, presented above: identifying the co-evolution dynamics of genetic and environmental inheritance channels. On this view, then, culture is accounted for by a blend of ecological and cognitive-epistemic niche construction processes.

"4E" cognitive science: the extended mind

TODO: use chemero-after-2008 for this summary

In a strikingly parallel movement in cognitive science and philosophy of mind, the nature of cognition and its units of analysis have been debated along two broad dimensions (see Chemero and Silberstein 2008 for a detailed review of questions and possible answers). (1) The boundaries of cognition: are cognitive processes brain-bound, do they extend to the body, or do they include the environment or the surrounding (cognitive) organisms, and if so in what sense (Clark and Chalmers 1998; Menary 2010). (2) The role of time-dependent dynamics, and the corresponding construal of the nature of cognition: are cognitive systems best described as digital computers processing information in the form of representations (i.e. symbol processing systems), where time can often be reduced to an ordering of events, or are they best described as dynamical systems where time is important to define rates of change, flows, or dynamic couplings (Gelder 1998; Beer and Williams 2015). In treating these questions, the extended, embedded, embodied, and enactive approaches to cognitive science (the so-called "4E") have argued to various degrees that cognition is not only (or not at all) an information-processing operation that can take place in the void, but also (or exclusively) a situated activity supported by (or a dynamic coupling with) its environment. The extended mind theory, among the less radical 4E approaches, is quite compatible with EES and thus with both Californian and Parisian cultural evolution. Indeed Sterelny (2010; 2012), building on NCT, has argued that the extended mind approach is a special case of epistemic niche construction. He suggests that the environments human beings grow in are the result of cumulative cognitive niche construction processes, that engineer the material and social environment of humans to support the

growth of everyday cognitive capacities, thus scaffolding cognition during development and life.

1.1.5 Criticisms

Developmental systems theory

A related and somewhat complementary extension to the standard evolutionary account has developed in parallel to NCT, with a more radical notion of extended inheritance: Developmental Systems Theory (DST, Oyama 2000; Oyama, Griffiths, and Gray 2001). Kim Sterelny characterises it, on one side, with three critical theses:

> "(1) We cannot simply assume that the organism/environment boundary is of theoretical significance for developmental and evolutionary biology … (2) It may be legitimate to foreground genetic structure and genetic change for specific explanatory or predictive purposes. But in general, the genes an organism carries are just one set of developmental resources among many. Genes and gene changes are important both to development and to evolution, but they are not of primary or privileged importance. (3) Developmental systems theorists are skeptical about the project of explaining intergenerational similarity by appealing to the transmission of phenotype-making information across generations." (Sterelny 2001, 335)

Crucially, DST claims that overlooked evidence in development indicates that there is a "causal parity" between genes and non-genetic development factors, such that evolutionary theories should not give greater (or smaller) importance to the former over the latter. This in turn sustains the third thesis: views of the genome as a bearer of biological information should be qualified in light of the complex interactions between developmental processes in which genes participate (for further detail, see Griffiths and Stotz 2013, who extensively review the ways in which genes can be, or historically have been, considered to bear information). Now the other side of Sterelny's characterisation of DST is its positive story:

> "The positive program of developmental systems theory is that the fundamental unit of evolution is the life cycle. In turn, the life cycle is the set of developmental resources that are packaged together and interact in such a way that the cycle is reconstructed. The most obvious life cycle is that of the organism plus its immediate environment, but developmental systems theorists are open to the idea that cycles will exist at both finer and coarser grains." (Sterelny 2001, 335)

A driving goal in DST is to recontextualise, explain, and if possible do without the conceptual divide between matter and form, that is between specification and realisation, which underlies most discussions of nature-nurture (Oyama 2000). This implies putting an endogenous account of the concept of information at the centre of its theory, by focusing on the way such information is generated through the dynamics of a system as it develops and as its resources interact.

In many aspects, NCT-EES and DST complement each other (see Griffiths and Gray 2005 on the complementarity of DST and Evo-Devo in particular). However for the current purposes I suggest we locate both approaches with respect to the two following questions:

- How far should models and theories of evolution integrate the detailed processes of development and environmental interaction to provide an accurate picture of evolution? This question is not about finding the right level of descriptive complexity, but about finding the relative importance of each level of complexity. In other words, it asks what is the shape of the cost

function representing the trade-off between parsimony and explanatory power (rather than where on that function should a theory operate). The classical account of evolution suggests development can be usefully abstracted away, such that analysing gene flow with the four recognised processes (natural selection, genetic drift, mutation, and migration) can account for all important evolutionary dynamics. NCT claims that organism-environment interactions can generate dynamics that do not fit into the standard account but have long term effects nonetheless, warranting an extension of the evolutionary processes considered. DST further claims that evolution's unit of analysis should be the full life cycle of a developmental system (organism or other), which makes it more difficult to abstract out absolute information items but guarantees an accurate view of the causal parity of developmental resources, such that developmental processes are not obviated.

- What notion of information should evolutionary theory rely on? Classical evolutionary theory and NCT rely on the idea that DNA bears the biological information that is used throughout development, in an interaction with the environment. Conversely, DST refuses to conceptually separate inherited from acquired traits, a separation it sees as unnecessary for a populational approach: instead it adopts a relational notion of information as the co-product of development, "not by special creation from nothingness, but always from the conditional transformation of prior structure—that is, by ontogenetic processes" (Oyama 2000, 4).

Notably, the stances adopted by DST put it at odds with a dual-channel account of cultural evolution. While the developmental systems approach is compatible with population thinking, and thus with darwinian approaches in general (Griffiths and Gray 2005), it sees no theoretical reason to conceptually isolate different genetic and cultural channels of inheritance. Aside from genetic material and ecological niches, developmental systems also inherit epigenetic material, behavioural patterns and communication systems (Jablonka 2001) and more generally the full matrix of resources involved in the development of the system at its next life cycle. It might be useful for practical or descriptive reasons to focus more on some resources than on others, as is done for instance in the study of phylogeny, but doing so does not change the developmental interactions and causal parity of those resources with the rest of the set. A similar point will be made, below, about representations for the study of cognition.

Convergence

The notion of developmental system, and the importance it gives to the ontogenetic niche in which organisms grow, is convergent with 4E cognitive science and Sterelny's scaffolded mind approach. Aside from providing a natural account of culture similar to that of EES, DST also integrates the role of the ontogenetic niche in development all the way up to the cognitive level (Stotz 2010). Wimsatt and Griesemer (2007) have argued that an appropriate focus on scaffolding and development could shed light on the mechanisms of inheritance across generations, a necessary step in an account of cultural evolution. In agreement with DST, however, the authors feel that fixed- or dual-channel accounts of inheritance based on a notion of information transferred to offspring[3] obviate the role of development. Conversely, grounding an account of constancy and change in developmental processes requires considering all the resources that a system inherits, and their interaction in development.

In spite of such differences, the literature indicates that many aspects of EES, DST, and 4E cognitive science seem possible to fruitfully integrate for the study of cultural evolution. Indeed, DST is

---

[3]The definition provided by Boyd and Richerson (2005), and adopted by Mesoudi, Whiten, and Laland (2006), is along these lines. The authors define culture as "information capable of affecting individuals' behavior that they acquire from other members of their species by teaching, imitation, and other forms of social transmission" (Boyd and Richerson 2005, 6).

compatible with the population approach necessary for a darwinist analysis of culture (Griffiths and Gray 2005; Lewens 2012, 477), which is one of the core elements on which both the Parisian and the Californian cultural evolution streams are built. Lewens (2012, 474) also remarks on the encouraging fact that Russell Gray is both one of the main authors of DST, and is now an outspoken proponent of cultural evolutionary theory. A final case in point is the successful application of these ideas in theoretical and empirical proposals: as noted above, Croft (2013) provides a compelling account of language evolution that integrates the main contentions of DST; McGraw et al. (2014) also merge an interactionist approach to mind with classical cultural evolutionary theory, relying on both research streams to analyse the products of the repeated interaction experiment they study.

The shift in focus, from intrinsic capabilities of information-processing systems to the dynamical properties of the coupling of organisms with their environment, is also aligned with parts of the criticisms addressed by anthropologists to the initial versions of Californian and Parisian cultural evolution (Fuentes 2006; 2009; Ingold 1998; 2001).

"4E" revisited: the enactive approach

TODO: use chemero-after-2008 for this summary

A second avatar of the debate on the nature of information in evolution presents itself with the nature of representations in cognitive science. There are two levels to this question. First, if cognitive systems are construed as information- or representation-processing systems, the naturalisation of the content of such representations is a non-trivial matter; indeed it has attracted much attention in philosophy of mind. Second, it is not clear that information processing, and thus an account centrally based on representations, is the best description of the nature of cognition itself (as noted above, this is one of the driving questions in the debate around 4E cognitive science). More radical streams of the 4E movement contend that a notion of representation is unnecessary to account for the vast majority—if not all—of human cognition, and are developing alternative proposals (the capacity of cognitive systems to represent, if maintained in the theory, may then be seen as a contingent property and not a constitutive part). The enactive approach, in particular, proposes such an account of cognition. As described by Varela, Thompson, and Rosch (1991), Di Paolo (2005), and Thompson (2007), the enactive account builds on the notion of autopoiesis and ties cognition to living systems, considered as networks of processes that depend on each other for continued operation and continually produce and reproduce both the boundaries separating them from their environment and the conditions of their operation. Given this definition, a living system dies, that is loses its identity, if its network of self-producing processes ceases from functioning, and as such every interaction with the environment bears intrinsic value in terms of its contribution to the maintenance of the system's identity. This value is the basis for the enactive notion of meaning, which displaces the focus on information, or content, in representationalist accounts. Since living systems use their environment to self-reproduce, they are continually coupled to it in order to maintain the organisation of their network of processes. Cognition, then, is the dynamic regulation that the system operates on its coupling with the environment, and is an intrinsically meaning-making activity.

The enactive approach leads to a notion of meaning as a property emerging from the dynamics of interaction with the environment, and can be relevant at several levels of a system's organisation. This notion, and the view of cognition as a *meaning-making* activity, are also central in enactive accounts of social cognition (De Jaegher and Di Paolo 2007) and of the basic processes underlying language (Cuffari, Di Paolo, and De Jaegher 2015). The rationale for the approach is quite similar to that of developmental systems theory: talk of representations (or of biological information, in the case of

DST) easily leads to what Thompson (2007), building on Oyama (2000), calls an "informational dualism". The conceptual separation between matter and content creates a gap, and reifies information in a way that makes it difficult to naturalise.

These works are not explicitly directed towards the study of cultural evolution, and are by no means the only proposals competing within the debate on representations. Yet I will argue in Chapters 3 and 4 that CAT's reliance on mental representations as a unit of analysis renders this matter especially relevant, both theoretically and empirically, to the study of cultural evolution. The enactive treatment, among the most radical of the positive accounts because of its non-representationalist commitment, can serve as a useful point of reference, at the far end of the spectrum, in assessing approaches to information and meaning in the context of cultural evolution.

ADD: Somewhere: "The epidemiological approach renders manageable the methodological problem raised by the fact that our access to the content of representations is unavoidably interpretive. The solution to this methodological problem of ethnography is not to devise some special hermeneutics giving us access to representations belonging to a culture, yet uninstantiated in the individual heads or the physical environment of its members. The solution is merely to render more reliable our ordinary ability to understand what people like you, Opote or me say and think. This is so because, in an epidemiological explanation, the explanatory mechanisms are individual mental mechanisms and inter-individual mechanisms of communication; the representations to be taken into account are those which are constructed and transformed by these micro-mechanisms. In other words, the relevant representations are at the same concrete level as those that daily social intercourse causes us to interpret." (p. 53) So it really isn't a reductionism, but a "bridging the gaps" between approaches. "The kind of naturalism I have in mind aims at bridging gaps between the sciences. not at universal reduction. Some important generalizations are likely to be missed when causal relationships are not accounted for in terms of lower-level mechanisms. Other valuable generalizations would be lost if we paid attention to lower-level mechanisms only. If we want bridges, it is so as to be able to move both ways." (p. 98)

ADD: Somewhere: "The psychological features pertinent to determining types of cultural things may well include features of their content. Of course, content features can be characterized only interpretively. To say that various representations share a content feature amounts to saying that they can all be interpreted, at a given level and from a given point of view, in the same way. Still, that property of common interpretability, with all its vagueness, may suffice, if not to describe, then at least to pick out, a class of phenomena all affected by some identical causal factors." (p. 54)

1.2 Open problems

Moving back into the core of the cultural evolution framework put forth by Californian and Parisian cultural evolution, we can now put the focus on a number of outstanding questions for current and future research. The following discussion far from exhausts the questions to tackle, but gives nonetheless an overview of what I consider to be the most actionable or central items in the field.

1.2.1 Attraction versus source selection

The Californian and Parisian research streams are built around two complementary processes: attraction and source selection. Attraction is the umbrella phenomenon studied mostly under the Parisian approach, and is a central concept to explain cultural constancy and change when there

is no clear copying behaviour (i.e. transmission is low-fidelity): if we find constancy and gradual change in a given cultural domain in spite of interpretation, rich effects of psychology, cognitive biases, interaction, and no clear copying behaviour of agents, then cultural attraction might be a good candidate to explain its evolution. In itself, finding a cultural attractor is not an explanation, but an indication that the transmission biases are interacting in such a way that the state of culture is maintained in spite of important changes in micro-level transmission events. Source selection is the umbrella process studied mostly under the Californian approach, and is an explanatory factor of evolution in domains that feature copying behaviours (i.e. transmission is high-fidelity): when agents copy traits, or attempt to copy them, with for instance conformity, prestige, or content biases, then evolution can be usefully explored by looking at the way agents select the sources from which they copy, and the differential spread that entails. Both source selection and attraction act on multiple scales, as cultural traits or elements can be copied and transformed on several dimensions that potentially interact.

As Acerbi and Mesoudi (2015) note, attraction and source selection are not incompatible, as both are part of the overall cultural evolution process. Given their multi-level nature, both processes can also be part of one another; for instance, transformation at the level of a sentence can be analysed as selection at the level of words or concepts. Sterelny (2017) also notes that the Parisian and Californian research streams differ mostly in what they aim to explain. For the Californians, the question is how humans managed to survive and develop successful practices in the face of an opaque environment (for instance poisonous plants that, only if processed properly, can become highly nutritive). They explain this by appealing to cumulative cultural learning, which allows agents to learn from the practices of their preceding generation by copying and slightly modifying them in the process. Some level of imitation or copy is crucial to this account, precisely because the opacity and the dangerousness of the environment makes the sort of self-confident experimenting one could observe without copy extremely risky. For the Parisians, the question is why cultural traditions with no clear utilitarian value can exist, and evolve, aside from survival-related practices such as cooking techniques. They argue that the evolution of such traditions crucially involves ostensive communication (where the recipient of the communication must recognise the intention behind the communicative act), which is fidelity-neutral but not content-neutral: not all pieces of content are communicated equally, and successful communication only rarely entails copy. The Parisians thus ask why, in the face of a low-fidelity process that introduces such variation at every step, some cultural elements maintain a level of constancy and keep being transmitted through time, thus becoming evolving traditions.

If the two approaches aim to explain different features of culture, in which domain is each approach most appropriate? Are there domains that involve both imitation and non-copying communication in important degrees? How do the two processes interact in such cases? These are the questions left open by recognising a complementarity between the Parisian and Californian approaches.

1.2.2   Interaction of cultural and genetic evolution

Opinions on the importance of gene-culture co-evolution dynamics vary widely. To what extent do genetic and cultural evolution interact, and in which cases does cultural change drive genetic change? Niche construction theorists, and more broadly the Extended Evolutionary Synthesis movement, have convincingly argued for the relevance of such interactions in some specific cases, such as lactose tolerance. Developmental systems theorists further argue that genetic material and culture in its broadest sense are part of a wider matrix of resources that participate in the growth of developmental systems, and are thus necessarily interacting. Proponents of the Californian approach to cultural evolution broadly agree with the niche construction perspective, considering that the cul-

tural processes they study (concerned more with norms than with traditions *per se*) can have a long-term impact on the selective niche in which later generations develop. In particular, one view has it that the centrality of cultural transmission in human beings created a selective pressure for transmission capacities themselves (Sterelny 2017), such that cultural evolution drives genetic changes that enhance transmission. While CAT is broadly compatible with a gene-culture co-evolution account, and also discusses cases of change in context with downstream effects, Morin (2016) is not convinced that an impact of culture on genetic change is necessary to explain the emergence of global human traditions. Indeed, he argues that faithful transmission itself is neither necessary nor sufficient to explain the diffusion of global traditions, and consequently that scenarios that do not involve genetic adaptation to imitation are just as plausible given the current evidence.

This question is intimately related to the relative importance of imitation and non-copying communication. But answers might also lie in the importance and exact nature of the cognitive niche described by Sterelny (2010): how does the construction of such niches contribute to both ecological and psychological (through scaffolding of cognitive development) factors of attraction as the Parisian stream views them? How can the process of niche construction be usefully modelled to test hypotheses on the feedback dynamics between different channels of inheritance? Here too much is open to explore, which leads us to the two next points: formalisation and further development of empirical studies.

1.2.3 Framework versus formal theory contrasted with alternatives

Sperber (1996, 83) argues that CAT should not aim to become a "grand unitary theory", a position which is well informed by the diversity of domains CAT seeks to explain. It also seems in accord with the variety of ways one can approach a single domain, as the Cinderella example reminds us. Instead, CAT proposes a framework, a way of thinking that generates certain questions for the explanation of culture. Nevertheless, the approach relies on two fundamental elements that provide some degree of unification. First, Sperber insists on providing a clear ontology to the study of culture: that of public and mental representations, the latter relying on cognitive science. Second, part of CAT's argument for cultural attraction rests on the idea that much human communication is *ostensive* communication (Morin 2016, chap. 2), that is it works through the inference of communicative intentions, a process which involves a great deal of reconstruction. Relevance Theory (Sperber and Wilson 1995; Wilson and Sperber 2004), an approach that integrates well with CAT and proposes a framework to understand how agents select salient dimensions and implications of behaviours in concrete situations, is one contender for the detailed explanation of ostensive modes of communication. Given these two fundamentals, what prevents CAT from developing an abstract but systematic mapping of communicative process to stylised phenomenon, in a similar manner to the modelling endeavours of Boyd and Richerson (1985)? Sterelny (2017, 49) notes indeed that no such systematic formal models have developed in the Parisian research stream (although some models have been developed, for instance Claidière and Sperber 2007; Claidière, Scott-Phillips, and Sperber 2014).

Part of the challenge, at least, is the formalisation of both representations and the context in which they are communicated and evolve. While models need not reach this level of detail to be useful (indeed Claidière and Sperber 2007; and Claidière, Scott-Phillips, and Sperber 2014 propose higher-level models based on Evolutionary Causal Matrices), the richness of CAT lies principally with the recognition of an important role of cognition in cultural evolution, that is, of transformative and reconstructive processes. Thus, constructing stylised, simple and tractable models for CAT without emptying the approach of its main contribution is a challenge that has yet to be overcome. Classical cultural evolution, to the contrary, rests on imitative processes, such that models can avoid

restrictions on the exact nature of a cultural trait and focus on its frequency or spread in a population, without having to worry too closely about mutation. Not so for CAT: a meaningful model of cultural attraction must account for representations and their transformations, up to a degree, but in a sufficiently general way to (1) elicit effects due to the added ingredient of transformation, and (2) be applicable to different contexts. Claidière and Sperber (2007) and Claidière, Scott-Phillips, and Sperber (2014) have developed the first steps of such an approach, with discrete or continuous one-dimensional representation spaces that already show that attraction can create behaviours not accounted for by imitation-only models. The next step, however, is much higher, and is likely to involve a simple version of Relevance Theory, that is on one side an account of the multi-level and multi-dimensional aspect of representations, and on the other side a mechanism for agents to sieve through that added complexity.

While such an endeavour seems quite ambitious given the current state of modelling, it would provide a well-defined playing field to confront accounts of cultural evolution and especially the theories of cognition on which they are based. Indeed, as we have seen in Section 1.1.5, defining the cognitive factor of cultural evolution in terms of representation processing (a view shared by CAT and Relevance Theory) is not the only option on the market; one could imagine, for instance, a modification of CAT where the cognitive-level processes have been swapped out in favour of an enactive account of interactions. Indeed, that approach is also developing a description of the way organisms make sense of their world, a description which can come to replace the information-processing account of organisms selecting and inferring relevant information in their communications (in the terms of information processing approaches).

Overall, modelling CAT has not yet been pushed to its limits, and for good reasons: the challenges involved are considerable. But such a line, if successful, is extremely promising for the confrontation of approaches that genuinely compete for accounts of the interaction of cultural evolution and cognition. In the meantime however, the empirical investigation of cultural attractors is a workable task has much to bring to these theoretical questions.

1.2.4   Empirical attractors

Reliably defining and observing phenomena that qualify as cultural attractors in real life can be challenging, first and foremost because of the multi-level nature of culture, representations, and attraction. As Acerbi and Mesoudi (2015, 494) note, the definition of what counts as a cultural trait is not settled. Should one focus on mental processes, on artefacts, or on both? At what descriptive level of artefacts or representations does one consider a transformation to be a meaningful cultural change, worthy of being included as an instance of cultural attraction? Take the much debated example of Cinderella: any telling of that story will differ from other instances on dozens of features, which could all be taken to be significant in a particular context. A change in prosody or in the choice of words might alter the overall feel of the story, but not its narrative structure. A change in narrative style or structure, or an instantiation of the characters in a modern setting, might completely change the face of the story while maintaining the "persecuted heroine" aspect that tale classification systems attribute to Cinderella. Telling the tale in a particular context or to certain people only, say as an intimate bed-time story for one's child versus as a political metaphor in public discourse, can dramatically change the way it is received by its listeners. Looking for the information encoded in a version of the tale, as it were, or the representation it can elicit, only serves to postpone the problem one step further. The nature of these effects is well recognised by most writings on CAT, and one way of tackling them could be using Relevance Theory. Nevertheless, treating this diversity in an empirical study, even if it is only by classifying levels to evaluate their isolated relevance, is

very much an open question (even though Acerbi and Mesoudi 2015 note that similar multi-level indetermination of the unit of analysis is also found in the study of genetics).

As we shall see, identifying a cultural attractor in a specific domain also opens the question of the feedback loops it emerges from or participates in. Indeed an attractor is expected to have effects on the ecological context from which it arises, since it changes the distribution of representations people are exposed to. When psychological and ecological factors are involved in the emergence of the attractor, feedback effects are to be expected. How does an attractor participate to or transform its own context? In which cases is that retroaction a factor in the emergence of the attractor, versus a side-effect? For long-lived attractors, is this process a form of niche construction?

Second, as explained in Section 1.1.2, the scope of the phenomena to measure makes practical data collection also quite challenging. Existing methods can be divided into the meta-analysis of large bodies of historical and anthropological works, laboratory transmission chains or micro-societies, and the analysis of digital traces, especially from social networks. The expertise necessary to uncover reliable patterns using each of those methods makes higher integration a demanding task. Nonetheless, there is much to gain by articulating these paradigms together, individually pushing them beyond their current limitations, and connecting them to studies in cognitive science. Developing empirical methods is an integral part of any theoretical endeavour, and creating better observation tools is a sure path to push theoretical issues forward and to open previously unavailable questions to exploration.

More generally, fleshing out the predictions that attraction makes in specific empirical cases and developing methods to test those situations will help bring the ideas underpinning CAT into sharper focus. Much more empirical application is needed to evaluate the framework, and only such extensive testing in varied domains will determine how fruitful that approach is for the study of cultural evolution.

The present thesis aims to contribute to this project. In the following chapters, I will present two empirical projects aimed at testing for the presence of attractors in a particular case: the evolution of short linguistic written utterances. The practical goals throughout this work have been (1) to combine disconnected but complementary disciplines to improve on current empirical techniques, and (2) to explore dimensions in which those techniques can be pushed beyond existing limitations. In doing so, we shall also face the tension between two general approaches. On one side, *in vivo* studies use passively collected, ecological data, and must face the full complexity of reality plagued with external factors. On the other side, *in vitro* (laboratory) studies control most of the situation in which their data is generated, but are hostage to those same conditions; in particular, it is often necessary to give a task—or something much like it—to participants of a laboratory study, making any results dependent on the implications of the task. The work I present has two additional final goals: (1) contribute to the empirical evaluation of CAT as a theory of the interactions of culture, evolution, and cognition, in the form of the data points that I was able to collect; (2) highlight outstanding questions that are in need of more attention to make progress in the understanding of those interactions, thanks to a discussion of the costs handled and opportunities navigated by empirical work in the linguistic domain.

1.3 *Notes on things to add*

These two parapraphs come from the removed discussion of Ingold, but can introduce the chat about NCT/EES/DST/Evo-devo. Simplify them.

Ingold argues that Cultural Attraction Theory, as well as other approaches inpired by Darwin, relies on a description of life in three broad layers: the biological layer, which serves as the substrate for the second layer, cognitive, which itself serves as the substrate for the third layer, cultural. Each layer identifies a conceptual domain taken to be fundamentally different from the other two. The biological level is described by the modern synthesis of evolutionary theory, centred on genetic change, and studies the *body*. The cognitive level is described by cognitive science using the computational metaphor, which allows for the study of *mind* without necessarily worrying about its biological manifestation. In turn, the cultural level is described by (for instance) Cultural Attraction Theory, which studies *culture* as a distribution of representations circulating in society. The biological and cognitive layers define constraints on the way representations evolve at the cultural level (in particular through cognitive biases), but knowledge about the cultural level is not crucial to study the essential, universal parts of the mind or the body.

Each layer thus corresponds to its own object of study, implemented by the lower layers but conceptually independent from them. Ingold calls this assembly the *complementarity thesis*, referring to the way body, mind and culture are construed as separate and complementary parts of reality (Ingold 1998). The criticism he opposes to this approach can then be grouped into three essential points: (1) Each layer of the complementarity thesis is rooted in a problematic dualism that separates form and substance. (2) Without such dualisms, it is not possible to conceptually distinguish the three layers: there concrete manifestations are inextricable from one another, as they appear interlocked in a single object of study: the organism. If it is necessary to conceptually dice reality into parts or layers, it is not clear that the separation between biology, cognition and culture is the best way of doing so. (3) The notion of organism is itself problematic.

- the question about the genetic/non-genetic divide is precisely what is discussed by NCT/EES/DST/Evo-devo, and is also well discussed by Griffiths and Stotz (2013) (read intro); we take it as an open question about how to cluster the inheritance lifecycles
- debates on the cognitive side of things are beyond the scope of this intro/review, though chapter 4 will touch on them

Chapter 2

Brains Copy Paste

Chapter 3

Gistr

Chapter 4

Discussion

4.1 Introduction

In this chapter, we aim to take a broader view on what would be necessary to achieve a fuller understanding of the processes at work in cultural change at the linguistic level. So far we have adopted wholesale the paradigm put forward by Cultural Attraction Theory, by seeking to identify and elucidate situations where linguistic representations are transformed as they are transmitted, and assessing, on one side, the extent to which the empirical evolution of content agrees with what is expected under CAT, and on the other side, the extent to which CAT provides productive guiding questions in understanding what is at work in the situations studied. This has led us to identify a number of behaviours which are consistent with Cultural Attraction Theory: studying word substitutions in online quotations first, and more general transformations in controlled transmission chains of short utterances second, we showed that the low-level lexical features of words evolve in a systematic manner to make utterances easier to produce, and that the direction of the evolution is consistent with the attraction pattern that can be observed in the individual step of word replacements. However, these approaches did not bring us any closer to understanding the semantic changes that utterances undergo when they are transformed, be it online or in controlled transmission chains.

We now wish to discuss the reasons for this limitation. Our purpose is first to convince the reader that meaning[1] is a crucial aspect in the evolution of content which must eventually be analysed in order to fully understand the way representations circulate and change. Manual exploration of the changes in transmission chains in particular show that the surface measures that we used in quantitative analysis have no handle on the evolution of meaning. Indeed, meaning will appear as a deeply context- and interaction-dependent property, which cannot be understood by simply focusing on the utterances themselves. Second, we aim to show how this challenge can be traced to what is known in philosophy of mind as the "hard problem of content", and to how approaches to pragmatics deal with it. We will thus discuss two important approaches to studying the meaning of utterances in relation to the context and interaction in which they appear: Relevance Theory and the Enactive approach. The first is better developed and integrated with linguistics, but is complex to implement and must face some version of the hard problem of content in order to provide a complete account of meaning. The second starts from a simpler endogenous notion of meaning

---

[1]In what follows, we will always assume that meaning is meaning *to someone*. In other words, meaning to a listener is the listener's interpretation, and meaning to a speaker is the meaning intended to be communicated.

which avoids the problem of content, but has yet to prove its viability and usefulness for the study of language. Favouring one or the other, or possibly combining parts of the two, is further related to the overall construal of cultural evolution and to the importance of representations in a theory of cultural change, as critiques of the cultural attraction framework have shown. Finally we believe that the question of meaning in cultural change, and the debates it relates to, can be moved forward through informed empirical investigation. After having laid out the alternatives, our final goal is therefore to put forward the approaches we believe are most useful to turn this problem into an empirical question.

We begin by discussing detailed examples of the role of semantics in our transmission chain experiment, to show how the lack of an account of utterance meaning renders the empirical question of attractors in this case under-specified. Next, we present in more detail two possible approaches to pragmatics and meaning, and discuss their relationship to an overall view of cultural change. Finally, we present possibilities for refining and advancing the debate through empirical investigation.

4.2 Empirical epidemiology of linguistic representations

4.2.1 Relevant results

The path we took so far has consisted in entirely adopting the cultural attraction paradigm and developing experiments to evaluate one of its strong hypotheses, namely the existence of attractors in the evolution of representations. Indeed, cultural attractors are in many ways a cornerstone for the theory, as they reflect its explanation of the stability of culture in spite of strong micro-level transformations (they are the product of ecological and psychological factors interacting with each other), and they provide intelligibility into the complexity of cultural change as a whole. Linguistic utterances appeared as a good proxy to study representations that are part of everyday life and for which large corpora are readily available. Language is also one of the most versatile means by which representations circulate, making linguistic utterances an important study case for the theory.

Our initial high-level question was thus whether attraction could be observed in the evolution of linguistic utterances as they are interpreted and produced anew by successive people. The first case-study we developed relied on online quotations, a type of representation for which an implicit rule mandates perfect copy, yet which often changes as it propagates across blogs and news outlets. Our investigation of single-word replacements showed that, when transformed, words are reliably replaced by words easier to produce. Evaluated on standard lexical features, individual word replacements showed an attraction pattern specific to each feature and consistent with the hypothesis of an attractor at the lexical level, which could be due to cognitive biases in word production. Our second case-study explored utterance transformations in a more controlled situation, by setting up artificial transmission chains of short utterances on an online platform. Here, the analysis first focused on developing a descriptive model that would provide an overview of transformations decomposed into more basic operations. We showed that transformations can be reliably described as made of chunks of word insertions and deletions interspersed with individual word replacements (as well as chunk exchanges, which were set aside for the analysis). This level of description showed that the transformation process has several regularities: operations strongly depend on each other (in particular, insertions appear to make up in size for some of the deletions, while still introducing substantial change), and their prevalence also depends on the length of, and their position in, the utterance (longer utterances receive more operations; replacements preferentially target the interior of utterances, and insertions and deletions the second half of utterances). The behaviour of insertion

and deletion chunks, as well as replacements, was shown to be consistent with the biases identified in individual replacements in online quotations: the susceptibilities for being targeted by deletion or replacement, and appearing by insertion or replacement, closely complemented each other, in accordance with the hypothesis of an attractor at the lexical level; the overall evolution of the lexical makeup of utterances also reflected those biases by drifting in a specific direction on each lexical feature (corresponding to easier recall). More generally, we argued that the modeling approach provides crucial detail about the transformations, achieving a middle-ground between the focus on lexical features in individual word replacements and the wide-angle view of contrasts in the aggregated evolution of content along chains.

These analyses were made at the cost of several trade-offs. Transformations in the online data set were restricted to single-word replacements so that we could infer missing source-destination links between quotations, and lack of data meant that no analysis could be made of the context surrounding the quotations. The transmission chain experiments were led with an extremely simple read-and-rewrite task (though this was an intentional first step), which also did not open the analysis to the role of context in transformations and in the overall evolution of content. Nonetheless, these studies demonstrate that it is possible to decompose the transformations of utterances into combinations of smaller operations, and fully connect the behaviour of those operations with known effects in psycholinguistics, be it online (with a partial view of the process) or in controlled transmission chains (with a full view of the transformations). They further suggest that, due to cognitive biases in the way utterances and words are recalled, the evolution of short utterances like quotations could be subject to an attractor at the lexical level, making the words of utterances gradually easier to recall, on top of other changes in the actual content conveyed.

4.2.2 Challenges

However, these studies do not tell us the way utterances evolve semantically. Indeed, apart from the vector-based comparison of individual words for scoring matched and mismatched pairs in utterance alignments (an arguably simplistic approach to word comparison), none of the analyses we put forward have a grip on the meaning of the utterances, and much less on the change in meaning upon transformation. While it is noteworthy that it was still possible to extract reliable decompositions of the transformations without such information (as the manual evaluation of alignments attests), these analyses are blind to changes in the content circulated by the utterances.[2]

Let us show a few examples of the types of meaning change that were observed in the transmission chain experiments of the previous chapter.

Minor operations can change the function of a part of the utterance

Consider the following root utterance from in Experiment 2:

> "Can you think of anything else, Barbara, they might have told me about that party?" (4.1)

---

[2]We also explored the semantic distance traveled by words upon replacement, and the possible hyponym-hypernym relationships between replaced and replacing words, but did not present the analyses in the previous chapter as they provided no additional insight about the process.

The second part of this sentence is slightly misleading, and could be seen as a mild case of garden path sentence:[3] to "tell about" can be either transitive or intransitive, and while the final "that party" determines it as a transitive verb (for which it is the object), several subjects in the experiment rewrote the following sentence:

"Can you think of anything else, Barbara, they might have told me about **at** that party?"   (4.2)

The added "at" turns "tell about" into an intransitive verb, and turns the final part of the sentence into an adverbial phrase of time, thus changing its function in the sentence. More importantly, the sentence in its new form implies that the speaker was at the party, whereas the original sentence implies the contrary (although one could imagine the speaker was present but does not remember the details of the party). There is therefore a substantial change in the high-level meaning of this utterance, through the addition of a single word which changes the function of part of the utterance.

Once this change has occurred, regularisations often happen in the rest of the branch, for instance removing "about" to turn the ending of the sentence into "told me at the/that party". Looking at the leaves of the seven branches this tree contains, 4 of them maintain the implication that neither the speaker nor Barbara were at the party, 2 imply that the speaker (and not Barbara) was at the party, and one implies that Barbara was at the party (and the speaker was not).

Minor operations can create an ambiguity triggering larger changes

As we discussed at the end of the previous chapter, minor changes can also lead to larger downstream consequences in surface representation (as well as in meaning). A second example of typographical error can be seen with the following sub-chain in Experiment 3 (putting aside the UK/US spelling change, "canceled" → "cancelled"):

"The charge of embezzlement against the artillery has been canceled."   (4.3)

"The charge of embezzlement **again** the artillery has been cancelled."   (4.4)

"The charge of embezzlement again, the charge has gone."   (4.5)

In this case, the "against" → "again" replacement operated in the first transformation leads the following subject to interpret the sentence quite differently, making an larger change. This behaviour is far from systematic, as many times such small errors are corrected by later subjects. Consider for instance the following error made by a subject in Experiment 2:

"At least when they say they're going to have a war, they keep their word."   (4.6)

"At least when they say they are going to have a war, they keep **there** word."   (4.7)

---

[3]A garden path sentence is a sentence that misleads the reader into parsing its syntax one way, but necessitates a different structure to be understood once all the words have been read. A classic example is the sentence "The horse raced past the barn fell", which misleads the reader into interpreting "The horse" as the subject of "raced"; the correct parse corresponds to the meaning of "The horse that was raced past the barn fell", where "The horse" is the object of "raced". The difficulty comes from the fact that the search for the correct parse becomes necessary only once the reader has seen the final word, "fell".

The "their" → "there" replacement is maintained by the next subject, but then reverted by the one after that, thus coming back to the original sentence (aside from the change in contraction, "they're" → "they are").

Weak and strong pragmatics

The examples above, and the variability they illustrate, testify to the fact that different subjects can interpret the same utterance in strongly divergent ways. Subjects do not only differ on their performance in accurately reproducing the utterances presented, their productions also signal that different meanings can be constructed from the same root utterance (such differences accumulate, as was illustrated by the divergence of branches observed in the previous chapter). Part of this observation is commonplace, as the meaning of an utterance depends in obvious ways on the context in which it is produced or read, such as when deictics are used (words such as "today" or "here", which are context-bound by nature). However, most isolated utterances are under-specified in a way that makes them much more dependent on the context and on the interaction they appear in then what deictics suggest.

Consider once again utterance 4.1. With no further context, it is not clear what party the speaker is referring to, who were the participants, or why the speaker is asking about it. As the interpretations made by subjects in Experiment 2 illustrate, one could imagine that the speaker was at the party but does not recall its events, or that Barbara witnessed someone telling the speaker about the party, a telling that the speaker would not recall, and so on and so forth with other hypotheses. The sentence is originally extracted from a movie script, and in this case the sentence immediately preceding it in the script is enough to drastically reduce the possible interpretations:

> "I've spoken to the other children who were there that day. Can you think of anything else, Barbara, they might have told me about that party?" (4.8)

With this minimal context, it is now clear that the speaker was not at the party, but is asking Barbara to tell him or her something he or she already knows. To fully understand the utterances however, much more information on the interaction is needed: one must know that the utterances, extracted from the 1997 movie "The Devil's Advocate", are pronounced by a lawyer defending his client, a sexual abuser, while accusingly questionning Barbara, a victim of the abuser and witness in his trial.

This example illustrates what Scott-Phillips (2017) calls *strong* pragmatics. Contrary to *weak* pragmatics, which construes the context-dependence of meaning as a layer to be added on top of semantics, syntax, morphology, phonology and phonetics, strong pragmatics refers to the fact that all communication fundamentally depends on social cognition, which cuts through the other layers of linguistic analysis such as semantics and syntax. Indeed, what is communicated through the utterances discussed above, which can be rephrased as "tell me this thing I already know but that the audience does not", could have been conveyed through an entirely different set of sentences (that is different semantics, syntax, morphology, and so on) because it depends above all on the social cognition situation that participants find themselves in.

Examples of this phenomenon abund, and are not restricted to face-to-face interactions as depicted by films: no matter the type of mediation, any interaction is likely to feature strong pragmatics. Twitter conversations are a good case in point for online platforms. The short conversation reproduced below, for instance, illustrates the fact that the meaning as understood by participants is a construc-

tion depending on context, past history, and interaction dynamics.[4] It starts with the following tweet:

"We are all good-looking and ugly to someone else's eyes"   (4.9)

This utterance seems a priori neutral, and is commonplace and consensual enough for it to be marked as favorite, retweeted and published anew regularly.[5] But as illustrated by the answers following it, the actual meaning exchanged in the conversation is not available to the non-interacting reader. A first answer is made in a humourous tone:

"but we're still ugly in the first place haha"   (4.10)

Then, two replies later, the conversation ends:

"[laughing out loud,] true for some girls especially, I would say"   (4.11)

Even after five replies, we cannot determine whether the meaning exchanged is about sexism and rejection, or simply a flimsy joke without consequence; yet when taken as cultural tokens, these two representations are diametrically opposed to each other. With no further information about the relationship between the participants, their past interactions or common history, and in spite of the conversation being entirely public, we cannot determine what the exchange is fundamentally about, or even decide what the initial tweet means to one participant or the other.

Summary of problems

Let us now return to our initial question, namely the identification of attractors in the evolution of linguistic content. As might be clear by now, this goal is challenging in at least three new and related ways. First, the importance of strong pragmatics renders it much more difficult to collect all the necessary data to understand the meaning that a subject attributes to an utterance, or what is exchanged in an interaction. Indeed, it is often necessary to rely on detailed information about the interactive situation to understand that meaning. Leaving aside the question of the theoretical and technical apparatus that would be required to quantitatively analyse such data, the situations in which an experimenter can have access to the whole interactive situation, and thus have access to meanings exchanged (i.e. determine the content of the representations that circulate), are extremely rare. In most cases, an experiment only gives access to artefacts that are part of a broader cycle of meaning creation.

Second, even when the interactive situation is available to observation, the meaning of an utterance is not reducible to a simple object, and remains a multi-scale (and inside each scale, multi-dimensional) target. Coming back once again to utterance 4.1 with its surrounding context, what aspect of the meaning should one focus on when examining its evolution to identify attractors? The presence

---

[4]The conversation is originally in French, and reads as follows: "On est tous le beau et le moche de quelqu'un" / "mais être moche c'est quand même la base ahah" / "[mort de rire,] pour certaines filles surtout, je pense".

[5]A simple search on Twitter using the original text in French shows that the utterance appears about once a month, with most instances retweeted several times.

of a request to publicise private information, the implication that Barbara is lying or holding back such information, the lower-level structure of the question? In other words, the goal of identifying attractors in the evolution of meaningful utterances is, at least in our current formulation, under-specified. This problem is not new, and might even not be a theoretical problem for Cultural Attraction Theory: behind the multi-dimensionality of meaning is the fact that culture itself is a multi-scale phenomenon (and multi-dimensional at each scale), difficult to characterise in simple mathematical terms. CAT works around this problem, as Sperber insists that it should not aim for a "grand unitary theory", and should rather generate useful domain-specific questions that depend on the matter at hand (Sperber 1996, 61, 83). Thus the empirical decision of which meaning level to focus on must be resolved by appealing to the importance of each level as individually observed.

Finally, a more important theoretical challenge comes from the fact that strong pragmatics puts an important part of the responsibility for meaning, that is for the content of a linguistic representation, in the interactive situation itself. If the meaning of an utterance is determined in great part by the interaction it features in, and if that meaning corresponds to the content of the linguistic representations whose epidemiology we wish to study, then how is it possible to identify two representations from different situations as being the same (or being close to each other)? To make progress in the epidemiology of meaning-bearing utterances, an approach to strong pragmatics must thus be able to relate meanings that come from different interactive situations, to some extent at least. Indeed, evaluating the evolution of representations requires us to be able to identify, if not the path taken by specific strands of representations which inherit from each other, at least the overall trajectory of a population of representations in a common state space. As a consequence, an approach to pragmatics useful to CAT must provide a way to declare meanings different, or identical, or evaluate the extent to which they differ, across situations (without which evolution can only be observed inside fixed interactive situations).

4.3 Approaches to meaning

If we thus broaden the scope of empirical studies of CAT to all interactions (face-to-face or digit-ally mediated, but not necessarily linguistic, and in any case beyond interaction-less transmission chains), as will eventually be necessary for strong pragmatics, we are faced with the concrete question of how to understand the way an agent (participant, subject, person, or non-human organism) extracts or constructs meaning in such an interaction. That is, which of the infinite possible meanings the agent selects (or constructs), and how that selection (or construction) operates. As we just saw, such meaning is highly dependent on the context and interaction the agent finds itself in, such that viable approaches to meaning will necessarily be coping with the complexity of possible inter-active situations. This makes the picture considerably more complicated than when dealing with simple context-free utterances.

In this section, we present two prominent approaches to meaning and pragmatics, both of which can prove useful for further exploration of cultural evolution. The first, Relevance Theory, fleshes out the idea (first introduced by Grice 1989) that human communication is ostensive communication, based on the recognition of relevant communicative intentions. The second, the Enactive approach, starts from a more bare-bones level of description and proposes an understanding of how mean-ing emerges from the interaction of agents seen as dynamically coupled organisms. As we will see, both these theories provide (part of) an answer to how agents select, infer or construct subtly varied meanings in the course of an interaction, but they do so by starting from opposite ends. The first builds on a propositional notion of representations that are processed and combined in inference

processes, while the second starts from a representation-less description of organisms whose inter-action and coupling with the environment endogenously generate (non-representational) meaning. The notions of meaning to which they arrive are quite disjoint, and have historically been considered in contradiction; indeed, we will then show how these differences can be grounds for a critique of CAT and other Darwin-inspired cultural evolution approaches. In spite of this, we will argue that both approaches to meaning could be productive guides for generating empirical questions and experiments regarding cultural evolution.

4.3.1   Relevance theory

Principles

As a general theory of communication, Relevance Theory has a very broad scope and relates to many areas of cognitive science. Sperber and Wilson (1995) and Wilson and Sperber (2002) provide detailed presentations of the full theory, and many publications in between and since then have fleshed out its relations to a number of neighbouring questions. Wilson and Sperber (2012), in particular, provides a thorough discussion of several linguistic phenomena based on Relevance Theory, as well as openings towards experimental and cultural evolution-related approaches to the question of meaning and relevance (for language evolution see in particular Sperber and Origgi 2012). Here we will restrict ourselves to a sorely abridged presentation of the already summarising Wilson and Sperber (2004), in the hopes that it will be enough for an approximate understanding of the principles underlying the theory and the explanations it provides.[6]

Relevance Theory (RT) opposes itself to the code model of linguistic communication, according to which a speaker's meaning is encoded in an utterance, passed on to the listener for instance by means of sound (the channel, or conduit), and then decoded by the listener to obtain the communic-ated meaning. By contrast, RT adopts an inferential model according to which an utterance does not encode a meaning per se, as the semantics of utterances provide only under-determined in-formation about the speaker's meaning (as illustrated by the examples discussed above); instead, the inferential model considers that utterances provide evidence (and exactly the right amount of evidence) for the intended meaning to be inferred given the situational context. This model of com-munication was first elaborated by Grice, building on the fact that people who are communicating usually assume that what the other person is saying is meant to be understood given the context at hand; in other words, people take their interlocutors to be neither stupid nor adversarial, and as-sume (consciously or not) that what a speaker says is a signal for a meaning that the listener should be able to understand, through inference. Grice thus identified four general rules (maxims) that listeners generally assume their interlocutor will follow, and on which they rely to infer meaning: Quality (truthfulness), Quantity (informativeness), Relation (relevance), and Manner (clarity). RT agrees with the intuition behind Grice's observations (although it differs on exactly which listener expectations should be necessary), and fleshes out this general inferential model of communication in cognitively plausible terms.

RT proposes that inferential communication is based on a cost-reward comparison of possible con-clusions that derive from a speaker's utterance. Indeed, a given utterance (or non-linguistic commu-nicative act) in a given context can lead a listener to any number of conclusions about the world. Each

---

[6]Our presentation focuses on the founding principles of Relevance Theory. The remainder of Wilson and Sperber (2004) fleshes out the way the inferential procedure is applied to linguistic utterances, how the theory explains typical phenomena such as loose uses of language (e.g. the meaning of 'square' in expressions such as 'square face' or 'square mind'), irony, or poetry, and how it fits with the massive modularity of mind approach introduced in Sperber (1996), along with many detailed examples.

of those conclusions about the world can matter more or less to the listener (RT formulates this as the strength of the contextual effects created by the conclusion), and is also more or less costly to derive from the speaker's utterance and its context (processing cost in RT terminology). A conclusion that matters more to the listener achieves higher relevance, and conversely a higher processing cost will lower the relevance realised by a conclusion. These two dimensions let listeners order the conclusions that can be derived from a speaker's utterance based on their (context- and listener-dependent) relevance. For instance, Sperber or Wilson hearing that their train to work is one minute late is less relevant (because it matters less to them) than hearing that their train is late by a half hour. Conversely, a public announcement stating that their train is late provides a more relevant conclusion (because easier to derive) than the same conclusion derived through more deductive effort from bits of a conversation overheard between the people sitting next to them. A central claim of RT is that evolution has shaped human cognition in such a way that people automatically and easily perform this derivation and comparison process on all the stimuli they perceive, picking out those among the myriad available which maximise relevance. The Cognitive Principle of Relevance expresses this claim: "Human cognition tends to be geared to the maximization of relevance" (Wilson and Sperber 2004, 610).

Wilson and Sperber (2004) then define inferential communication as consisting of two elements. An *informative intention*, that is the intention of a speaker to inform an audience of something (more precisely, to make certain assumptions more, or less, manifest to the listener), and a *communicative intention*, that is the speaker's intention to inform the audience of their informative intention. In other words, inferential communication happens whenever the speaker says (or does) something in order to make her audience recognise that she wants to convey X. The meaning is successfully understood when the audience recognises the speaker's informative intention, that is when the audience recognises that the speaker wants to convey X (note that X itself might not be conveyed if the audience does not trust the speaker – the communication event is nonetheless successful, since the intention to convey X was recognised). Most often, the speaker does this by making an ostensive communication act (e.g. pointing, staring, or saying something that attracts the audience's attention) which signals to the audience that there is something worth processing to attend to. Indeed, ostensive stimuli create in the audience an automatic expectation for relevance, as the audience looks for the reason for which the speaker is attracting their attention. More precisely, RT posits that the audience automatically expects the stimulus to be *optimally* relevant; in the theory's terminology, this is formulated as the Communicative Principle of Relevance: "Every ostensive stimulus conveys a presumption of its own optimal relevance." This principle is the basis on which the audience's inferential process works: the speaker's ostensive stimulus signals something worth processing to reach a relevant conclusion (since she attracted their attention to process it), and it is also the stimulus that makes that relevant conclusion the easiest one to reach.

The authors discuss an example to illustrate this: we are at a table and my glass is empty, a fact that you might notice. If you do (without me communicating anything), one conclusion you could reach is that I might like a drink. If, however, I wave my glass at you, or say "My glass is empty" (ostensive stimulus attracting your attention to my empty glass), a relevant conclusion you would reach is that I want to communicate that I want a drink (and, if you trust me, conclude that I want a drink, although that is not necessary for the communication to succeed). RT thus proposes a procedure that can account for the way utterances are understood: when perceiving a stimulus (possibly ostensive), and given a certain context, compute the relevance of its conclusions (i.e. the strength of contextual effects pitted against the processing costs) following a path of least effort first (since the stimulus is expected to be optimal), and stop whenever you have reached your expected level of relevance. In other words, test hypotheses about the speaker's utterance such as possible disambiguations, resolution of entities and implicatures, and stop whenever the conclusions you

have reached seem relevant enough to you. The conclusion you have then obtained will be your assumption of the speaker's meaning for the context chosen at the beginning. Finally, note that this inference procedure can be operated in different possible contexts, as long as they are available given the memory constraints of the listener. The procedure thus also optimises on the context in which conclusions are drawn, and selects the context for which the final conclusion is most relevant.

Application

The framework provided by Relevance Theory is extremely rich, and has been the subject of extensive experimental exploration and validation (see Noveck and Sperber 2012; and Henst and Sperber 2012 for reviews). In particular, it brings direct insight to some of the limitations concerning meaning in the experimental approach of the previous chapter. The transmission chains we set up are a clear case of ostensive communication: we ostensively ask the subjects to direct their attention to the utterances they are asked to memorise and rewrite. However, the utterances are presented with no context other than the task itself, which frames the experiment as a memory exercise. There is no background information against which the subjects can evaluate the relevance of conclusions derived from the utterances, nor are the subjects involved in an activity that would make the conclusions matter in one way or another. Without an ecological activity to which the utterances can become relevant, the experiment has no control over the meanings that subjects will infer from the utterances, leaving the matter entirely under-specified. It is also easier to understand why subjects spontaneously wrote sentences directed to the experimenter such as "I can't remember": if the task does not create an ecological communicative activity that relates subjects to each other, and is instead (correctly) understood to be a memory task, the only valid interlocutor is the experimenter evaluating the memory performance. As a consequence, asking the subjects to keep in mind that their productions were sent to other subjects (as we did) was likely to create a slight discrepancy.

The relevance-theoretic approach also opens the door for the analysis of interaction, context, or past history in the evolution of meanings. Using carefully constructed contexts to orient what is available to the inferential process, it should be possible to greatly reduce the possible meanings interpreted by subjects, and thus explore the way interpretations evolve through chains of contextually-augmented utterances (or chains of constrained interactions). In practive however, such an implementation is likely to be extremely challenging (much more so than the procedure developed in the previous chapter): whatever the theory, it is still necessary to extract the basic propositions semantically encoded in the utterances typed in by subjects, determine the way subjects select contexts, and automatically or manually derive the possible conclusions that can be reached for a given utterance in a given context. The three tasks are far from trivial. Second, efficiently constraining the context in which an utterance is interpreted will likely be much more difficult than it sounds, as real life interpretation involves our own personal history, memory, preoccupations and any other pregnant contexts we can recruit during the process (see Sperber and Wilson 1995, secs 3.3–4, which discusses the ways contexts are chosen in the inferential process). It is doubtful that simply adding a few sentences around the target utterance would suffice. Instead, it could be necessary to create more encompassing situations such as a controlled video game where much larger parts of the many contexts available to subjects can be experimentally manipulated.

Meaning as indexed on knowledge optimisation

We have just seen that the notion of meaning provided by Relevance Theory is based on a maximisation of the relevance of conclusions derived by the listener. This account ultimately rests on the

three following cognitive mechanisms:

- Reconstruction of the logical form of an utterance, in order to start the inferential process (see Sperber and Wilson 1995, sec. 4.3, for details),
- Creation or selection of contexts inside which the inferential process operates (see Sperber and Wilson 1995, secs 3.3–4, for details),
- The inferential process itself, operated by what is hypothesised to be a special-purpose deductive device (see Sperber and Wilson 1995, secs 2.4–5, for details).

This account can also be formulated in terms of a system which optimises its representation of the world (without access to the truthfulness of what it perceives), and for which relevance indicates the path of strongest optimisation growth. To see this we must briefly return to the exact definition of relevance in the theory. Relevance in Sperber and Wilson (1995) is defined in the following three broad steps:

1. Define the *deductive device* that is used for inference: it is a mechanism for deriving conclusions from a set of premises P (usually coming from an utterance from a speaker) in a set of contextual assumptions C (Sperber and Wilson 1995, secs 2.4–5); in this device, all assumptions, premises and conclusions have a certain strength, corresponding to their level of accessibility (this is not a logical measure of confidence that can be quantified, but rather an ordinal property that can be used to compare assumptions between each other).

2. Define the notion of *contextual effect*: a set of premises P (coming from an utterance) in a set of contextual assumptions C generates a contextual effect if and only if the deductive device can derive conclusions from the combination of P and C that it cannot derive from P or C alone. Such conclusions can be new to C, can strengthen existing assumptions in C, or can weaken and even erase assumptions in C (Sperber and Wilson 1995, secs 2.6–7). The notion of contextual effect thus provides a indication of the strength of the relationship between an utterance and a set of contextual assumptions C.

3. Define the degree of *relevance* realised by conclusions derived by the deductive device from P and C: conclusions are more relevant if they have stronger contextual effects, and less relevant if they have higher processing costs (in terms of deductive steps involved).

With relevance thus defined, Relevance Theory's procedure for interpreting utterances and other stimuli can be seen as a tentative procedure to always improve the system's representation of the world: if the processing system has no access to the truthfulness of the stimuli and utterances it perceives, its best option is to process the incoming information in a way that maximises what it can infer about it, given its level of trust in the speaker. In other words, it will look for the set of assumptions that can most benefit from the new information. If the system functions with a deductive device such as the one defined above, this corresponds to finding the set of contextual assumptions C on which the new information (premises P) has the strongest contextual effect, with given processing cost constraints and for a given level of trust in the speaker (i.e., strength of the premises P); given the above definition of relevance, that is precisely the procedure to reach the most relevant conclusions. Under this description, higher relevance indicates a stronger update in contextual assumptions, thus a stronger update to the system's overall representation of the world. Thus Relevance Theory can be seen as indexing meaning on the increase in reliability of a listener's representation of the world. The Communicative Principle of Relevance then simply states that speakers know that listeners work by maximising inferred relevance, and will behave accordingly in order to be understood (i.e. by saying things which they know will trigger the right inferences for the listeners).

Whichever the formulation we choose, RT crucially relies on a deductive device which can represent

propositions extracted from utterances and process such propositions in order to derive new conclusions. Once the inference process is completed however, the meaning defined by RT is partially propositional, as it is made of a set of new assumptions that are made more less manifest (through a change of strength). Such meanings can thus be at least partially defined and used without reference to the situation they were deduced from, making them (partially) comparable to other meanings from other situations. The approach to pragmatics developed by RT is thus quite amenable to the study of cultural evolution (which is no surprise, given the authors).

One disadvantage of the relevance-theoretic approach is the high level at which it starts its description, making concrete implementations more challenging. As we indicated earlier, it relies on the reconstruction of the logical form of utterances, on a mechanism for the creation of contexts, and on the inferential process itself. Second, a theoretically important, but experimentally less important consequence of the theory's reliance on propositions and mental representations is that a full account of meaning will eventually require an account of the content of such representations (a problem known in philosophy of mind as the hard problem of content, Hutto and Myin 2013). We will now turn to a second approach to meaning, one that does not rely on propositions or even representations, and starts from a much lower level of description. Our hope is to convince the reader that this second approach, although less connected to the standard body of linguistic research, should also be a fruitful avenue to explore the effects of interaction in relation to meaning in cultural evolution.

4.3.2   The enactive approach

A non-computational metaphor of cognition

The enactive approach proposes a different foundational metaphor for the study of cognition. Indeed, Relevance Theory and Cultural Attraction Theory, along with our own experimental approach to their questions, mostly rely on a computational metaphor for the description of cognition: the mind is taken to be like a computer, that is an information-processing device which continuously receives stimuli, updates an internal representation of the world based on what it perceives, and acts based on its current representation and predictions given current stimuli. The human brain is our implementation of such an information-processing device. The approach we are interested in here is part of a range of approaches that question the utility of conceiving the mind as such an information-processing system,[7] and explore the extent to which parts of (or all) the metaphor can be relaxed or replaced by other paradigms (see Chemero and Silberstein 2008 for a review of the options available in the debate, and the fields corresponding to each choice). In this area, the enactive approach has the advantage of being extremely consistent in its rejection of the computational paradigm and of the idea that cognitive systems represent their environment, and is to our knowledge the only contender that has started developing a detailed non-computational approach to language itself. As we will see, instead of a computational paradigm, the Enactive approach proposes to base cognition on the dynamical coupling of organisms with their environment and with each other. Compared to Relevance Theory, it is located at the other end of the computational spectrum, and uses a simpler initial level of description. Nonetheless, it is concerned with questions common with RT: both aim to reach complete and plausible explanations of language and meaning. As Chemero and Silberstein (2008) argue however, these two types of approaches are not necessarily opposed, and could be usefully combined to form complementary explanations. Our goal here is to present the basic tenets of the enactive approach and show how, by starting with a different metaphor, it faces an orthogonal

---

[7]These approaches are sometimes collectively termed the "E turn", in reference to the many titles starting with the letter "e" (in particular, enactive, embedded, embodied and extended approaches to cognition).

set of problems compared to RT. In particular, the notion of meaning it develops seems more endogenous than that of RT (among other things, by being non-representational, it does not face the hard problem of content), but is currently much more low-level and not yet usable to fully comprehend actual linguistic interactions. What the theory currently provides can be seen as the explanation of preliminary steps common to language and less structured interactions, eventually to grow into a full theory of linguistic interactions (or, in enactive terms, "enlanguaged" interactions).

The first concrete articulation of this approach in cognitive science is usually attributed to Varela, Thompson, and Rosch (1991) who develop a view of cognition based on Merleau-Ponty's phenomenology. They propose to look at mind, cognition and meaning as fundamentally embodied and situated processes in which self-organisation plays a central role. Of course, nobody basing themselves on the computational paradigm would deny that what they talk about is ultimately grounded in physical embodied things; however the specificity of the enactive approach (and of other non-representational approaches with it) is that its explanations draw deeply on the embodiedness and situatedness of the processes, in that they create notions of cognition and meaning defined in terms of the coupling of physical systems, rather than in terms of symbolic processing. The initial formulation by Varela, Thompson, and Rosch (1991) led to many developments. We present here the main theory going under the name "enactive approach", and do so in four important conceptual stages which we believe roughly (though drastically) summarise what has been developed by Torrance (2006), Thompson (2007), De Jaegher and Di Paolo (2007), and Cuffari, Di Paolo, and De Jaegher (2015). While this will by no means do justice to the complete approach, we hope these stages will provide a clear-enough sketch of the dynamical and embodied account of cognition that the enactive approach develops and proposes to use instead of the computational metaphor of mind.

Stage 1: sensorimotor contingencies

The first stage is a reconceptualisation of the way an organism perceives its environment. This conceptualisation, known as the sensorimotor approach to perception (and thoroughly developed for vision by O'Regan and Noë 2001), essentially takes perception to be an exploratory activity based on a continuous perception-action loop. By contrast, the default approach to perception is to construe it as an inference problem: through its senses, an organism receives information about the world and attempts to reconstruct an internal representation of it, which is challenging because the information is degraded in a number of ways. Instead, the sensorimotor approach construes perception as the exploration of the regularities in the way stimulations change when the organism moves around or acts on its environment (or on an object). Rather than inferring and internally representing the properties and shape of an object that is being perceived (for instance), the sensorimotor approach construes an organism as exploring the changes it generates in the sensory stimulations when moving, thus making perception and action two parts of a common loop. As O'Regan and Noë (2001) put it: "seeing constitutes the ability to actively modify sensory impressions in certain law-obeying ways." An extreme example of such actively perceived properties is the softness of a sponge, which is felt by prodding and squeezing it but not through static contact (Myin 2003).

One of the strong motivations for this approach is that it provides an endogenous account of the feel of a perceptual modality (i.e. its perceptual consciousness), a longstanding problem in inferential approaches to perception. According to the sensorimotor approach, seeing and hearing feel differently (i.e. one can easily differentiate visual from auditory consciousness) not because they are processed by different parts of the brain, but because of the specific regularities with which stimulations are deformed in each sensory modality when the organism moves. Turning our head, for instance, generates a certain change of stimulation in vision, and a different change in hearing. The way each

modality sees its stimulation change with movement is referred to as its *sensorimotor contingencies*, and is directly tied to the type of perceptual consciousness the modality creates.

An interesting confirmation of this approach is found is experiments using "Tactile Visual Substitution systems", where blind people are equipped with a device that reproduces on their skin (through an array of stimulators) the luminance patterns captured by a camera. The subjects are then tested on their ability to recognise objects using this cutaneous stimulation, and are only able to do so if they actively control the movements of the camera itself (O'Regan and Noë 2001, 958). Furthermore, once they do control the camera, their sensations seem relatively close to actually seeing, because the sensorimotor contingencies are so similar: they begin to perceive objects as not on their skin but in front of them (in particular, they can be frightened by a zooming effect in the stimulations, which corresponds to an object approaching very fast), and the location of the stimulator array on the body becomes unimportant (subjects can easily transfer from stimulation on the back to on the forehead). Such experiments have contributed to showing that perception and action are two sides of the same dynamical interaction loop with the environment, and by generalising to other modalities, they suggest that sensorimotor contingencies provide an endogenous account of perceptual consciousness.

Stage 2: sense-making

The second stage extends this approach to life itself (here we follow De Jaegher and Di Paolo 2007; and Thompson 2007). In a nutshell, it can be seen as taking the reconceptualisation operated by the sensorimotor approach, which goes from a notion of perceptual consciousness based on inference to a notion made of sensorimotor contingencies arising in perception-action loops, and applying it to meaning in cognition: instead of being seen as the result of an inferential process, meaning will be seen as a property (or a regularity) of the dynamical interaction of an organism with its environment.

Let us make this step more precise. Inspired by the notion of autopoiesis developed by Maturana and Varela (1980), the enactive approach considers a living organism as an *autonomous system*, that is a network of processes with the following properties:

1. The system is self-produced and self-maintained. As a consequence the processes depend on each other for continued operation, that is, every process in the network is conditioned on the activity of one or several other processes of the network (a property called *operational closure*). A second consequence is that the network of processes acquires an identity (defined by its operational closure).
2. The system continually produces a boundary that distinguishes it from the environment (this need not be a physical boundary).
3. The system actively regulates its interaction with the environment in order to maintain its identity.

Crucially, the identity generated by operational closure is precarious: it disappears if some or all of the processes that make up the system cease. The system is thus in a permanent tension to regenerate the conditions for the continuation of its identity, and any interaction with the environment thus acquires an inherent value to the system since it can have positive or negative consequences on the continuity of the system's identity and autonomy. Since interactions with the environment are necessary for the network of processes to keep self-generating, the system is continuously regulating the strength of its coupling with the environment in order to maintain its identity. Interaction with the environment then becomes inherently meaningful to the system, and the enactive approach calls it "sense-making".

In this framework, cognition *is* precisely the sense-making activity, that is a system's actively regulating its coupling to the environment in order to maintain its identity. Notice how the enactive notion of meaning is defined in a parallel manner to the sensorimotor account of perceptual consciousness: instead of being inferred and represented, it is a property of the dynamics of the system's interaction with its environment.

Stage 3: participatory sense-making

The third stage extends the theory to interaction between two autonomous systems, and introduces the notion of an autonomy of the interaction itself. De Jaegher and Di Paolo (2007) develop this in two steps. First, they show that some interactions can only be explained at the level of the interaction itself, rather than at the level of participants. An interesting point in that direction has been made in an experiment by Auvray, Lenay, and Stewart (2009). The experiment involves two subjects who share a virtual line on which they each have a cursor. The line and cursors are all invisible, but the subjects receive haptic feedback whenever their cursor is overlapping with the other's cursor. Aside from the subject's cursors, two fixed obstacles are placed on the line (each is perceivable by one subject and not the other), and the cursor of each subject has a shadow that follows it at a fixed distance: when subject A's cursor touches the shadow of subject B's cursor, subject A receives haptic feedback but subject B does not (and vice-versa). The subjects are told about obstacles but not about shadows, and are tasked with clicking as much as possible on each other's cursors. Interestingly, they succeed in doing so, but not because they are able to distinguish between real cursor and shadow. The experiment shows instead that they are not able to make the distinction individually, but solve the task because the interaction of real cursors is more stable (and thus more frequent) than the interaction with a shadow: subjects individually fail the task while succeeding collectively, in a way that can only by understood because of the inherent (and unnoticed) stability of their interaction. The principle highlighted by this experiment is that of the stability of *perceptual crossings*: two organisms can have a dynamically stable interaction because they each look for a behaviour that they themselves create, without necessarily being aware of that fact (for instance mutual gaze of an infant and his mother, where the infant may not be aware that his mother maintains the gaze because he does too). Variations and detailed behaviours in this experimental paradigm have been extensively explored in this literature, providing further support for the results above (see for instance Bedia et al. 2014; Froese, Iizuka, and Ikegami 2014).

Second, De Jaegher and Di Paolo (2007) argue that such stable interactions can acquire an autonomy of their own. An example that most people have experienced in everyday life usefully illustrates their point: when trying to cross someone else in the corridor of a train, and moving to the side to avoid them, at times the other person spontaneously moves to the same side you did; when this happens, you and the other person enter an interaction which both are trying to break from the start: each one moves to one side, and the other does the same, until your movements desynchronise and the interaction breaks down. During the time it persisted however, the interaction acquired its own autonomy which constrained both you and the other person, as neither could break free from it.

This autonomy serves as the basis for defining sense-making at the level of the interaction itself: when two organisms interact while at the same time regulating their coupling to their environment (and respecting each other's autonomy), the interaction itself can spontaneously self-organise and become self-sustaining. Similarly to organisms, then, it acquires an identity of its own, and an interest in maintaining that identity: in that case, since the couplings of each organism to their environment and with each other have an impact on the continuation of the interaction, they become meaningful *to the interaction* which can then partly regulate them. A new sense-making activity thus appears

at the level of the interaction itself, a level that neither of the participants fully control, and which has the potential to create constraints on them. This notion, termed *participatory sense-making* (De Jaegher and Di Paolo 2007), has become a key building block of the enactive theory of interaction as it provides a well-founded and naturalised path to explaining emergent effects in interactions.

Stage 4: languaging

The fourth and final stage brings us to language. Relying on the concepts defined above, Cuffari, Di Paolo, and De Jaegher (2015) propose to see language as a specially structured pattern of participatory sense-making, governed by several levels of conventions interlocked with one another. More precisely, since a crucial feature of participatory sense-making is that the interaction itself acquires regularities that neither participant controls, it follows that interactions create some sort of tension between the way individual organisms regulate their autonomy and the regularities that the interaction may impose on them if they are to continue interacting. Consider once again the perceptual crossing experiment introduced above. In the initial setup by Auvray, Lenay, and Stewart (2009), subjects are not able to distinguish between the other's cursor and its shadow, such that prosociality is neither presupposed nor observed and yet the pair collectively succeeds in accomplishing the task (clicking more on the other's real cursor than on any other object on the shared line). They succeed because the interaction that appears when the two cursors cross each other is naturally stable: when the subjects cross each other, both are informed by haptic feedback, such that both come back on their steps to explore the object they just touched. The interaction thus leads both cursors to criss-cross each other for a small period of time, until one of them moves a bit too far and the stability breaks down; this kind of behaviour does not appear when a cursor touches a shadow, as in that case one of the two subjects is not informed of the encounter. Thus the stability of the interaction results from the way the spontaneous actions of the two subjects dynamically interlock and become coupled; this is a regularity at the level of the interaction that participants do not control, and do not even detect (recall that they fail to individually distinguish between the other's real cursor and their shadow).

Now suppose that subjects can be sensitive to that regularity: a tension appears between the naturally occurring stability, on one side, and the way subjects would like to act. Indeed, subjects become able to identify when they are in the course of a stable interaction and when they are not, but have a priori no way of influencing that interaction without breaking it, since its very existence relies on the naive behaviour described above: the only way to interact is by following the naive rules. Froese, Iizuka, and Ikegami (2014) created exactly that situation with two small changes to the perceptual crossing experiment: first, they allowed each participant a single click per session, making them much more conservative in their behaviours; second, they framed the experiment as a cooperative task where subjects should help each other in detecting each other's cursor (subjects are still not aware of the behaviour of the shadow cursor). In this situation, subjects become sensitive to interactive stabilities, and most importantly they manage to resolve the tension described above. Instead of both cursors permanently criss-crossing each other, a kind of turn-taking behaviour spontaneously appears where one subject stays still while the other criss-crosses it, then the roles are reversed and the first one criss-crosses the second one that is now staying still. Thus a new order of interactive regularity appears, built on the previous one: turn-taking in the perceptual crossing.[8]

Cuffari, Di Paolo, and De Jaegher (2015) generalise and recursively expand this kind of emergence of

---

[8]Interestingly, the authors also ask the subjects to give Perceptual Awareness Scale ratings for the moments at which they click, and find that such turn-taking episodes correspond to a mutually heightened perceptual awareness of the presence of an other.

a higher-order interactive norm. The level we just described corresponds to the emergence of what they call *co-defined social acts*. Co-defined social acts are like salutations, or acts of giving and receiving: they cannot be completed by one person alone. One person initiates the act (e.g. extending a tentative hand to be shaken in the case of a salutation, or holding out your keys to the person you want to give them to), but the other person must appropriately react to that initiation in order to complete the act (grasping the extended hand and shaking both together, for the case of salutation, or taking the keys offered in the case of giving and receiving). Otherwise the act fails and the interaction breaks down. On top of this level of normativity, another level can develop when social acts themselves serve to regulate other social acts (e.g. ostensively staring at your own extended hand to signal to your interlocutor that they should shake it), leading to yet another higher level of normativity. The expansion thus continues by building each level of normativity as the resolution of a tension between the types of individual and interactive autonomies that exist at the previous level. Cuffari, Di Paolo, and De Jaegher (2015) propose 8 levels of normativity,[9] each one corresponding to a new sensitivity of the interacting organisms to a regularity or constraint at the previous level. Often, the new regularity and its regulation by the participants appears at a different time scale, or in a different dimension than at the previous level. The authors thus propose that linguistic interactions (or languaging in enactive terms) can be understood through a gradual progression of interactive norms, tensions, and resolution by new norms, where each step accounts for additional aspects of full linguistic behaviour (words, for instance, then appear as 'patterns available for enacting certain forms of sense-making', Cuffari, Di Paolo, and De Jaegher 2015, 32). To our knowledge, the higher levels of this expansion have not yet been empirically validated in the manner described above for the first two levels. The theory nonetheless proposes a clear roadmap for constructing an explanation of language, meaning, and linguistic interactions which is fully grounded in the dynamics of interaction between participants. More precisely, the explanation is in terms of recursive regularities and conventions in social interactions. Similarly to how the sensorimotor approach to perception accounts for visual consciousness in terms of regularities in the perception-action loop, the enactive approach accounts for meaning itself as being a combination of aspects of the regularities in social interactions.

Discussion

A number of points can be noted about the approach we just outlined. Overall, the approach strongly reflects the intuitive idea hinted to in our previous discussion of meaning changes in transmission chains (Section 4.2.1): in meaningful interactions, "everything matters". More precisely, anything *can* matter: any seemingly minor detail of the dynamics of an interaction may (or may not) become extremely important if for some reason the participants are sensitive to it in one way or another, and rely on it for instance to resolve a tension. In particular, the simplifications that can occur when symbolically encoding utterances for use in Relevance Theory can neglect aspects of meaningful interactions which turn out to be essential ingredients. A reconstruction that starts from simpler interactions, such as the one encouraged by the enactive standpoint, is more likely to pick up on such ingredients. As noted previously, the problem here is the extreme complexity of interactions and contextual situations, which the enactive approach tackles by starting from simpler (but, crucially, always meaningful) interactions, and by using the language and tools of dynamical systems theory (see for instance Beer 2000; 2014). A second point related to the "anything can matter" intuition is that the coordination of interacting organisms that is necessary to achieve dynamical coupling can

---

[9]The levels are Participatory sense-making (which we started with), Social Agency (e.g. turn-taking in perceptual crossing), Coordination of Social Acts (e.g. giving and receiving), Normativity of Social Acts, Community of Interactors, Mutual Recognition and Dialogical Structure, Participation Genres, and finally Languaging.

rely on a diversity of dimensions: while interacting organisms need to have comparable dynamics to make it possible for an actual coupling to emerge in their interaction, different dimensions of the dynamics are eligible to that role at different levels of interactive normativity. For instance, coupling in perceptual crossing experiments is likely to emerge only when the subjects make movements of comparable magnitude at the sub-second timescale. Turn-taking on the other hand, is likely to require the subjects to have comparable behaviour at the timescale of a few seconds (the duration of a turn in turn-taking). The poorer the match in dynamics in a given dimension at a given scale, the more difficult it should be for a coupling to appear in that dimension at that scale. Higher levels of interactive normativity will likely involve yet larger timescales (a point that could be related to multi-scale complexity matching in conversations, Abney et al. 2014).

Dale et al. (2014) provide a review of the empirical work that has already been done in (not exclusively enactive) dynamical approaches to interaction. At the level of simple interactions, promising applications have been made through software implementations: Botelho et al. (2015), for instance, develop software agents endowed with inherent goals, such that they could have a very simple but endogenous notion of meaning; Froese, Gershenson, and Rosenblueth (2013) further illustrate the dynamical coupling of maximally simple software agents that manage to collectively solve a task precisely (and only) thanks to their coupling (similar to what the perceptual crossing paradigm explores with human subjects). Now as regards language itself, the approach evidently needs to be much further developed and empirically explored. The problem seems tractable however, as the mysterious aspects of meaningful interaction are already part of the simpler levels of interaction that the current theory convincingly accounts for. We also note that the general approach of expanding normativity levels on top of the previous levels is promising in yet another aspect: on the enactive account, the grammar of a particular language as it is classically understood (i.e. structured utterances with phonetics, phonology, morphology and syntax in English or Spanish for instance – leaving aside semantics and pragmatics since they are closer to meaning, which is accounted for across levels) could correspond to a particular expansion of normativity levels that differs from that of another language. In particular, if the grammar-related normativity levels differ, the levels above and below will also, a fact that could correspond to the different types of agency, and of interaction, afforded by different languages. Any speaker who is fluent enough in more than one language has experienced the change in the way social interactions feel and unfold when switching from one language to another (the effect is strongest when using different languages with the same person). English and Spanish for instance afford different types of interactions, as one constrains meanings differently than the other, each language implicitly expressing a particular set of relationships and making it necessary to spell out other parts more explicitly. In the words of Evans (2011), who details this link between a language and social interaction: "Languages differ not so much in what you can say as in what you must say" (2011, 70). The enactive account of social interaction provides a natural continuity between a particular language and the type of agency that goes with it, and one can expect this type of phenomenon to be explicable once the theory has been further fleshed out.

4.3.3   Applied to cultural attraction

Compared to Relevance Theory, the Enactive approach starts from radically simpler types of interaction, and relies neither on a capacity for symbolic processing nor on internal representations of the environment. This makes the approach slightly more involved to present than Relevance Theory. In spite of their differences, both approaches provide a notion of relevance or value to the individual, which is then used to ground a notion of meaning (be it linguistic or not). Unlike RT, the enactive notion of meaning exists even in the most basic types of interaction an organism can have with its environment.

The two approaches can be seen as starting from different descriptive levels and building what is missing for an account of meaning (though this characterisation does not exhaust their differences): RT starts with representations and symbolic processing, which are implementable in bodies (by following the model of computers) and come already structured in similar ways to language, and constructs on top of those a notion of meaning, with a corresponding interpretation procedure (inference), that is subtle and flexible enough to apply to fuzzy cases like poetry or loose language. The Enactive approach starts from an embodied and dynamic notion of meaning, which by definition exists for all organisms and need not be inferred, but comes without any particular structure; this approach then builds its account of language by detailing how interaction (and thus meaning) can become increasingly structured through a series of emerging levels of interactive normativity.[10] Unlike RT, it does not (yet) provide a clear way to compare meanings across interactive situations, as its very definition of meaning is intrinsically related to the subtle differences of dynamics in different interations. In RT, that work is theoretically done by the notion of representation (or more precisely, the informative intention that is inferred and represented), although in practice much remains to be defined to directly compare representations between each other. In its current state, the Enactive approach is applicable to much simpler interactions than those tackled by RT, as more experimental work is needed to confirm the higher-level details.

This finally brings us back to the usefulness of both these approaches for CAT. Without he does not flesh out the connection, Sperber (1996) refers repeatedly to RT as an important tool to understand the role of interpretation in the epidemiology of representations; indeed, the information-processing account provided by RT fits well with the representational foundation of CAT. But the fact that CAT is formulated in terms of representations is not necessarily a theoretical constraint to integrate it with an enactive approach to meaning: similarly to what we argued above for RT, information-processing can be seen as a particular starting point for the description with no strong import for the ontology of what is being transmitted or evolved,[11] and we see no reason to consider a priori that the two approaches would be incompatible.

In current practice however, the fact that CAT gives so much autonomy to a contentful notion of representation encourages empirical approaches to use a code model and give context a minimal role (i.e. a representation is an encoding of some content). Most applications thus strip down the context-dependence of CAT, thereby obviating the need for Relevance Theory in the first place. By not seeing that the contents of a representation are inherently contextual and constructed in interaction, one reduces the cultural evolution process to a simple accumulation of interpretations that do not rely on context: such a simple model depicts representations as being straightforwardly interpreted into mental versions (with some degree of transformation through reconstruction) then produced anew as public versions (again with some degree of transformation), and the circulation and tranformation of representations creates a dynamical system with attractors. As we just saw, both the Enactive approach and RT show that taking context into account drastically changes the picture. The fact that it is possible to easily degrade CAT into a code model theory also suggests that integrating it with an approach to meaning might require some amendments. We thus see great value in contrasting and possibly combining the two approaches to replace the naive code model that is used in many applications of CAT. In practice, attempting to apply these two approaches will also let us explore if

---

[10]In doing so, it also provides a partial account of the phenomenology of meaning, something that RT can only provide through a definition of the exact content of representations, and a mechanism for how they represent that content. For more details, see again Hutto and Myin (2013) on the hard problem of content. Harvey (2015) also provides a useful discussion of that question.

[11]Indeed, Sperber (1996, 135, footnote 40) explains that his view of the content of concepts (which we can assume to be close enough to the content of a representation) is influenced by Millikan (1984), which is quite close to non-representational views of content (Harvey 2015).

the theory must be amended in order to fully take the situatedness of meaning into account.[12]

4.4 Empirical speculations

Following Chemero and Silberstein (2008) and Beer and Williams (2015), we believe that contrasting and combining practical uses of the information-processing and dynamical approaches is the best way to move forward in debates that otherwise turn into scholasticism. This section proposes a few avenues to do so in the context of meaning-related cultural evolution. The first point we discuss is an additional method that is directly applicable to the previous chapter's data. The second, third and fourth points discuss approaches similar to the paradigm presented in the previous chapter, which work with ecological material; these approaches must deal with the full complexity of language. The final point discusses an approach similar to the perceptual crossing paradigm, which works with much simpler interaction situations; here the dimensionality of behaviours is lower, such that it should be easier to understand complex dynamical patterns.

4.4.1 Hand-coded meaning classes

Our first point is an analysis method that combines manual and computational steps. It is directly applicable to the data sets of the previous chapter without necessarily adding a notion of context, but is also usable for analysing the data that would be generated by the approaches we delineate further down.

Its first step is to devise a manual measure of the similarity between random pairs of utterances in a tree; given such a manual measure, a dimensionality reduction method can identify classes of meanings in the tree, and attribute each utterance of the tree to a particular meaning class. The operation makes the evolution much more manageable, as each utterance is now assigned to one of a finite number of meaning classes. Since such classes can be approximately represented in a 2-dimensional space (a result of the dimensionality reduction based on similarity measures), it then becomes possible to plot the evolution happening in each tree and observe when a transformation creates a transition from one class to another. The transition probabilities between each meaning class also give an idea of the types of transformations that happen most often at the level of meanings, as encoded in the first step.

The main challenge for this method is the first step, that is gathering manual measures of similarity between utterances in a tree. One reliable approach to this problem is to gather similarity ratings in a triad comparison task (Romney et al. 1996): manual coders are presented with three utterances, and must decide which of the three is most different in meaning to the other two (in which case

---

[12] Anthropologist Tim Ingold, for instance, has argued at length that the whole project of a Darwin-inspired theory of cultural change can only make sense if one accepts a misguided dualism between context-free information on one side and material implementation on the other, a dualism that is encouraged by the computational metaphor of cognition (Ingold 1998; 2001; 2004; 2007). The requirement of being able to compare meanings across situations (so as to analyse their evolution), in particular, would rest on being able to identify information that exists independently of the situation in which it emerged. The alternative he proposes is heavily inspired by dynamical approaches to cognition (such as the Enactive approach) and a developmental focus on biology and heredity. While we agree that computational approaches to cognition are prone to such dualism, information-processing analyses can also be used as a tool to combine with dynamical approaches, without taking the computational metaphor too seriously. Moreover, we see no reason to believe that dynamical approaches could not be compatible with Darwin-inspired approaches to cultural change. The question of how to relate meanings from different interactive situations is, we believe, better tackled through further formalisation and empirical investigation of the available accounts of meaning.

the other two are considered to have some degree of similarity). While the complete set of triad comparisons grows as n^3 (n being the number of utterances in a tree) and is thus too expensive for trees containing 71 utterances (such as in Experiment 3 in the previous chapter), it is not necessary to rate all the combinations in order to obtain a reliable measure. Indeed, in the complete set of triad comparisons, each pair of utterances appears $n - 2$ times. The so-called Balanced-Incomplete Block Design (Weller and Romney 1988, 49–55) compares triads without repeating pairs more than a fixed number of times, in which case the number of triads grows as n^2.[13] Triad comparisons can be obtained in large quantities by outsourcing the task on platforms such as Amazon Mechanical Turk, or can alternatively be integrated in the online transmission chain platform.[14]

The modified Correspondence Analysis used by Romney et al. (1996) on this type of data yields an n-dimensional representation of the utterances, where the first dimension distinguishes the utterances the most, and the last dimension the least. Utterances can then be plotted on the first two dimensions, grouped into classes by a clustering method, and the evolution along the branches thus reduced to transitions between meaning classes. Such a measure would provide an interesting first insight into the meaningful transformations operated by the subjects.

4.4.2 Minimal interaction and context

The transmission chain paradigm can also be tweaked in at least two ways to begin exploring the role of context and interaction. One area to explore is to consider utterances not in isolation, but as part of a contextual paragraph. The surrounding paragraph could provide enough background for subjects to have a feel of what it amounts to pronounce that utterance in context. The task can then be framed as role-playing: subjects would be asked to imagine the scene depicted by the paragraph they just read, imagine themselves as the person pronouncing the last utterance (or an utterance in the middle, highlighted as they were reading), and rewrite it. The larger the context, the more constrained we expect interpretation to be, thus the more limited we expect transformations to be.

A second change, which can be combined with the first, is to introduce minimal forms of live communication in the task so as to embed the subjects in an actual communicative task. For instance, the transmission step could be turned into a minimal interaction where the first subject proposes an utterance (that is, their memorisation of what they read) and the second can either accept it or ask for a better reformulation (up to a maximum number of times), in which case the first subject must rewrite their proposal. The interaction requires a fine balance of bonuses and rejection penalties so that the functionality is not abused, but it gives subjects an interest in the task: a receiving subject is encouraged to ask for a consistent utterance, because they will later be asked to pass on their own memorisation of that utterance to another subject. Combining such minimal interactions with contextual paragraphs could further ensure that subjects do not change to a completely different utterance in order to see their proposal accepted: if the receiver is presented with the contextual

---

[13]A design where each pair appears once for $n = 70$ does not exist, however designs exist for $n = 69$ or $n = 73$, and can be created by removing utterances or adding dummy utterances. $n = 69$ yields 805 triad comparisons, and $n = 73$ yields 876 (see Weller and Romney 1988 for the detailed computation). More reliable measures can be obtained by having each pair appear twice, which doubles the number of triad comparisons.

[14]Consider for instance an experiment similar to Experiment 3 of the previous chapter, with 71 utterances per tree (one root, and 7 branches of 10 reformulations), and a targeted 70 subjects in total. In a given tree, the number of triad comparisons with each pair appearing exactly once is at most 876 (see previous footnote), which can be distributed as an average 12.51 comparisons per subject. Counting about 20 seconds per comparison, the added comparisons thus require each subject to spend, on average, an additional 4m10s on each tree. Given that individual transformations took an average 1m12s in Experiment 3, that is subjects spend on average 1m12s on each tree in Experiment 3, this conservative estimate multiplies the total cost of the experiment by about 4.5. Collecting these triad comparisons for all the trees is thus quite costly, but doing it for one or two trees only is very affordable.

paragraph when deciding to accept or reject the proposed utterance, then they will expect the two to be consistent with each other.

While these changes allow us to introduce minimal forms of context and interaction in a transmission chain, the paradigm dissociates the complexity of one communication means, namely the utterances (which have highly complex linguistic structure), from the complexity of another communication means, namely the interaction itself (which is minimal). This is quite compatible with Relevance Theory, but the result is still somewhat unecological: if context and interactive situation are crucial to the way meaning is understood (according to both Relevance Theory and the Enactive approach), it would be more natural to match the complexity allowed by the interactive situation with the complexity of other communication means that are provided to the subjects. At the very least, it seems necessary to have an interactive situation at least as versatile as the productions that are asked of the subjects. Thus, asking subjects to write complex utterances while constraining their non-verbal interaction to a binary acceptance-rejection outcome still only makes sense in a code model theory, where complex meanings can be understood in spite of the interactive situation being extremely simple. To create situations where the meshing of context, interaction and meaning can be understood, then, it is necessary to match the complexity of all the communicative means provided to the subjects (interactive, verbal, or other). In what follows we discuss possibilities for analysing situations where the complexity is close to that of real life. We then move on to situations where both the interaction situation and the possible meanings have a much reduced complexity.

4.4.3   Fully measured contexts

In some cases, it is possible to fully measure all observables in an unconstrained interactive situation. The first way of doing this is to have enough sensors in an *in vivo* situation: the Human Speechome Project (Roy et al. 2006), for instance, equips a family's house with wide-angle ceiling cameras and microphones that map the entire space of the house, and records the quasi-totality of what happens in the first three years of the life of a newborn in the family (with some privacy controls). Everything the child hears and sees, all the interactions she is involved in are taped in a way that makes it possible to reconstitute the detailed movements, vocal productions, and relevant interactive features (such as gaze) of participants. The analysis of such rich data is humongous and involves many novel semi-automated coding techniques (as the dozens of data-analysis publications related to the project[15] attest to), but gives access to the full detail of interactions that a child is exposed to in her house. Roy et al. (2015), for instance, use the data to explore the spatial and linguistic contexts in which a child is exposed to a word, and relate them to the context in which she first produces said word. Such longitudinal multi-modal data is exactly the type of measurement that is necessary to fully understand the meaning that is produced in an interaction, explore when that meaning is reproduced, and see how it changes through time.

The second way is to create an *in vitro* interactive situation that is as encompassing as possible, and measure every possible aspect of the interaction in it. In the laboratory, this corresponds to the approach taken by Moussaïd, Brighton, and Gaissmaier (2015), who taped unconstrained pairwise conversations chained one after the other, hand-coded them for specific features, and then measured the evolution of such features along chains. Another approach consists in taking advantage of online video games that create complete worlds in which the interactions of players can be measured in multiple modalities (gaming behaviours and parallel verbal conversations), as has been used for instance in the study of language learning (Zheng, Newgarden, and Young 2012). As developing

---

[15]See https://www.media.mit.edu/cogmac/projects/hsp.html for a full list.

such a game for experimental purposes involves a substantial investment however, researchers must rely on existing gaming environments and communities to access the data.

Fully measuring unconstrained interactions is thus one way of matching the complexity of the different communicative means available to the subjects. However, the problem with this approach for cultural evolution is precisely the increased complexity of context and interaction: existing works use important manual or semi-manual steps in their analyses, such that their access to meaning in the data is in large part interpretive. Using the relevance-theoretic approach to delve into the detail of how meaning is inferred in such situations is likely to become quickly unmanageable. We therefore turn to the other end of the spectrum: approaches which, by relying on the Enactive account for which simpler meanings can exist without the requirement of symbolic processing, aims to lower the complexity of interactions and possible meanings.

4.4.4   Preliminary enactive steps to language

The final approach we discuus aims to take advantage of the empirical appeal of the Enactive approach: using paradigms similar to that of perceptual crossing, one might be able to create interactions that have meaning to the participants without the need to use complex linguistic material. In such a situation, participants would interact through a combination of low-dimensional channels in a task that has inherent meaning to them, and both the interaction and the meaning emerging from it would have extremely low complexity. Such an approach would not enable participants to have everyday life conversations, but it would let the experimenter introduce complexity in experimental tasks little by little, with the end goal of creating situations whose complexity can approach that of actual linguistic interactions.

In its current state however, the Enactive approach does not yet provide a full account of language. The phenomena it does account for, such as sensorimotor contingencies and perceptual crossings, are better described as potential preliminary steps to language: they are elements that can be combined and fleshed out in order to develop an explanation of language.

The theory of languaging developed by Cuffari, Di Paolo, and De Jaegher (2015) proposes a way to do so: it progresses in a series of normative levels of interaction, each one appearing as a resolution of a tension at the previous level. The first normativity level is that of Participatory sense-making, which the perceptual crossing stability (Auvray, Lenay, and Stewart 2009) illustrates: two participants are coupled in an interaction that neither of them controls, or even detects. The second normativity level is that of Social Agency, illustrated by the turn-taking phenomenon that appears in perceptual crossing when participants are sensitive to an interactive stability (Froese, Iizuka, and Ikegami 2014). As we mentioned earlier, this phenomenon can be seen as a co-defined social act, that is an act that is initiated by one person (who makes a *partial* act), and must be completed by the other person recognising it and responding appropriately (e.g. giving and receiving). The authors propose another 6 conceptual stages which together would provide a first account of the languaging behaviour of human beings. While these stages are proposed as conceptual steps, and not as causal steps that would correspond to the actual progression of communicative complexities found in other species (or through evolution), an important milestone here would be to empirically validate the remaining six stages in a similar fashion to the first two. If successful, completing such a validation would provide a more comprehensive view of the enactive language account, and would open the way for integrations with cultural evolution theories.

The third normativity level, for instance, is that of Coordination of Social Acts; it emerges when one social act is used to regulate another social act. The authors' example of this normativity level is a

japanese woman extending her personal card to a westerner. The woman offers her card by holding it with both hands, which is the polite way in Japan. The polite way of responding to this partial act in Japan is to accept the card with both hands too. However, a westerner would spontaneously take the card with only one hand, a response that the woman would not consider appropriate (indeed, it amounts to answering with part of one's body to a partial act that involves the whole body). In response to this, the japanese woman could hold on to her card, and ostensively stare at the westerner's other hand, thus initiating a second partial act to regulate the first. The westerner, understanding the regulatory stare, could nod (thus completing the regulatory act) and accept the card with both hands (thus completing the initial act of giving).

This type of regulatory social act can appear when a second channel and a repertoire of acts are available to regulate what happens in a primary channel. To empirically validate this normativity level, then, one could imagine setting up two parallel perceptual crossing tasks: the first, more complex, would involve cursors on a shared surface instead of a line; the second, simpler, would be the classical uni-dimensional perceptual crossing setup. The reasoning is that the simpler channel could emerge as a regulatory aid for a new type of social act to emerge in the more complex channel. This simple extension of perceptual crossing is most likely not the best, but it illustrates the type of experiment that one could devise in order to observe the emergence of the third stage.

In the process of validating the third normativity level, several conventions will appear that depend on the history of interactions between agents and in a community. For instance, one repertoire of social acts will develop in one community of frequently-interacting participants, and a second repertoire will develop in another. Participants from different communities that are brought together will be forced to adjust, expand, or develop anew their repertoire of social acts. This setting opens a number of questions about the evolution of such minimal social acts in communities. In order to explore the integration of this approach with CAT, it will be necessary to empirically flesh out the full range of normativity levels in this manner. While the task is not easy, we believe that such a project has great potential to possibly complement a relevance-theoretic approach to meaning, on one side, and to identify incompatibilities and possibilities for integration with the current theories of cultural evolution, on the other.

4.5   Conclusion

In this chapter, we took a more in depth look at what would be required in order to understand the transformation of the meaning of utterances in short-term cultural evolution, be it in online quotations or in artificial transmission chains. We first discussed a number of examples of meaning change that appeared in the experiments of the previous chapter. We then presented two radically different, but both prominent, approaches to meaning in language: Relevance Theory, which bases its account on the inference of relevant conclusions given the context in which an utterance is pronounced; and the Enactive approach, which bases its account on the agent's sense-making activity by which it maintains its identity as an agent. While the two approaches sit at opposite ends of the computational-dynamical spectrum in cognitive science, both base their account of meaning on some notion of the relevance that interactions have for agents (though those notions are very different for the two theories). Notwithstanding the simpler integration of RT with Cultural Attraction Theory, we proposed that both RT and the Enactive approach could be valuable paths to explore in the study of meaning in this context. Finally, then, we extended a few speculations as to how these approaches could inspire future work aimed at understanding the way meanings evolve along with cultural evolution.

Our stance may be taken as very ecumenical, too much so maybe. How could it make sense to try and combine approaches that rely on bodies of philosophical works that continuously butcher each other? In their current state, neither Relevance Theory nor the Enactive approach provide complete accounts of what linguistic meaning is or how we understand it, but both provide extremely valuable steps to begin understanding the phenomenon. Our belief is that philosophical butchery is a healthy and necessary activity, and empirical combination and contrasting of the outcomes is too. While the two approaches clearly have disagreements on starting points and approaches to cognition overall, it is not said that different approaches to meaning, when fully formalised at the right level, could not be related to one another. In the meantime, both can inspire valuable empirical work and the design of new methods, be it to contrast or to combine them, all of which contribute to better understanding the issues at stake.

General conclusion

References

Abney, Drew H., Alexandra Paxton, Rick Dale, and Christopher T. Kello. 2014. 'Complexity Matching in Dyadic Conversation'. *Journal of Experimental Psychology: General* 143 (6): 2304–15. doi:10.1037/xge0000021.

Acerbi, Alberto. 2016. 'A Cultural Evolution Approach to Digital Media'. *Frontiers in Human Neuroscience* 10 (December). doi:10.3389/fnhum.2016.00636.

Acerbi, Alberto, and Alex Mesoudi. 2015. 'If We Are All Cultural Darwinians What's the Fuss About? Clarifying Recent Disagreements in the Field of Cultural Evolution'. *Biology & Philosophy* 30 (4): 481–503. doi:10.1007/s10539-015-9490-2.

Acerbi, Alberto, and Jamshid J. Tehrani. 2017. 'Did Einstein Really Say That? Testing Content Versus Context in the Cultural Selection of Quotations'. *SocArXiv Preprints*, April. https://osf.io/preprints/socarxiv/x8db2.

Acerbi, Alberto, and Claudio Tennie. 2016. 'The Role of Redundant Information in Cultural Transmission and Cultural Stabilization'. *Journal of Comparative Psychology* 130 (1): 62–70. doi:10.1037/a0040094.

Adamic, Lada A., Thomas M. Lento, Eytan Adar, and Pauline C. Ng. 2016. 'Information Evolution in Social Networks'. In *Proceedings of the Ninth ACM International Conference on Web Search and Data Mining*, 473–82. New York, NY, USA: ACM. doi:10.1145/2835776.2835827.

Althoff, Tim, Cristian Danescu-Niculescu-Mizil, and Dan Jurafsky. 2014. 'How to Ask for a Favor: A Case Study on the Success of Altruistic Requests'. *arXiv:1405.3282 [Physics]*, May. http://arxiv.org/abs/1405.3282.

Auvray, Malika, Charles Lenay, and John Stewart. 2009. 'Perceptual Interactions in a Minimalist Virtual Environment'. *New Ideas in Psychology* 27 (1): 32–47. doi:10.1016/j.newideapsych.2007.12.002.

Bakshy, Eytan, Jake M. Hofman, Winter A. Mason, and Duncan J. Watts. 2011. 'Everyone's an Influencer: Quantifying Influence on Twitter'. In *Proceedings of the Fourth ACM International Conference on Web Search and Data Mining*, edited by Irwin King, Wolfgang Nejdl, and Hang Li, 65–74. WSDM '11. New York, NY, USA: ACM. doi:10.1145/1935826.1935845.

Bakshy, Eytan, Brian Karrer, and Lada A. Adamic. 2009. 'Social Influence and the Diffusion of User-Created Content'. In *Proceedings of the 10th ACM Conference on Electronic Commerce*, 325–34. New York, NY, USA: ACM. doi:10.1145/1566374.1566421.

Bangerter, Adrian. 2000. 'Transformation Between Scientific and Social Representations of Conception: The Method of Serial Reproduction'. *British Journal of Social Psychology* 39 (4): 521–35.

doi:10.1348/014466600164615.

Barrett, Justin L., and Melanie A. Nyhof. 2001. 'Spreading Non-Natural Concepts: The Role of Intuitive Conceptual Structures in Memory and Transmission of Cultural Materials'. *Journal of Cognition and Culture* 1 (1): 69–100. doi:10.1163/156853701300063589.

Bartlett, Sir Frederic Charles. 1995. *Remembering: A Study in Experimental and Social Psychology*. Cambridge University Press.

Baumard, Nicolas, Jean-Baptiste André, and Dan Sperber. 2013. 'A Mutualistic Approach to Morality: The Evolution of Fairness by Partner Choice'. *Behavioral and Brain Sciences* 36 (1): 59–78.

Baumard, Nicolas, Alexandre Hyafil, Ian Morris, and Pascal Boyer. 2015. 'Increased Affluence Explains the Emergence of Ascetic Wisdoms and Moralizing Religions'. *Current Biology* 25 (1): 10–15. doi:10.1016/j.cub.2014.10.063.

Bedia, Manuel G., Miguel Aguilera, Tomás Gómez, David G. Larrode, and Francisco Seron. 2014. 'Quantifying Long-Range Correlations and 1/F Patterns in a Minimal Experiment of Social Interaction'. *Frontiers in Psychology* 5. doi:10.3389/fpsyg.2014.01281.

Beer, Randall D. 2000. 'Dynamical Approaches to Cognitive Science'. *Trends in Cognitive Sciences* 4 (3): 91–99. doi:10.1016/S1364-6613(99)01440-0.

———. 2014. 'Dynamical Analysis of Evolved Agents: A Primer'. In *The Horizons of Evolutionary Robotics*, edited by Patricia A. Vargas, Ezequiel A. Di Paolo, Inman Harvey, and Phil Husbands, 65–76. Cambridge, Mass. ; London: MIT Press.

Beer, Randall D., and Paul L. Williams. 2015. 'Information Processing and Dynamics in Minimally Cognitive Agents'. *Cognitive Science* 39 (1): 1–38. doi:10.1111/cogs.12142.

Botelho, Luis, Luis Nunes, Ricardo Ribeiro, and Rui J. Lopes. 2015. 'Software Agents with Concerns of Their Own'. *arXiv:1511.03958 [Cs]*, November. http://arxiv.org/abs/1511.03958.

Bourdieu, Pierre. 1980. *Le Sens Pratique*. Paris: Editions de Minuit.

Boyd, Robert, and Peter J Richerson. 1985. *Culture and the Evolutionary Process*. Chicago: University of Chicago Press.

———. 2005. *The Origin and Evolution of Cultures*. New York, N.Y. ; Oxford: Oxford university press.

Boyer, Pascal. 2001. *Religion Explained: The Evolutionary Origins of Religious Thought*. Basic Books.

Caldwell, Christine A., and Ailsa E. Millen. 2008a. 'Experimental Models for Testing Hypotheses About Cumulative Cultural Evolution'. *Evolution and Human Behavior* 29 (3): 165–71. doi:10.1016/j.evolhumbehav.2007.12.001.

———. 2008b. 'Studying Cumulative Cultural Evolution in the Laboratory'. *Philosophical Transactions of the Royal Society B: Biological Sciences* 363 (1509): 3529–39. doi:10.1098/rstb.2008.0133.

Caldwell, Christine A., and Kenny Smith. 2012. 'Cultural Evolution and Perpetuation of Arbitrary Communicative Conventions in Experimental Microsocieties'. *PLOS ONE* 7 (8): e43807. doi:10.1371/journal.pone.0043807.

Carr, Jon W., Kenny Smith, Hannah Cornish, and Simon Kirby. 2017. 'The Cultural Evolution of Structured Languages in an Open-Ended, Continuous World'. *Cognitive Science* 41 (4): 892–923.

doi:10.1111/cogs.12371.

Cavalli-Sforza, L. L, and Marcus W Feldman. 1981. *Cultural Transmission and Evolution: A Quantitative Approach*. Princeton, N.J.: Princeton University Press.

Chemero, Tony, and Michael Silberstein. 2008. 'After the Philosophy of Mind: Replacing Scholasticism with Science'. *Philosophy of Science* 75 (1): 1–27.

Claidière, Nicolas, and Dan Sperber. 2007. 'The Role of Attraction in Cultural Evolution'. *Journal of Cognition and Culture* 7 (1): 89–111. doi:10.1163/156853707X171829.

Claidière, Nicolas, Thomas C. Scott-Phillips, and Dan Sperber. 2014. 'How Darwinian Is Cultural Evolution?' *Philosophical Transactions of the Royal Society B: Biological Sciences* 369 (1642): 20130368. doi:10.1098/rstb.2013.0368.

Claidière, Nicolas, Kenny Smith, Simon Kirby, and Joël Fagot. 2014. 'Cultural Evolution of Systematically Structured Behaviour in a Non-Human Primate'. *Proceedings of the Royal Society of London B: Biological Sciences* 281 (1797): 20141541. doi:10.1098/rspb.2014.1541.

Claidière, Nicolas, Emmanuel Trouche, and Hugo Mercier. 2017. 'Argumentation and the Diffusion of Counter-Intuitive Beliefs'. *Manuscript Submitted for Publication*. https://sites.google.com/site/hugomercier/Argumentation%20and%20counter-intuitive%20beliefs.pdf.

Clark, Andy, and David Chalmers. 1998. 'The Extended Mind'. *Analysis* 58 (1): 7–19. http://www.jstor.org.ins2i.bib.cnrs.fr/stable/3328150.

Cointet, J. P., and C. Roth. 2009. 'Socio-Semantic Dynamics in a Blog Network'. In *International Conference on Computational Science and Engineering, 2009. CSE '09*, edited by Alex Pentland, Justin Zahn, and Daniel Zeng, 4:114–21. Washington, DC: IEEE Computer Society. doi:10.1109/CSE.2009.105.

Cointet, Jean-Philippe, and Camille Roth. 2007. 'How Realistic Should Knowledge Diffusion Models Be?' *Journal of Artificial Societies and Social Simulation* 10 (3): 5. http://jasss.soc.surrey.ac.uk/10/3/5.html.

Cornish, Hannah, Kenny Smith, and Simon Kirby. 2013. 'Systems from Sequences: An Iterated Learning Account of the Emergence of Systematic Structure in a Non-Linguistic Task'. In *Proceedings of the 35th Annual Conference of the Cognitive Science Society*, edited by Markus Knauff, Michael Pauen, Natalie Sebanz, and Ipke Wachsmuth. Austin, TX: Cognitive Science Society.

Croft, William. 2013. 'An Evolutionary Model of Language Change and Language Structure'. In *Explaining Language Change: An Evolutionary Approach*, Draft 2nd edition (revised). http://www.unm.edu/~wcroft/Papers/ELC2-Chap02.pdf.

Cuffari, Elena Clare, Ezequiel Di Paolo, and Hanne De Jaegher. 2015. 'From Participatory Sense-Making to Language: There and Back Again'. *Phenomenology and the Cognitive Sciences* 14 (4): 1089–1125. doi:10.1007/s11097-014-9404-9.

Dale, Rick, Riccardo Fusaroli, Nicholas D. Duran, and Daniel C. Richardson. 2014. 'The Self-Organization of Human Interaction'. In *The Psychology of Learning and Motivation. Volume 59 Volume 59*, edited by Brian H Ross, 43–96. Amsterdam: Academic Press. http://search.ebscohost.com/login.aspx?direct=true&scope=site&db=nlebk&db=nlabk&AN=585381.

Danescu-Niculescu-Mizil, Cristian, Justin Cheng, Jon Kleinberg, and Lillian Lee. 2012. 'You Had Me at Hello: How Phrasing Affects Memorability'. In *ACL '12 Proceedings of the 50th Annual Meeting*

of the Association for Computational Linguistics: Long Papers, edited by Haizhou Li, Chin-Yew Lin, and Miles Osborne, 1:892–901. Stroudsburg, PA: ACM. http://arxiv.org/abs/1203.6360.

Danescu-Niculescu-Mizil, Cristian, Lillian Lee, Bo Pang, and Jon Kleinberg. 2011. 'Echoes of Power: Language Effects and Power Differences in Social Interaction'. *arXiv:1112.3670 [Physics]*, December. http://arxiv.org/abs/1112.3670.

Danescu-Niculescu-Mizil, Cristian, Moritz Sudhof, Dan Jurafsky, Jure Leskovec, and Christopher Potts. 2013. 'A Computational Approach to Politeness with Application to Social Factors'. *arXiv:1306.6078 [Physics]*, June. http://arxiv.org/abs/1306.6078.

De Jaegher, Hanne, and Ezequiel Di Paolo. 2007. 'Participatory Sense-Making'. *Phenomenology and the Cognitive Sciences* 6 (4): 485–507. doi:10.1007/s11097-007-9076-9.

Di Paolo, Ezequiel A. 2005. 'Autopoiesis, Adaptivity, Teleology, Agency'. *Phenomenology and the Cognitive Sciences* 4 (4): 429–52. doi:10.1007/s11097-005-9002-y.

Durkheim, Emile. 2012. *Le Suicide: Étude de Sociologie*. Project Gutenberg. http://www.gutenberg.org/ebooks/40489.

Eriksson, Kimmo, and Julie C. Coultas. 2012. 'The Advantage of Multiple Cultural Parents in the Cultural Transmission of Stories'. *Evolution and Human Behavior* 33 (4): 251–59. doi:10.1016/j.evolhumbehav.2011.10.002.

———. 2014. 'Corpses, Maggots, Poodles and Rats: Emotional Selection Operating in Three Phases of Cultural Transmission of Urban Legends'. *Journal of Cognition and Culture* 14 (1): 1–26. doi:10.1163/15685373-12342107.

Evans, Nicholas. 2011. 'Your Mind in Mine: Social Cognition in Grammar'. In *Dying Words: Endangered Languages and What They Have to Tell Us*, 69–80. New York, NY, USA: John Wiley & Sons.

Fay, Nicolas, Simon Garrod, Leo Roberts, and Nik Swoboda. 2010. 'The Interactive Evolution of Human Communication Systems'. *Cognitive Science* 34 (3): 351–86. doi:10.1111/j.1551-6709.2009.01090.x.

Fisher, Ronald Aylmer. 1930. *The Genetical Theory of Natural Selection*. Oxford, UK: Clarendon Press. http://www.biodiversitylibrary.org/title/27468.

Fodor, Jerry A. 1983. *The Modularity of Mind: An Essay on Faculty Psychology*. Cambridge, Mass.: MIT Press.

Froese, Tom, Carlos Gershenson, and David A. Rosenblueth. 2013. 'The Dynamically Extended Mind'. In *2013 IEEE Congress on Evolutionary Computation*, 1419–26. doi:10.1109/CEC.2013.6557730.

Froese, Tom, Hiroyuki Iizuka, and Takashi Ikegami. 2014. 'Embodied Social Interaction Constitutes Social Cognition in Pairs of Humans: A Minimalist Virtual Reality Experiment'. *Scientific Reports* 4 (January): 3672. doi:10.1038/srep03672.

Fuentes, Agustín. 2006. 'Evolution Is Important but It Is Not Simple: Defining Cultural Traits and Incorporating Complex Evolutionary Theory'. *Behavioral and Brain Sciences* 29 (4): 354–55.

———. 2009. 'A New Synthesis. Resituating Approaches to the Evolution of Human Behaviour'. *Anthropology Today* 25 (3): 12–17.

Futuyma, Douglas J. 2005. *Evolution*. Sunderland, MA, USA: Sinauer Associates.

Galantucci, Bruno. 2005. 'An Experimental Study of the Emergence of Human Communication

Systems'. *Cognitive Science* 29 (5): 737–67. doi:10.1207/s15516709cog0000_34.

Galantucci, Bruno, Simon Garrod, and Gareth Roberts. 2012. 'Experimental Semiotics'. *Language and Linguistics Compass* 6 (8): 477–93. doi:10.1002/lnc3.351.

Garrod, Simon, Nicolas Fay, John Lee, Jon Oberlander, and Tracy MacLeod. 2007. 'Foundations of Representation: Where Might Graphical Symbol Systems Come from?' *Cognitive Science* 31 (6): 961–87. doi:10.1080/03640210701703659.

Gauld, Alan, and Geoffrey M. Stephenson. 1967. 'Some Experiments Relating to Bartlett's Theory of Remembering'. *British Journal of Psychology* 58 (1): 39–49. doi:10.1111/j.2044-8295.1967.tb01054.x.

Gelder, Tim van. 1998. 'The Dynamical Hypothesis in Cognitive Science'. *Behavioral and Brain Sciences* 21 (5): 615–28. https://www.cambridge.org/core/journals/behavioral-and-brain-sciences/article/the-dynamical-hypothesis-in-cognitive-science/C121F1B65A534F3E7A27075EE489AD1E.

Giddens, Anthony. 1984. *The Constitution of Society: Outline of the Theory of Structuration*. Cambridge, UK; Oxford, UK: Polity Press & Blackwell.

Gilbert, Scott F., Thomas C. G. Bosch, and Cristina Ledón-Rettig. 2015. 'Eco-Evo-Devo: Developmental Symbiosis and Developmental Plasticity as Evolutionary Agents'. *Nature Reviews Genetics* 16 (10): 611–22. doi:10.1038/nrg3982.

Grice, Herbert Paul. 1989. *Studies in the Way of Words*. Cambridge, MA, USA: Harvard University Press.

Griffiths, Paul E., and Russell D. Gray. 2005. 'Discussion: Three Ways to Misunderstand Developmental Systems Theory'. *Biology and Philosophy* 20 (2): 417–25. doi:10.1007/s10539-004-0758-1.

Griffiths, Paul, and Karola Stotz. 2013. *Genetics and Philosophy: An Introduction*. http://dx.doi.org/10.1017/CBO9780511744082.

Griffiths, Thomas L., and Michael L. Kalish. 2007. 'Language Evolution by Iterated Learning with Bayesian Agents'. *Cognitive Science* 31 (3): 441–80. doi:10.1080/15326900701326576.

Griffiths, Thomas L., Brian R. Christian, and Michael L. Kalish. 2008. 'Using Category Structures to Test Iterated Learning as a Method for Identifying Inductive Biases'. *Cognitive Science* 32 (1): 68–107. doi:10.1080/03640210701801974.

Griffiths, Thomas L., Michael L. Kalish, and Stephan Lewandowsky. 2008. 'Theoretical and Empirical Evidence for the Impact of Inductive Biases on Cultural Evolution'. *Philosophical Transactions of the Royal Society of London B: Biological Sciences* 363 (1509): 3503–14. doi:10.1098/rstb.2008.0146.

Gruhl, Daniel, R. Guha, David Liben-Nowell, and Andrew Tomkins. 2004. 'Information Diffusion Through Blogspace'. In *Proceedings of the 13th International Conference on World Wide Web*, edited by Stuart I. Feldman, Mike Uretsky, Marc Najork, and Craig E. Wills, 491–501. New York, NY: ACM. doi:10.1145/988672.988739.

Haldane, John Burdon Sanderson. 1932. *The Causes of Evolution*. London, UK; New York, NY, USA; Toronto, Canada: Longmans Green & Co.

Hall, K. R. L. 1950. 'The Effect of Names and Titles Upon the Serial Reproduction of Pictorial and Verbal Material'. *British Journal of Psychology. General Section* 41 (3): 109–21. doi:10.1111/j.2044-8295.1950.tb00269.x.

Harvey, Matthew I. 2015. 'Content in Languaging: Why Radical Enactivism Is Incompatible with Representational Theories of Language'. *Language Sciences* 48 (March): 90–129.

doi:10.1016/j.langsci.2014.12.004.

Heath, Chip, Chris Bell, and Emily Sternberg. 2001. 'Emotional Selection in Memes: The Case of Urban Legends'. *Journal of Personality and Social Psychology* 81 (6): 1028–41. doi:10.1037/0022-3514.81.6.1028.

Henst, Jean-Baptiste van der, and Dan Sperber. 2012. 'Testing the Cognitive and Communicative Principles of Relevance'. In *Meaning and Relevance*, edited by Deirdre Wilson and Dan Sperber, 279–306. Cambridge, UK: Cambridge University Press.

Hutto, Daniel D, and Erik Myin. 2013. *Radicalizing Enactivism: Basic Minds Without Content*. Cambridge, Mass.: MIT Press. http://public.eblib.com/choice/publicfullrecord.aspx?p=3339551.

Ingold, Tim. 1998. 'From Complementarity to Obviation: On Dissolving the Boundaries Between Social and Biological Anthropology, Archaeology and Psychology'. *Zeitschrift Für Ethnologie* 123 (1): 21–52. http://www.jstor.org/stable/25842543.

———. 2001. 'From the Transmission of Representations to the Education of Attention'. In *The Debated Mind: Evolutionary Psychology Versus Ethnography*, edited by Harvey Whitehouse, 113–53. Oxford & New York: Berg. http://lchc.ucsd.edu/MCA/Paper/ingold/ingold1.htm.

———. 2004. 'Beyond Biology and Culture. the Meaning of Evolution in a Relational World'. *Social Anthropology* 12 (2): 209–21. doi:10.1111/j.1469-8676.2004.tb00102.x.

———. 2007. 'The Trouble with "Evolutionary Biology"'. *Anthropology Today* 23 (2): 13–17. doi:10.1111/j.1467-8322.2007.00497.x.

Jablonka, Eva M. 2001. 'The Systems of Inheritance'. In *Cycles of Contingency: Developmental Systems and Evolution*, edited by Susan Oyama, Paul Griffiths, and Russell D Gray, 99–116. Cambridge, Mass.: MIT Press.

Kalish, Michael L., Thomas L. Griffiths, and Stephan Lewandowsky. 2007. 'Iterated Learning: Intergenerational Knowledge Transmission Reveals Inductive Biases'. *Psychonomic Bulletin & Review* 14 (2): 288–94. doi:10.3758/BF03194066.

Kashima, Yoshihisa. 2000a. 'Maintaining Cultural Stereotypes in the Serial Reproduction of Narratives'. *Personality and Social Psychology Bulletin* 26 (5): 594–604. doi:10.1177/0146167200267007.

———. 2000b. 'Recovering Bartlett's Social Psychology of Cultural Dynamics'. *European Journal of Social Psychology* 30 (3): 383–403. doi:10.1002/(SICI)1099-0992(200005/06)30:3<383::AID-EJSP996>3.0.CO;2-C.

Kirby, Simon, Hannah Cornish, and Kenny Smith. 2008. 'Cumulative Cultural Evolution in the Laboratory: An Experimental Approach to the Origins of Structure in Human Language'. *Proceedings of the National Academy of Sciences* 105 (31): 10681–6. doi:10.1073/pnas.0707835105.

Kirby, Simon, Mike Dowman, and Thomas L. Griffiths. 2007. 'Innateness and Culture in the Evolution of Language'. *Proceedings of the National Academy of Sciences* 104 (12): 5241–5. doi:10.1073/pnas.0608222104.

Kirby, Simon, Monica Tamariz, Hannah Cornish, and Kenny Smith. 2015. 'Compression and Communication in the Cultural Evolution of Linguistic Structure'. *Cognition* 141 (August): 87–102. doi:10.1016/j.cognition.2015.03.016.

Laland, Kevin, Tobias Uller, Marc Feldman, Kim Sterelny, Gerd B. Müller, Armin Moczek, Eva Jablonka, et al. 2014. 'Does Evolutionary Theory Need a Rethink?' *Nature News* 514 (7521): 161.

doi:10.1038/514161a.

Leskovec, Jure, and Andrej Krevl. 2014. 'SNAP Datasets: Stanford Large Network Dataset Collection', June. http://snap.stanford.edu/data.

Leskovec, Jure, and Rok Sosič. 2016. 'SNAP: A General-Purpose Network Analysis and Graph-Mining Library'. *ACM Transactions on Intelligent Systems and Technology (TIST)* 8 (1): 1.

Leskovec, Jure, Lars Backstrom, and Jon Kleinberg. 2009. 'Meme-Tracking and the Dynamics of the News Cycle'. In *Proceedings of the 15th ACM SIGKDD International Conference on Knowledge Discovery and Data Mining*, edited by John Elder, Françoise Fogelman-Soulié, Peter A. Flach, and Mohammed J. Zaki, 497–506. New York, NY: ACM. doi:10.1145/1557019.1557077.

Lewens, Tim. 2012. 'Cultural Evolution: Integration and Skepticism'. In *The Oxford Handbook of Philosophy of Social Science*, edited by Harold Kincaid, 458–80. Oxford; New York: Oxford University Press.

Lewontin, R. C. 1982. 'Cultural Transmission and Evolution: A Quantitative Approach'. *American Journal of Human Genetics* 34 (5): 831–32. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1685425/.

Liben-Nowell, David, and Jon Kleinberg. 2008. 'Tracing Information Flow on a Global Scale Using Internet Chain-Letter Data'. *Proceedings of the National Academy of Sciences* 105 (12): 4633–8. doi:10.1073/pnas.0708471105.

Maturana, Humberto R, and Francisco J Varela. 1980. *Autopoiesis and Cognition: The Realization of the Living*. Dordrecht, Holland; Boston: D. Reidel Pub. Co.

Mauss, Marcel. 1936. 'Les Techniques Du Corps'. *Journal de Psychologie* 32 (3): 271–93. http://classiques.uqac.ca/classiques/mauss_marcel/socio_et_anthropo/6_Techniques_corps/Techniques_corps.html.

Maxwell, R. S. 1936. 'Remembering in Different Social Groups'. *British Journal of Psychology. General Section* 27 (1): 30–40. doi:10.1111/j.2044-8295.1936.tb00814.x.

McGraw, John J., Sebastian Wallot, Panagiotis Mitkidis, and Andreas Roepstorff. 2014. 'Culture's Building Blocks: Investigating Cultural Evolution in a LEGO Construction Task'. *Frontiers in Psychology* 5 (September). doi:10.3389/fpsyg.2014.01017.

Menary, Richard. 2010. *The Extended Mind*. Cambridge, MA, USA: MIT Press. http://public.eblib.com/choice/publicfullrecord.aspx?p=3339152.

Mercier, Hugo, and Dan Sperber. 2011. 'Why Do Humans Reason? Arguments for an Argumentative Theory'. *Behavioral and Brain Sciences* 34 (2): 57–74. doi:10.1017/S0140525X10000968.

Mesoudi, Alex, and Andrew Whiten. 2004. 'The Hierarchical Transformation of Event Knowledge in Human Cultural Transmission'. *Journal of Cognition and Culture* 4 (1): 1–24. doi:10.1163/156853704323074732.

———. 2008. 'The Multiple Roles of Cultural Transmission Experiments in Understanding Human Cultural Evolution'. *Philosophical Transactions of the Royal Society of London B: Biological Sciences* 363 (1509): 3489–3501. doi:10.1098/rstb.2008.0129.

Mesoudi, Alex, Andrew Whiten, and Robin Dunbar. 2006. 'A Bias for Social Information in Human Cultural Transmission'. *British Journal of Psychology* 97 (3): 405–23. doi:10.1348/000712605X85871.

Mesoudi, Alex, Andrew Whiten, and Kevin N. Laland. 2006. 'Towards a Unified Science of Cultural

Evolution'. *Behavioral and Brain Sciences* 29 (4): 329–47. doi:10.1017/S0140525X06009083.

———. 2007. 'Science, Evolution, and Cultural Anthropology. a Response to Ingold (This Issue)'. *Anthropology Today* 23 (2): 18–18. doi:10.1111/j.1467-8322.2007.00498.x.

Millikan, Ruth Garrett. 1984. *Language, Thought, and Other Biological Categories: New Foundations for Realism*. Cambridge, Mass.: MIT Press. http://search.ebscohost.com/login.aspx?direct=true&scope=site&db=nlebk&db=nlabk&AN=49593.

Mitkidis, Panagiotis, John J. McGraw, Andreas Roepstorff, and Sebastian Wallot. 2015. 'Building Trust: Heart Rate Synchrony and Arousal During Joint Action Increased by Public Goods Game'. *Physiology & Behavior* 149 (October): 101–6. doi:10.1016/j.physbeh.2015.05.033.

Miton, Helena, Nicolas Claidière, and Hugo Mercier. 2015. 'Universal Cognitive Mechanisms Explain the Cultural Success of Bloodletting'. *Evolution and Human Behavior* 36 (4): 303–12. doi:10.1016/j.evolhumbehav.2015.01.003.

Morin, Olivier. 2013. 'How Portraits Turned Their Eyes Upon Us: Visual Preferences and Demographic Change in Cultural Evolution'. *Evolution and Human Behavior* 34 (3): 222–29. doi:10.1016/j.evolhumbehav.2013.01.004.

———. 2016. *How Traditions Live and Die*. New York: Oxford University Press. http://search.ebscohost.com/login.aspx?direct=true&scope=site&db=nlebk&db=nlabk&AN=1074945.

Moritz, Maria, Andreas Wiederhold, Barbara Pavlek, Yuri Bizzoni, and Marco Büchler. 2016. 'Non-Literal Text Reuse in Historical Texts: An Approach to Identify Reuse Transformations and Its Application to Bible Reuse'. In *Proceedings of the 2016 Conference on Empirical Methods in Natural Language Processing*, edited by Jian Su, Xavier Carreras, and Kevin Duh, 1849–59. Austin, TX: Association for Computational Linguistics.

Moussaïd, Mehdi, Henry Brighton, and Wolfgang Gaissmaier. 2015. 'The Amplification of Risk in Experimental Diffusion Chains'. *Proceedings of the National Academy of Sciences* 112 (18): 5631–6. doi:10.1073/pnas.1421883112.

Myin, Erik. 2003. 'An Account of Color Without a Subject?' *Behavioral and Brain Sciences* 26 (1): 42–43.

Norenzayan, Ara, Scott Atran, Jason Faulkner, and Mark Schaller. 2006. 'Memory and Mystery: The Cultural Selection of Minimally Counterintuitive Narratives'. *Cognitive Science* 30 (3): 531–53. doi:10.1207/s15516709cog0000_68.

Northway, Mary L. 1936. 'The Influence of Age and Social Group on Children's Remembering'. *British Journal of Psychology. General Section* 27 (1): 11–29. doi:10.1111/j.2044-8295.1936.tb00813.x.

Noveck, Ira, and Dan Sperber. 2012. 'The Why and How of Experimental Pragmatics: The Case of "Scalar Inferences"'. In *Meaning and Relevance*, edited by Deirdre Wilson and Dan Sperber, 307–30. Cambridge, UK: Cambridge University Press.

O'Brien, Michael J., and Kevin N. Laland. 2012. 'Genes, Culture, and Agriculture: An Example of Human Niche Construction'. *Current Anthropology* 53 (4): 434–70. doi:10.1086/666585.

O'Regan, J. Kevin, and Alva Noë. 2001. 'A Sensorimotor Account of Vision and Visual Consciousness'. *Behavioral and Brain Sciences* 24 (5): 939–73. doi:10.1017/S0140525X01000115.

Odling-Smee, F. John, Kevin N Laland, and Marcus W Feldman. 2003. *Niche Construction: The Neglected Process in Evolution*. Princeton: Princeton University Press.

Omodei, Elisa, Thierry Poibeau, and Jean-Philippe Cointet. 2012. 'Multi-Level Modeling of Quo-

tation Families Morphogenesis'. In *Proceedings of the 4th ASE/IEEE International Conference on Social Computing*, edited by Anton Nijholt, Alessandro Vinciarelli, and Dirk Heylen, 392–401. Washington, DC: IEEE Computer Society. http://arxiv.org/abs/1209.4277.

Oyama, Susan. 2000. *The Ontogeny of Information: Developmental Systems and Evolution*. Durham, NC: Duke University Press.

Oyama, Susan, Paul Griffiths, and Russell D Gray, eds. 2001. *Cycles of Contingency: Developmental Systems and Evolution*. Cambridge, Mass.: MIT Press.

Perfors, Amy, and Daniel J. Navarro. 2014. 'Language Evolution Can Be Shaped by the Structure of the World'. *Cognitive Science* 38 (4): 775–93. doi:10.1111/cogs.12102.

Purzycki, Benjamin Grant, and Aiyana K. Willard. 2016. 'MCI Theory: A Critical Discussion'. *Religion, Brain & Behavior* 6 (3): 207–48. doi:10.1080/2153599X.2015.1024915.

Reali, Florencia, and Thomas L. Griffiths. 2009. 'The Evolution of Frequency Distributions: Relating Regularization to Inductive Biases Through Iterated Learning'. *Cognition* 111 (3): 317–28. doi:10.1016/j.cognition.2009.02.012.

Risjord, Mark. 2012. 'Models of Culture'. In *The Oxford Handbook of Philosophy of Social Science*, edited by Harold Kincaid, 387–408. Oxford; New York: Oxford University Press.

Roberts, Gareth, and Bruno Galantucci. 2017. 'Investigating Meaning in Experimental Semiotics'. *Psychology of Language and Communication* 20 (2): 130–53. doi:10.1515/plc-2016-0008.

Rogers, Everett M. 2005. *Diffusion of Innovations*. New York, NY: Free Press.

Romney, A. K., J. P. Boyd, C. C. Moore, W. H. Batchelder, and T. J. Brazill. 1996. 'Culture as Shared Cognitive Representations'. *Proceedings of the National Academy of Sciences* 93 (10): 4699–4705. http://www.pnas.org/content/93/10/4699.

Roy, Brandon C., Michael C. Frank, Philip DeCamp, Matthew Miller, and Deb Roy. 2015. 'Predicting the Birth of a Spoken Word'. *Proceedings of the National Academy of Sciences* 112 (41): 12663–8. doi:10.1073/pnas.1419773112.

Roy, Deb, Rupal Patel, Philip DeCamp, Rony Kubat, Michael Fleischman, Brandon Roy, Nikolaos Mavridis, et al. 2006. 'The Human Speechome Project'. In *Proceedings of the 28th Annual Cognitive Science Conference*, edited by Ron Sun and Naomi Miyake, 2059–64. Austin, TX, USA: Cognitive Science Society.

Ruan, Zhongyuan, Gerardo Iñiguez, Márton Karsai, and János Kertész. 2015. 'Kinetics of Social Contagion'. *Physical Review Letters* 115 (21): 218702. doi:10.1103/PhysRevLett.115.218702.

Scott-Phillips, Thomas C. 2017. 'Pragmatics and the Aims of Language Evolution'. *Psychonomic Bulletin & Review* 24 (1): 186–89. doi:10.3758/s13423-016-1061-2.

Scott-Phillips, Thomas C., and Simon Kirby. 2010. 'Language Evolution in the Laboratory'. *Trends in Cognitive Sciences* 14 (9): 411–17. doi:10.1016/j.tics.2010.06.006.

Scott-Phillips, Thomas C., Simon Kirby, and Graham R. S. Ritchie. 2009. 'Signalling Signalhood and the Emergence of Communication'. *Cognition* 113 (2): 226–33. doi:10.1016/j.cognition.2009.08.009.

Scott-Phillips, Thomas C., Kevin N. Laland, David M. Shuker, Thomas E. Dickins, and Stuart A. West. 2014. 'The Niche Construction Perspective: A Critical Appraisal'. *Evolution* 68 (5): 1231–43.

doi:10.1111/evo.12332.

Silvey, Catriona, Simon Kirby, and Kenny Smith. 2015. 'Word Meanings Evolve to Selectively Preserve Distinctions on Salient Dimensions'. *Cognitive Science* 39 (1): 212–26. doi:10.1111/cogs.12150.

Simmons, Matthew P., Lada A. Adamic, and Eytan Adar. 2011. 'Memes Online: Extracted, Subtracted, Injected, and Recollected'. In *Proceedings of the Fifth International AAAI Conference on Weblogs and Social Media*, edited by Nicolas Nicolov, James G. Shanahan, Lada A. Adamic, Ricardo Baeza-Yates, and Scott Counts, 353–60. Menlo Park, CA: The AAAI Press. http://www.aaai.org/ocs/index.php/ICWSM/ICWSM11/paper/view/2836.

Slingerland, Edward G. 2008. *What Science Offers the Humanities: Integrating Body and Culture*. Cambridge; New York: Cambridge University Press.

Smith, Kenny, and Elizabeth Wonnacott. 2010. 'Eliminating Unpredictable Variation Through Iterated Learning'. *Cognition* 116 (3): 444–49. doi:10.1016/j.cognition.2010.06.004.

Sperber, Dan. 1996. *Explaining Culture: A Naturalistic Approach*. Oxford, UK; Cambridge, Mass.: Blackwell.

Sperber, Dan, and Gloria Origgi. 2012. 'A Pragmatic Perspective on the Evolution of Language'. In *Meaning and Relevance*, edited by Deirdre Wilson and Dan Sperber, 331–38. Cambridge, UK: Cambridge University Press.

Sperber, Dan, and Deirdre Wilson. 1995. *Relevance: Communication and Cognition*. Oxford UK & Cambridge USA: Blackwell.

Sterelny, Kim. 2001. 'Niche Construction, Developmental Systems, and the Extended Replicator'. In *Cycles of Contingency: Developmental Systems and Evolution*, edited by Susan Oyama, Paul Griffiths, and Russell D Gray, 333–49. Cambridge, Mass.: MIT Press.

———. 2010. 'Minds: Extended or Scaffolded?' *Phenomenology and the Cognitive Sciences* 9 (4): 465–81. doi:10.1007/s11097-010-9174-y.

———. 2012. *The Evolved Apprentice: How Evolution Made Humans Unique*. Cambridge, MA, USA; London, UK: The MIT Press.

———. 2017. 'Cultural Evolution in California and Paris'. *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences* 62 (April): 42–50. doi:10.1016/j.shpsc.2016.12.005.

Stotz, Karola. 2010. 'Human Nature and Cognitive–Developmental Niche Construction'. *Phenomenology and the Cognitive Sciences* 9 (4): 483–501. doi:10.1007/s11097-010-9178-7.

Tamariz, Monica, and Simon Kirby. 2016. 'The Cultural Evolution of Language'. *Current Opinion in Psychology* 8 (April): 37–43. doi:10.1016/j.copsyc.2015.09.003.

Tamariz, Mónica, and Simon Kirby. 2015. 'Culture: Copying, Compression, and Conventionality'. *Cognitive Science* 39 (1): 171–83. doi:10.1111/cogs.12144.

Tamariz, Monica, T. Mark Ellison, Dale J. Barr, and Nicolas Fay. 2014. 'Cultural Selection Drives the Evolution of Human Communication Systems'. *Proceedings of the Royal Society of London B: Biological Sciences* 281 (1788): 20140488. doi:10.1098/rspb.2014.0488.

Thompson, Evan. 2007. *Mind in Life: Biology, Phenomenology, and the Sciences of Mind*. Cambridge,

Mass.: Belknap Press of Harvard University Press.

Torrance, Steve. 2006. 'In Search of the Enactive: Introduction to Special Issue on Enactive Experience'. *Phenomenology and the Cognitive Sciences* 4 (4): 357–68. doi:10.1007/s11097-005-9004-9.

Varela, Francisco, Evan Thompson, and Eleanor Rosch. 1991. *The Embodied Mind: Cognitive Science and Human Experience*. MIT Press.

Verhoef, Tessa, Simon Kirby, and Bart de Boer. 2014. 'Emergence of Combinatorial Structure and Economy Through Iterated Learning with Continuous Acoustic Signals'. *Journal of Phonetics* 43 (March): 57–68. doi:10.1016/j.wocn.2014.02.005.

Wallot, Sebastian, Panagiotis Mitkidis, John J. McGraw, and Andreas Roepstorff. 2016. 'Beyond Synchrony: Joint Action in a Complex Production Task Reveals Beneficial Effects of Decreased Interpersonal Synchrony'. *PLOS ONE* 11 (12): e0168306. doi:10.1371/journal.pone.0168306.

Ward, T. H. G. 1949. 'An Experiment on Serial Reproduction with Special Reference to the Changes in the Design of Early Coin Types'. *British Journal of Psychology. General Section* 39 (3): 142–47. doi:10.1111/j.2044-8295.1949.tb00213.x.

Watts, Duncan J. 2002. 'A Simple Model of Global Cascades on Random Networks'. *Proceedings of the National Academy of Sciences* 99 (9): 5766–71. doi:10.1073/pnas.082090499.

Weller, Susan C, and Antone K Romney. 1988. *Systematic Data Collection*. Newbury Park, CA, USA: Sage Publications.

Weng, L., A. Flammini, A. Vespignani, and F. Menczer. 2012. 'Competition Among Memes in a World with Limited Attention'. *Scientific Reports* 2 (March). doi:10.1038/srep00335.

Weng, Lilian, Márton Karsai, Nicola Perra, Filippo Menczer, and Alessandro Flammini. 2015. 'Attention on Weak Ties in Social and Communication Networks'. *arXiv:1505.02399 [Physics]*, May. http://arxiv.org/abs/1505.02399.

Whiten, Andrew, Christine A Caldwell, and Alex Mesoudi. 2016. 'Cultural Diffusion in Humans and Other Animals'. *Current Opinion in Psychology*, Culture, 8 (April): 15–21. doi:10.1016/j.copsyc.2015.09.002.

Wilson, Deirdre, and Dan Sperber. 2002. 'Truthfulness and Relevance'. *Mind* 111 (443): 583–632. doi:10.1093/mind/111.443.583.

———. 2004. 'Relevance Theory'. In *The Handbook of Pragmatics*, edited by Laurence R Horn and Gregory Ward, 607–32. Oxford, UK: Blackwell.

———. 2012. *Meaning and Relevance*. Cambridge, UK: Cambridge University Press.

Wimsatt, William C., and James R. Griesemer. 2007. 'Reproducing Entrenchments to Scaffold Culture: The Central Role of Development in Cultural Evolution'. In *Integrating Evolution and Development: From Theory to Practice*, edited by Roger Sansom and Robert N Brandon, 227–323. Cambridge, MA, USA: MIT Press.

Winters, James, Simon Kirby, and Kenny Smith. 2015. 'Languages Adapt to Their Contextual Niche'. *Language and Cognition* 7 (3): 415–49. doi:10.1017/langcog.2014.35.

Xu, Jing, Mike Dowman, and Thomas L. Griffiths. 2013. 'Cultural Transmission Results in Convergence Towards Colour Term Universals'. *Proc. R. Soc. B* 280 (1758): 20123073. doi:10.1098/rspb.2012.3073.

Zheng, Dongping, Kristi Newgarden, and Michael F. Young. 2012. 'Multimodal Analysis of Lan-

guage Learning in World of Warcraft Play: Languaging as Values-Realizing'. *ReCALL* 24 (3): 339–60. doi:10.1017/S0958344012000183.