



**Vocalizing Behavior in Killer Whales (*Orcinus orca*)
– an Evolutionary Account**

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**Fiskeldis- og fiskalífræðideild
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90 ECTS thesis submitted in partial fulfillment of a
Magister Scientiarum degree in Aquatic Biology

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Abstract

In this thesis, we compare human language, as defined by Noam Chomsky in his biolinguistic account of language, with killer whale (*Orcinus orca*) vocalizations and what we call the *orca vocalization* and *orca symbolic vocalization* systems. We postulate hypothetical orca counterparts of the elements of language described in Chomsky's account and trace out the relevant contingencies of such counterparts. We ask whether they might allow orcas to achieve what the faculty of language allows humans to achieve—such things as thinking, planning, interpreting and creativity—and whether an orca counterpart to the faculty of language in the narrow sense that Chomsky postulates, needs to rest upon a functionally recursive operator. Taking an ecological, evolutionary, developmental approach, we discuss the possible evolutionary and developmental trajectories of the species-specific orca expression of the type of cognitive system that makes abstract symbolic representations possible for an organism.

Útdráttur

Í þessari ritgerð er manlegt tungumál, eins og Noam Chomsky skilgreinir það í kenningu sinni um tungumálið sem lífrænt málkerfi (líkamleg eining sem reiknar með sérstökum hætti), borið saman við *raddtjáningarkerfi* og sér í lagi *táknrænt raddtjáningarkerfi háhyrninga* (*Orcinus orca*). Við gefum okkur þá tilgátu að háhyrningar búi yfir reiknieiningum hliðstæðum við þá frumþætti tungumálsins sem Chomsky eignar mannskepnunni, og rekjum afleiðingar þeirrar tilgátu. Við spyrjum hvort þessar lífrænu hliðstæður gætu hugsanlega gefið háhyrningum sambærilega möguleika og tungumálið veitir mönnum, eins og hæfileika til hugsunar, áætlanagerðar, túlkunar og sköpunargetu, og enn fremur hvort hinar meintu hliðstæður hjá háhyrningum þyrftu nauðsynlega að byggjast á ótakmörkuðu endurkvæmu reikniferli (líkt og manlegt tungumál samkvæmt Chomsky) til þess að geta stutt slíka hæfileika. Þá er beitt vist-, þróunar- og þroskunarfræðilegum nálgunum til að skoða möguleg þróunar- og þroskaferli tegundarsértæks birtingarforms vitsmunagetu hjá háhyrningum af því tagi sem gerir lífverum kleift að hugsa, skilja og tjá sig með táknrænum hætti.

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1. Introduction

Like other cetaceans, such as sperm whales (*Physeter macrocephalus*) (Weilgart & Whitehead, 2011) and bottlenose dolphins (*Tursiops truncatus*) (Herman, Richards & Wolz, 1984), killer whales (*Orcinus orca*) vocalize in diverse and complex ways. However, very little is understood of the functions of orca vocalizations, or about their development and evolution. This thesis will survey these matters. After briefly introducing our focal organism, the killer whale, we will explain the purpose and plan of this work.

1.1 Killer whales and their lifestyle

Killer whales are marine mammals and toothed whales (odontocetes) belonging to the family Delphinidae or oceanic dolphins, and they are found all over the world, in both cold and tropical waters, as well as in coastal and offshore areas. They are phenotypically diverse, forming ecotypes (morphs) in relation to different resources. Populations can differ in their diet, morphology, behavior, genetics and movement patterns. For example, the *resident*, *transient* and *offshore* killer whales in the North Pacific differ in several ecological, morphological and behavioral features (Forney & Wade, 2006; Baird, 2000).

These animals have highly developed social lives (Chwalibog, Kachar & Sawosz, 2018), living in close-knit matrilineal units, and staying with the same group likely most of their lives, although they may often socialize regularly with other families (Filatova, Samarra, Deecke, Ford, Miller & Yurk, 2015). A matriline group contains “a matriarch and all her descendants (children, grandchildren and grand-grandchildren)” (Filatova, Guzeev, Fedutin, Burdin & Hoyt, 2013). Sons stay in the matriline group of their mothers, but mate in other groups. Daughters stay in their family group with their offspring, and so all grandchildren in the group are the children of daughters (Bigg, Olesiuk & Ellis, 1990). A recent study in which a pod of killer whales was observed with drones, fascinatingly found that killer whales spend more time with certain individuals of their pod, and tend to favor those individuals that are of the same sex and similar age. The animals were also found to be very tactile with each other. (Weiss, Franks, Giles et al., 2021).

Matrilines form pods, which are groups of closely related matrilines that associate frequently (Ford, 1991), and share a repertoire of stereotyped vocalizations, i.e. a dialect (Miller, Shapiro, Tyack & Solow, 2004; Ford, 1991; Filatova et al., 2013). Dialects are stable for periods of at least 50 years (Yurk, Filatova, Matkin, Barrett-Lennard & Brittain, 2010). Pods form clans with other pods that share parts of their repertoires with other related groups that they associate with (Filatova et al., 2013), and all the pods that socialize with each other form communities (Whale and Dolphin Conservation, n.d.). Communities can consist of one or more associating clan (Ford, 1991).

Killer whale calves learn their matrilineal dialect socially, possibly primarily from their mother. In addition to killer whales and humans, local dialects that do not seem to involve genetic differences, have been observed in one primate, the red-chested mustached tamarins (*Saguinus labiatus labiatus*), and in tamarins, there is no evidence of different vocal populations interacting with each other. (Ford, 1991). These types of dialects are based on phenotypic plasticity, i.e. the ability of the phenotype to respond to environmental factors. In killer whales, pods with entirely different vocal repertoires regularly mix. Ford mentions that “the closest parallel to this can be seen in urban human communities that are stratified both socially and linguistically” (Ford, 1991, p. 1476).

1.2 Purpose and plan of this study

In this thesis, we will explore vocalization in killer whales with an eye to developmental and evolutionary issues. Orca vocalizations are sufficiently complex, plastic, and interrelated that it seems reasonable to speak of an *orca vocalization system*. It is not clear just how the development or evolution of such a system is to be studied. In order to frame an approach, we will here imagine that orca vocalization belonging to this system (which is unlikely to include everything describable as “orca vocalization”) might play a role in the lives of orcas comparable to the role played by spoken language—speech—in the lives of human beings. How close or distant a comparison is warranted is an open question upon which it is impossible to take any decision, however tentative, prior to exploring the relevant contingencies of orca vocalizations.

Which contingencies are taken to be relevant will depend upon the view of spoken language—and language more generally—to which the orca vocalization system is to be compared. For, as Ray Jackendoff (2010) remarks, “Your theory of language evolution depends upon your theory of language”; and, as Hauser, Chomsky & Fitch (2002) earlier remarked, “The word ‘language’ has highly divergent meanings in different contexts and disciplines.” There are, in short, many different accounts of language, and thus of spoken language, or human speech, which it is impossible to survey here. In fact, we must make a very narrow choice.

For the purposes of the present investigation, we will use, for our comparison, the biolinguistic view of language taken by Noam Chomsky and some of his close collaborators, in the form in which it is outlined in Hauser, Chomsky & Fitch (2002): “The Faculty of Language: What Is It, Who Has It, and How Did It Evolve?” and more recently in Chomsky (2015a), Berwick & Chomsky (2016), and numerous articles, such as Chomsky (2011). Our reasons for restricting our attention to this particular view of language and speech are (1) although it has been widely criticized and many alternatives have been offered, it remains the most influential perspective, (2) it has been much discussed by Chomsky and others in connection with developmental and evolutionary questions (see, in particular Hauser, Yang, Berwick, Tattersall, Ryan, Watumull, Chomsky & Lewontin, 2014 and the succinct and focused overview in Bolhuis, Tattersall, Chomsky & Berwick, 2014).

To avoid any misunderstanding, it must be mentioned here that our purpose is *not* to try to argue, or even hint, that the orca vocalization system is a system of speech—that is, of spoken language—or that killer whales have language or what Chomsky calls a “language faculty”. Such claims would not fit with the account of language that we have chosen as our

basis of comparison, and much ink has been needlessly spilled in pointless arguments over whether or not certain non-human animals have language—arguments which are generally framed without doing what Chomsky has often, and rightly, insisted must be the first step in any study of the architecture, acquisition, development, evolution, or other characteristics of language, namely to give a clear definition of language, i.e. to say what language *is*. This may be a working definition, and language may be differently defined to fit different purposes and different discussions. But any debate over whether a given creature has or lacks language must rest upon a common understanding of language among the debaters if the debate is to have any point. In the present case, we will cleave to Chomsky’s definition, or account, of language, and our discussion will not include the question of whether orcas have language, spoken or otherwise.

It is not important whether we call orca vocal communication, or the communication of some other nonhuman animal, *linguistic* or claim that such creatures have *language* in the sense that is widely considered appropriate for linguistics. What is more interesting is whether their vocalizations can be analyzed in terms of what, for human linguistic expression, we call *syntax*, *semantics* and *pragmatics*— whether a non-human organism can be to a certain extent *creative* in its vocalizations, and whether creative vocalizations can be understood by other organisms of its kind. Might killer whales have a heritable, cognitive *symbolization faculty* (cf. the language faculty) that although not the same as the language faculty in humans, manages to accomplish some of the same things such as thinking and planning? And might this symbolization faculty have first arisen as an internal ability and since then been externalized into vocal expressions that are assigned to “sensory data in perception” (Chomsky, 2010, p. 1)? The complexity and diversity of killer whale vocalizations suggests that there is a lot to be learned about their sentience, thought, cognition and emotion by studying their vocalizing behavior.

As mentioned above, Chomsky’s perspective on language and speech belongs to biolinguistics, or the biology of language. As Lyle Jenkins (1997) succinctly notes, “[w]e can divide up the study of the biology of language into three main areas: 1) language, 2) development of language and 3) evolution of language” (p. 1). The general plan of this thesis will be, first, to give a brief account of language as formulated by Chomsky; this account begins with what Chomsky calls the language faculty in the narrow sense, progresses to an account of what he call an “internal language” (I-language), and progresses further to an account of spoken language (the “externalization” of I-language). Next, we will survey much of what is currently known, or at least believed, about orca vocalizations, based upon empirical research, and will both concurrently and subsequently discuss the syntactic, semantic, functional and psychological aspects of killer whale vocalization by looking at empirical studies that have (over the past 20-30 years) analyzed the vocalizing behavior of killer whales. In this connection, we will discuss whether, and on what basis, it is plausible to speak of the grammar, syntax, and semantics of this vocal behavior and will propose that, even admitting that the orca vocalization system differs in (what Chomsky and many others view as) some essential ways from human speech—spoken language—one might still plausibly hypothesize a *syntactical symbolization faculty* in Orcas, at least distantly analogous to the human internal language faculty and providing an underpinning for a *symbolic vocalization faculty*, at least distantly analogous to the human faculty of speech. This hypothesis is then applied to the discussion of developmental and evolutionary aspects of the orca vocalization system against the background of Chomsky’s discussion of perceived parallels between some theses of biolinguistics and of ecological, evolutionary and developmental (eco evo devo) approaches.

2. Chomsky on language and speech

As explained in the introduction, we begin with a brief review of Chomsky's account of language and speech, commenting also on the ramifications of this account, as Chomsky sees them, for matters of development and evolution. Since this thesis is of fairly brief compass, and since its main topic is not biolinguistic theory (but rather a discussion of developmental and evolutionary questions pertaining to orca vocalizations), nor its intended readership students of linguistics, this account will be kept as brief and simple as possible, avoiding technicalities not relevant to our purposes.

In any case, Chomsky's biolinguistic account of language has been in fluid development since it was introduced in the 1950's. Some terminology has changed, Chomsky's generative-grammar model has gone through several transformations, and what he has to say about developmental and evolutionary matters has taken on board many of the views of his collaborators in comparative and evolutionary biology and biolinguistics. Thus, our review here of his account is meant to be a condensation of the current Chomskyan orthodoxy (although with some non-orthodox aspects introduced by collaborators), distilled from various sources and ordered to our project.

Language, according to Chomsky (2010), is, on one of his main accounts, "a particular computational cognitive system, implemented neurally" (Bolhuis et al, 2014, para. 2), like the systems of vision or proprioception. For him, language—or the language faculty—in this narrow and specific sense is a heritable, biologically seated system, spoken communication being but one the functions or activities that it supports (albeit a significant one). More broadly, Chomsky believes that the language faculty as just described is the foundation of *the human capacity* "for creative imagination, [speech] and other modes of symbolism, mathematics, interpretation and recording of natural phenomena, intricate social practices and the like" (Chomsky, 2004, para. 9).

According to Chomsky (2010), human language developed first as an internal ability to plan, to think in complex ways, to interpret situations and to create possible worlds mentally. Later, internal linguistic symbols were externalized, and started to be used for interaction, including especially spoken communication with human conspecifics. This ability is, Chomsky (2010) believes, unique to humans. According to him, it likely did not develop before the appearance of *Homo sapiens* and was, indeed, not an initial species characteristic.

Many scientists [certainly including Chomsky] agree with paleoanthropologist Ian Tattersall, who writes that he is "almost sure that it was the invention of language" that was the "sudden and emergent" event that was the "releasing stimulus" for the appearance of the human capacity in the evolutionary record—the "great leap forward" as Jared Diamond called it, the result of some genetic event that rewired the brain, allowing for the origin of human language with the rich syntax that provides a multitude of modes of expression of thought, a prerequisite for social development and the sharp changes of behavior that are revealed in the archaeological record, also generally assumed to be the trigger for

the rapid trek from Africa, where otherwise modern humans had apparently been present for hundreds of thousands of years. (Chomsky, 2004, pp. 2-3; cf. Tattersall, 2012)

Tattersall dates the abrupt and sudden event as probably lying somewhere within the very narrow window of 50,000 to 100,000 years ago. The exact dates are unclear, and not relevant to our concerns . . . , but the abruptness of the emergence is. (Chomsky, 2016, p. 3)

Here, Chomsky has in mind *language*—or the *language faculty*—in its narrowest sense: a biological object, understood as the seat of a computational ability, internal to an individual, that, according to the core theory of language—Universal Grammar (UG)—must provide, first, a *structured inventory of possible lexical items* deriving from a different modular system (or biological faculty), most often referred to as the *conceptual-intentional* system, and must also provide, in the second place, *a variety (in principle unlimited) of internal structures constructed—sometimes referred to as “symbols”, but more often as “expressions”—generated from these lexical items*, that enter into thought, interpretation planning, and other human mental acts (Chomsky 2005, p. 4; cf. Berwick & Chomsky (2016), p. 7).

In an individual, the resulting system of symbols or expressions, whose systematic (grammatical, syntactical) properties conform to the principles of the language faculty in its narrow sense as described by UG, is a particular individual’s internal language, or “I-language”. Here, “language” refers to something other than the language faculty *per se*—not language in the sense of the biological language faculty, narrowly understood, but to a language, the (first) “language” acquired by an individual, which will be, in general, the internal manifestation (in the form of systematic abilities) of the “culturally specific communication system” (Hauser, Chomsky & Fitch, 2002) shared by the members of a particular language community.

Used to refer to a “culturally specific communication system (Japanese, Urdu, English), “language” is employed in yet a third meaning. For the sake of participation in such a shared system of linguistic communication, the language faculty must interact with a third modular system, or set of systems, most often referred to as the *sensory-motor system*, or rather a subset that might better be called the *phonological system*, by means of which I-languages are “externalized”. (For simplicity, we stick throughout with “externalization” through speech, or at least vocalization. But Chomsky is clear that externalization is, in large part, modality-independent, as shown by the use of signing—which may even be spontaneous if not learned in a community—among individuals endowed with the language faculty but who lack the powers of vocalization, which is also available to people gifted with speech.)

This view of language as the language faculty in the narrow sense—that includes “the basic engine that drives language syntax”—captures what Chomsky calls the *Basic Property of human language*: “each language yields a digitally infinite array of hierarchically structured expressions with systematic interpretations at interfaces with two other internal systems, the sensorimotor system for externalization and the conceptual system for inference, interpretation, planning, organization of action, and other elements of what is informally called ‘thought.’” (Berwick & Chomsky (2016), pp. 89-90; cf. Chomsky (2015a), p. ix.).

The hierarchical structure (syntax) of the symbols or expressions generated by the language faculty is inferred from the properties of the uttered expressions of human language, as studied mostly through empirical descriptive linguistics; such studies provide the test cases for analytical linguistic theory and computational hypotheses. The idea that “The most elementary property of our shared language capacity is that it enables us to construct and interpret a discrete infinity of hierarchically structured expressions: discrete because there are 5 word sentences and 6 word sentences, but no 5½ word sentences; infinite because there is no longest sentence,” rests upon the inference that “Language is based on a *recursive generative procedure* that takes elementary word-like elements from some store, call it the lexicon, and applies repeatedly to yield structured expressions, without bound” (Berwick & Chomsky, 2010, p. 19, italics added; but he point is made widely).

The recursiveness of the generative grammatical function has been considered to be a distinctive attribute of human language, “shared by no other animal system” (Tallerman & Gibson, 2011, p. 2.) According to Hauser et al. (2014), recursion is an inherent property of the human language faculty. These authors maintain that recursive capacities in non-human animals are limited to the training level and that such animals show no evidence of having the “set of properties defining the generative procedure”. (Hauser et al., 2014, p. 7).

Indeed, most contemporary linguists say, without necessarily being precise, that “human language is recursive”. And Tecumseh Fitch has written carefully about three different meanings for “recursion”, each fitted for different disciplines (Fitch, 2010). We cannot delve into the technicalities here. But in connection with Chomsky’s account of language, the matter of recursion is fairly clear. As a computationalist, Chomsky has put much effort into trying to determine the operation, or algorithm, by which the language function generates its array of hierarchically structured expressions. His most recent (but no longer recent) idea is that the computational algorithm is the recursive operation that he calls *unbounded Merge* (Chomsky, 2010 and widely elsewhere; cf. especially Chomsky, 2015a).

The simplest recursive operation, embedded in one way or another in all others, takes two objects already constructed, say *X* and *Y*, and forms a new object *Z* without modifying either *X* or *Y* or adding any further structure. Accordingly, *Z* can be taken to be just the set $\{X, Y\}$. In current work, the operation is called Merge. Since Merge imposes no order, the objects constructed, however complex, will be hierarchically structured, but unordered, and operation on them will necessarily keep to structural distance, ignoring linear distance. It follows that the linguistic operations yielding the language of thought will be structure-dependent, as indeed it the case, resolving the puzzle. (Chomsky 2017, p. 5; cf. Chomsky 2010, p. 52)

Given *merge*, two items such as *the* and *apples* are assembled as the set $\{the, apples\}$. Crucially, merge can apply to the results of its own output so that a further application of merge to *ate* and $\{the, apples\}$ yields the set $\{ate, \{the, apples\}\}$, in this way deriving the full range of characteristic hierarchical structure that distinguishes human language from all other known nonhuman cognitive systems. (Bolhuis et al. 2014, para. 3)

The “Strong Minimalist Thesis” (SMT) holds that *merge* along with a general cognitive requirement for computationally minimal or efficient search suffices to

account for much of human language syntax. The SMT also requires two mappings: one to an internal conceptual interface for thought and a second to a sensory- motor interface that externalizes language as speech, sign, or other modality. (Bolhuis et al. 2014, para. 3)

The postulation of Merge as the computational operation at the heart of the narrow language faculty—a postulate that has stood up to testing—reinforces what descriptive linguistics has found to be the case in its examination of human speech across a wide range of natural languages.

So now we have a picture in which the language function (or simply language) in the narrow sense—called in Hauser, Chomsky & Fitch (2002) the *Faculty of Language - Narrow Sense* (FLN)—with Merge as its basic, and arguably only, computational syntactical-structuring operation, generates I-languages (and supports all language-mediated activities) in conformity with the account of UG, which consist of an in-principle unbounded array of hierarchically-structured symbols or “expressions” which can be externalized, through interaction with the sensory-motor (phonological) system and receive content and interpretation through interaction with the conceptual-intentional system. (This is the minimal apparatus; further “peripheral” systems may well be involved). The resulting “language” keeps to the simplest recursive operation, Merge, and is perfectly designed to satisfy interface conditions. Language in this (now the fourth) sense, summed up by Chomsky in the slogan “Interfaces + Merge = Language” is what is called in Hauser, Chomsky & Fitch (2002) the *Faculty of Language - Broad Sense* (FLB).

It is FLB that supposedly founds, and makes possible, the *human capacity* “for [thought, planning] creative imagination, [speech] and other modes of symbolism, mathematics, interpretation and recording of natural phenomena, intricate social practices and the like” (Chomsky, 2004, para. 9) discussed earlier. It is not FLN (with its operation of Merge) alone. *However, Chomsky’s central question about the “evolution of language”, by which he means here a heritable change in genetic make-up, concerns just the evolutionary advent of FLN.* Hauser, Chomsky & Fitch (2002) go so far as to suppose that the relevant conceptual-intentional and phonological (sensory-motor) modules existed in *Homo sapiens* (and perhaps in ancestor species) for a long time prior to the advent of FLN, which Chomsky speculates came about through a small genetic mutation—“a minor rewiring of the brain”—that put Merge into possible interaction with the other two modules. Presumably, there was no phenotypic change in those modules *per se*. Only in connection with the advent of FLN, did language (FLB) come into existence. Of course, both the conceptual-intentional and sensory-motor modules had to be “recruited” into synergy with FLN (or they had to recruit FLN into synergy with themselves) for there to be language; and since the posited genetic change presumably appeared at first in a small number of individuals, there was little reason for such synergy to develop, prior to the distribution of FLN as a species characteristic through the genome of *Homo sapiens*. Chomsky argues that there was no selective pressure favoring the small, but significant, “rewiring” that produced FLN and so is skeptical of the possibility of a Darwinian account.

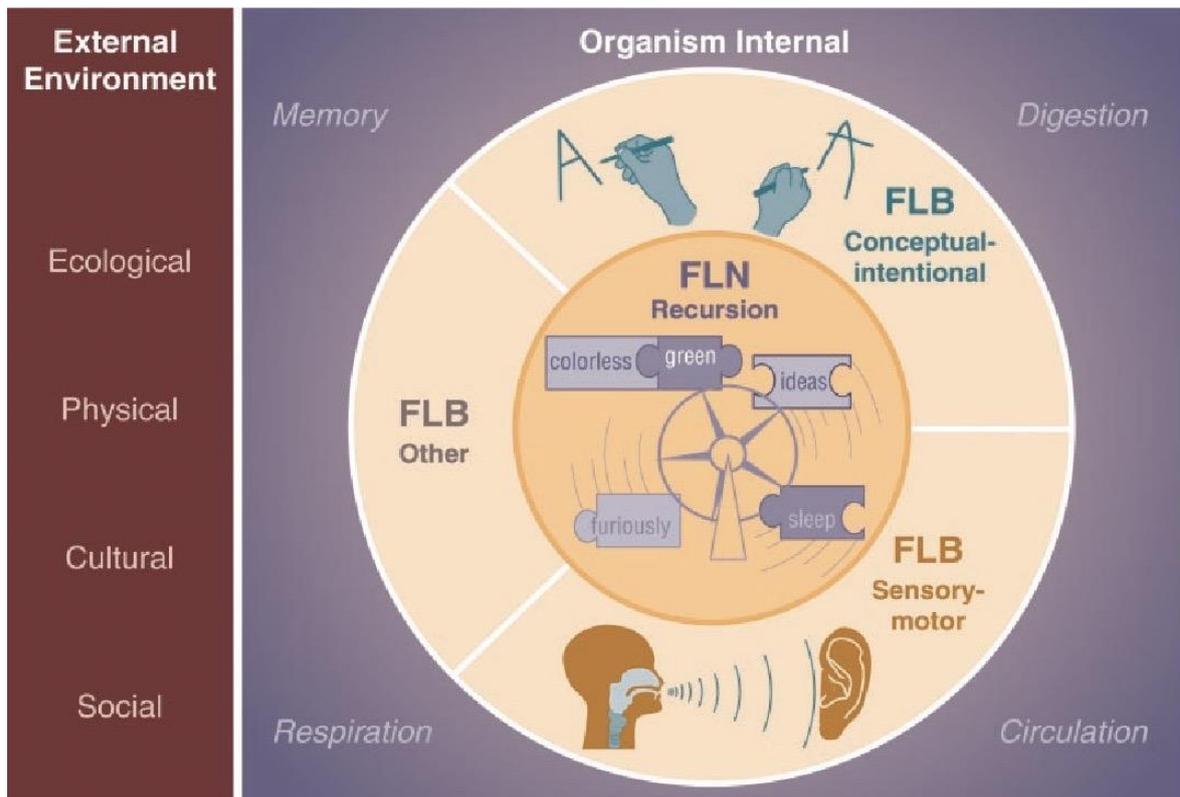


Figure 1. A schematic representation of organism-external and -internal factors related to the faculty of language. From “The Faculty of Language: What Is It, Who Has It, and How Did It Evolve?” by M. D. Hauser, N. Chomsky & W. T. Fitch 2002, *Science*, 298(5598), 1570. Copyright c 2002 by the American Association for the Advancement of Science.

As we will discuss later, there are other evolutionary questions that might be asked about language than just the one that Chomsky himself focuses upon.

The account of language just given will be used as a point of comparison in exploring the question whether, even admitting that the orca vocalization system differs in (what Chomsky and many others view as) some essential ways from human speech—spoken language—one might nevertheless plausibly hypothesize a *syntactical symbolization faculty* in orcas, at least distantly analogous to the human internal language faculty and providing an underpinning for a *symbolic vocalization faculty*, at least distantly analogous to the human faculty of speech. Nothing much can be done in that direction until we learn in some detail about what is currently known, or at least believed, about orca vocalizations, based upon empirical research; and to this we now turn.

3. The vocalizing behavior of killer whales: a survey

Most organisms communicate with conspecifics, and some understand signals produced by other species (Tallerman & Gibson, 2011), but only the communication signals of humans are usually called linguistic. Human language is considered unique (Hauser et al., 2014; Pinker & Jackendoff, 2009) because of its compositionality (Tallerman & Gibson, 2011), generativity (Corballis, 1992), humans' ability to use recursion (Hauser, Chomsky & Fitch, 2002), and because animals do not learn to use it (Chomsky, 2000). Moreover, each expression of (human) language is a pairing of a sign (e.g. sound or gesture) and meaning, and “sentences are built up out of discrete units” (Hauser, Chomsky and Fitch, 2002, p. 1570). Both Chomsky (2010) and Hauser et al. (2014) believe that no other organism exhibits vocal behavior with characteristics comparable to those of human speech.

But killer whales (*Orcinus orca*) and other cetaceans, such as sperm whales (*Physeter macrocephalus*) (Weilgart & Whitehead, 2011), and bottlenose dolphins (*Tursiops truncatus*) (Herman, Richards & Wolz, 1984), have evidently developed rather sophisticated vocal communication systems independently from the human lineage.

In order to avoid controversial questions, we avoid attributing speech—spoken language—to killer whales but speak instead of “vocalization”. By *vocalization* we will mean any sound produced through the action of an animal's respiratory system. Vocalizations are used by many animals, such as birds, frogs, geckos, crocodilians, and mammals, including humans and may indicate territoriality, aggression, alarm, fright, contentment, hunger, the presence of food, the need for companionship, or may guide cooperative behavior. Vocalizations used in these ways, if we believe that they are *understood by conspecifics* that could *react behaviorally to the content indicated*, would all be examples of *communication*; but vocalization is also used for non-communicative purposes, such as echolocative vocalization by some animals, such as bats and many cetaceans.

In this chapter, we examine the phonetic, syntactic, semantic, functional aspects of the complex vocalizations, and the vocalizing behavior, of killer whales. As a part of the functional aspects, we will also be looking at some of the psychological aspects of vocalizations.

3.1. Phonetic classification of orca vocalizations

Killer whale vocalizations have been observed to exhibit a large variety of structures.¹ The largest sound categories are clicks, pulsed calls and whistles. But within each of these types

¹ Icelandic Orca Project. *Herding calls, Low frequency sounds produced by Icelandic orcas & Acoustic recording of Icelandic orcas foraging* [Audio recording] [3 soundtracks] SoundCloud. <https://soundcloud.com/user-452682658>

there is considerable variation. (Filatova et al., 2015b, p. 2009). Each sound category can be described by certain characteristics. There is no definitive classification of call types, but for example, Saulitis, Matkin and Fay (2005) reported the following distribution of sound categories: whistles 38.9% of all recorded vocalizations, pulsed calls 61.1%, variable pulsed calls 19.6%, and aberrant pulsed calls 6%. Clicks were recorded in 7% of the samples. Discrete pulsed calls made up 41.5% of all calls, and 14 types of discrete calls were identified. An average of 5.29 characteristics per call was measured.

The function and meanings of killer whale vocalizations remains largely unclear (Weiss, Ladichs, Spong & Symonds, 2006), but their complexity and apparent effects suggest that they may be more apt for comparison to speech than the vocalizations of most other nonhuman animals.

3.1.1. Echolocation clicks

Clicks, which are mainly used as echolocation signals, are “brief pulses of sound, typically given in series” and “quite variable in structure” (Ford 1989, p. 729). Clicks are produced “individually or in click trains” (Holt, 2008, p. 6).

3.1.2. Pulsed calls

Harmonically rich pulsed calls seem to be the most commonly emitted sounds in killer whales, at least the most commonly observed ones (Thomsen, Franck & Ford, 2002). They consist of “several short pulses emitted at such a high repetition rate that they sound tonal to humans” (Simon, McGregor, Ugarte, 2007, p. 48).

Pulsed calls are either discrete (stereotyped) or variable in structure (Riesch, Ford & Thomsen, 2008). Usually, they are structurally categorized into discrete (stereotyped), variable and aberrant calls (Holt, 2008; Ford, 1989). Discrete calls “fall into distinctive structural categories”. They are repetitive, and pods have different and distinguishable repertoires of these types of calls that “are emitted consistently by all whales in a group over time”. (Saulitis et al., 2005, p. 1016). Variable calls do not have a consistent spectral structure, and in general lack repetitiveness and structural categorization. Aberrant calls are structurally highly modified, or distorted versions of discrete call formats that killer whales emit when engaging in activities such as socializing and feeding. (Ford, 1989/2011).

3.1.3. Whistles

Whistles are sinusoidal (Ford, 1989), high pitched, complex (Riesch et al., 2008) tonal signals (Holt, 2008) with a “nonpulsed or continuous waveform” (Ford, 1989, p. 729), Killer whales produce ultrasonic whistles with the highest fundamental frequency reported in delphinids (Samarra, 2010). Whistles seem in general to be “much more complex than those described for other delphinids” (Thomsen, Franck & Ford, 2001, p. 1245), 93,5% of whistles observed in a study contained several harmonics, with the main energy concentrated in the fundamental frequency (Thomsen et al., 2001).

Whistles are likely perceived by the receiver as a single tone, because of how small the intervals between harmonic bands are (Thomsen et al., 2001). Whistles occur at different frequencies and for different durations (50 ms to 10–12 s), and most of them contain several “modulations or abrupt shifts in frequency” (Ford, 1989, p. 729). Whistles are longer in

duration and lower in frequency than clicks, and low-intensity compared to pulsed calls (Holt, 2008). They are used as isolated sounds as well sequences of the same type of distinct whistles, or so called “multiloops” (Riesch et al., 2008, p. 1827). Riesch, Ford and Thomsen (2006) found 30% of whistles recorded during a period of 3 years to be stereotyped and further categorizable into four distinct categories (p. 84).

3.2. Syntactic aspects of vocalizations

The term *syntax* usually refers to the grammatical structuring of linguistic elements (such as words) and their combination into longer linguistic constructs (such as phrases, clauses, or sentences). Thus, animal vocalizations are not commonly described as having syntactic structure since non-human animals are not thought to have language. We, however, will adapt the word *syntax* to our purposes, letting it refer to the structuring of vocal elements and the systematic combination of such elements into longer constructs. We may also speak of the syntax of such internal symbols (if any) that underlie the vocal structures.

Hauser et al. (2014) maintain that in non-human animals, “utterances are holistic, with no evidence of complex syntactic composition derived from an inventory of discrete morphological elements . . . [and] are not marked by anything remotely resembling grammatical classes, agreement, etc.” (p. 4). However, Suzuki, Wheatcroft & Griesser (2017) cf. Russell & Townsend (2017), through research on the Japanese tit (*Parus minor*), a common garden bird of eastern Asia, found rather persuasive indications that the birds used an ordering rule to compose and extract meanings from novel call sequences, i.e. by joining specific calls in rule-guided combinations — a requisite of compositional syntax. Continuing to explore the evolution of syntactic communication through innovative analyses of the vocalizations of non-human animals, selected birds and social primates, Suzuki, Wheatcroft & Griesser (2019), found, first, that “Non-syntactic combinations of meaningful elements . . . provide the basis for compositional expressions” and speculate that these “were probably produced by the last common ancestor of human and apes.” But even more strikingly, they note that:

Compositional syntax has recently been documented in call sequences of a few species of birds and primates, suggesting novel parallels between animal communication systems and human language. Combinations of meaningful calls may sometimes result in non-compositional messages (idiomatic sequences), reflecting a disassociation between syntax and semantics. (Suzuki, Wheatcroft & Griesser, 2019, (p. 7)

So, even if orca vocalizations do not incorporate certain “higher” grammatical characteristics such as grammatical agreement, syntactical structuring at both the phonological and the morphosyntactic levels and the novel combination of vocal symbols according to grammatical rules may be present. According to some research on orcas, “phonological and lexical borrowings (horizontal transmission of features and types of calls), the presence of conservative and changeable words (call types), and rectified changes in certain phonemes in all words of language (rectified changes in similar syllables in various types)”, may exist in orca vocalizations (Filatova et al., 2010, p. 970).

Scientists who have studied killer whale vocalizations have been able to distinguish discrete units that are combined and sequenced in different ways. Spectrograms of vocalizations show that orcas use a variety of sub-units or syllables in calls, change them, and employ them in various combinations and recombinations (Filatova et al., 2015b, pp. 2015–2016; Ford, 1989; Ford, 1991; Strager, 1995; Yurk, 2005). Shapiro, Tyack & Seneff (2011) categorized Norwegian killer whale complete calls into subunits and found that “(1) there were fewer subunits than call types and (2) nearly 75% of all call types shared at least one subunit” (p. 377). Out of 31 call types, 18 “were composed entirely of shared subunits and another five contained at least one shared subunit”, and “some segments were used much more frequently than others” (p. 382). These whales also produced compound calls, which are “concatenations of multiple discrete calls, each of which can be produced individually or within other compound calls” (p. 378). In the northeastern Pacific, an orca population produced 42% of recorded whistles as isolated signals, and 58% “as part of whistle sequences” (Riesch & Deecke, 2011, p. 1381).

Orca call sequences can occur in predictable patterns or sequences (Ford 1989), for example, by three or four calls (including repetitions) occurring together more often than expected and being repeated more often than expected”. However, lone whales only produced a few sequences of calls from the large number of possible sequences “that could be generated from eight call types” (Saulitis et al., 2005, p. 1021). This may be because socialization is such an important aspect of vocalization that lone whales mainly only produce sounds to find their conspecifics or group members, and do not necessarily have many other reasons to vocalize on their own.

Killer whales are also known to make “context specific-modulations of discrete call structures”, and Ford suggests that these modulations “are governed by a set of rules common to all killer whales, and that such modulations in the calls of one whale are recognizable to others, even those with different repertoires of calls”. (Ford, 1989, p. 743). Since whales with entirely different dialects interact, this kind of shared understanding of syntax makes vocal communication possible for animals with different repertoires of calls.

There are developmental limits to the type of sounds an organism can produce. Partly because of these constraints, humans use a few dozen phonemic units to generate an open-ended number of words. It is possible that sub-units of vocalizations are similarly rearranged by killer whales to produce a “larger repertoire of call types” than would otherwise be possible, within the limits of their “sound production apparatus” which “operates within a finite temporal and spectral range” (Shapiro et al., 2011, p. 378, 384). And similar to humans, each group of killer whales apparently uses a portion of universal sub-units for its own vocal repertoire. The animals may also increase their vocal repertoires by changing and varying the pairing of low- and high-frequency sounds. They are able to produce low- and high-frequency call components synchronously, presumably by using two different parts of the animal’s vocal apparatus. (Shapiro et al., 2011).

Syntactic aspects of vocalizations can provide information on the foraging ecology and social systems of killer whales. For example, in the North Pacific, the foraging habits and social structure of whales has affected and molded the vocal repertoires of killer whale populations, which have been classified into three groups: mammal-eating transients, piscivorous residents and offshores. In the northeastern Pacific for example, there are clear differences between the bioacoustic parameters and behavioral context of the whistles of transient and resident whales.

Transients are silent most of the time, while residents and offshores are vocal most of the time. (Yurk et al., 2010). One study that compared two populations found that transients had only 3 stereotyped whistles, while residents had 11 stereotyped whistles “of varying contour” (Riesch & Deecke, 2011, p. 1386). It has been suggested that these differences in repertoires are due to the fact that, because the prey species of transient and resident populations have different hearing abilities, killer whales have adapted their vocal behavior to ensure successful hunting and feeding tactics. When hunting a marine mammal, it is important to keep silent when moving in for an attempted kill, because the hearing spectrum of the prey animals overlaps the vocalization spectrum of killer whales. (Riesch & Deecke, 2011).

In addition to foraging habits, the social structure of transients likely affects their call use. Transient whales have a much more fluid social system than residents, in which they may form temporary hunting groups with whales that they do not encounter frequently; so it makes sense that they have a smaller vocal repertoire of stereotyped calls, as this may facilitate “successful cooperation and temporary bonding between infrequent social companions” (Riesch & Deecke, 2011, p. 1386).

But even with a limited repertoire of stereotyped calls, the overall repertoire of transients in the northeastern Pacific is not small. Out of 1218 whistles recorded, 897 were variable in structure, “with no apparent similarities in spectrographic contour”. 321 of the recorded sounds fell into one of the three discrete categories. These stereotyped whistles “were often multi-looped (i.e. repetitive sequences of the same whistle type)”, but also “found as isolated whistles”. (Riesch & Deecke, 2011, p. 1380). There was also variability between whistles of the same discrete type, which could mean that each individual has its own version of the same whistle type (Riesch & Deecke, 2011).

In human beings, new signal combinations may be produced out of elements found in signal repertoires in the proximate environment of developing individuals, given our genetically inherited generative grammar and syntax. Something comparable may be the case for other animals, such as songbirds and killer whales, for which acoustic signal repertoires seem to be socially transmitted (Brainard & Doupe, 2002), and do not “evolve in absence of an acoustic template” (Filatova et al., 2015b, p. 2009).

3.2.1. Might there be an orca syntactical symbolization faculty as a counterpart to the human FLN?

If orca vocalizations really exhibit syntactical structuring at both the phonological and the morphosyntactic levels and the novel combination of vocal symbols according to grammatical rules, even in limited and simple ways compared to human speech—which is of course far from certain but at least suggested from what we know or believe about orca vocalizations—might this not be explained in a manner comparable to the way Chomsky explains the syntactic structuring of speech?

Employing something close to Chomsky's own reasoning, we might hypothesize that killer whales have an inherited, genetic, *syntactical symbolization faculty*, at least distantly analogous to the human internal language faculty (that Hauser, Chomsky & Fitch (2004) call “FLN”), that although surely not the same as the narrow language faculty in humans, could provide a basis for accomplishing some of the same things, such as thinking and planning.

This faculty might have first arisen as an internal ability to structure, combine and restructure meaningful symbols that afterwards supported systematic symbolic externalization by becoming coupled to a system of vocal expressions, in consequence assigned to “sensory data in perception” (cf. Chomsky, 2010, p. 1), and resulting finally in what might be called a *symbolic vocalization faculty*.

As we have seen, killer whales organize sounds into a variety of sequences or combinations, and seem to have the ability to make complex structures out of simpler ones. Their vocalizations evidently show, albeit in small measure, some of the syntactic aspects and plasticity of human speech—more so than the vocalizations of most other vocalizing animals. This complexity and diversity makes such an hypothesis plausible.

3.2.2. The issue of recursion

The recursiveness of the generative grammatical function has been considered to be a distinctive attribute of human language, “shared by no other animal system” (Tallerman & Gibson, 2011, p. 2.). On Chomsky’s account of language, the computational operation central to FLN is, hypothetically, the maximally simple recursive operation Merge. This hypothesis is well tested and supports the computational biolinguistic account. The hypothetical counterpart of FLN for orca vocalization is what we called the *orca syntactical symbolization faculty*. If we attempt to develop accounts of non-human animal vocalization that are counterparts to Chomsky’s account of language and speech, then, first, this will be appropriate only for species whose vocalizations exhibit some measure of syntactic structuring and plasticity; second, will be species specific; and, third, will arguably place the species-specific counterpart of FLN within a plausible counterpart of FLB.

Nothing says that the hypothetical counterpart of FLN, which will be understood as a computational “module”, must be based upon a recursive operation, and certainly not upon Merge. Such would be the case if—accepting Chomsky’s account of language—our objective were to attribute language to non-human animals; but it is not. We are at this stage only supposing (in a Chomsky-esque fashion) that, if a vocalizing animal species exhibits some degree of syntactic facility in its employment of vocalizations, there must be some heritable computational competence in those animals that accounts for the syntactic structuring. One can then investigate whether, and to what extent, this competence functions spontaneously from birth (like vision) or is acquired or shaped in the course of development (through experience or training), and whether it is a discrete competence (a “faculty”)—this is what Chomsky thinks about language—or whether it rather represents a subset of the combined activities of other competences. It appears to us that only considered as a discrete competence does it make sense to speculate as to how and when “it” evolved.

Sticking with the (highly uncertain but potentially fruitful) hypothesis of an orca counterpart of FLN—an *orca syntactical symbolization faculty*—we do not see that it would need to be based upon an unbounded recursive operation, whether Merge or any other. The question would be about the sort of operation(s) that could account for the observed syntactic vocalization competences of orcas, which appear to be limited in comparison with those of humans. If this could be accomplished by means of a different, more limited, operation or set of operations, then that would suffice for the purposes of the intended explanatory account.

On the other hand, it may be the case that at least some non-human animals do syntactically structure and re-structure some subsets of their vocalizations (or gestural equivalents) according to recursive rules.

Suzuki, Wheatcroft and Griesser (2017) found that Japanese tits (*Parus minor*) could “extract a compound meaning from novel call sequences using an ordering rule” (p. 2331). The birds were able to interpret such meanings, and responded to novel calls when they were played in a specific order. These results do not mean that the birds have an ability to produce an unlimited variety of call sequences from a limited number of components, but it tells us that the birds are not limited to understanding a fixed repertoire and can construct compound meaningful utterances out of meaningful vocal components, and interpret such constructed utterances using a rule of compositional syntax. These are wild birds, and no training—but perhaps some learning in natural conditions—was involved. The lexicon is small and the constructions studied consisted of no more than two elements. It is unknown whether the lexicon could be expanded or the rule be reapplied to yield longer expressions, but the syntactic rule works as a recursive rule would work in a highly restricted domain. The authors themselves remark in a later article that:

All reported known cases for meaningful call combinations in animals involve only two meaningful units. Therefore, meanings are linearly connected within a sequence. By contrast, human language can be hierarchical [given the parameters of the combinatory syntactical operation, Merge]. Future investigations are required to explore whether recursion is truly unique to human language and whether the hierarchical structure of meaningful elements can be observed in animals. (Suzuki, Wheatcroft and Griesser, 2019, p. 6)

Hauser et al (2012) discuss studies that make claims of the use of recursive syntactical operations by songbirds (Gentner, Margoliash, & Nusbaum, 2006; cf. Abe & Watanabe, 2011) and baboons (Rey, Perruchet & Fagot, 2011). Referring to Hauser, Chomsky & Fitch (2002) and Fitch, Hauser & Chomsky (2005), Gentner, Margoliash, & Nusbaum (2006) write:

Recent hypotheses make the central claim that the capacity for syntactic recursion forms the computational core of a uniquely human language faculty. Here we show that European starlings (*Sturnus vulgaris*) accurately recognize acoustic patterns defined by a recursive, self-embedding, context-free grammar. They are also able to classify new patterns defined by the grammar and reliably exclude agrammatical patterns. Thus, the capacity to classify sequences from recursive, centre-embedded grammars is not uniquely human. This finding opens a new range of complex syntactic processing mechanisms to physiological investigation (p. 1204).

While Rey, Perruchet & Fagot (2011) write that:

Influential theories have claimed that the ability for recursion forms the computational core of human language faculty distinguishing our communication system from that of other animals (Hauser, Chomsky, & Fitch, 2002). In the present study, we consider an alternative view on recursion by studying the contribution of associative and working memory processes. After an intensive

paired-associate training with visual shapes, we observed that baboons [*Papio papio*] spontaneously ordered their responses in keeping with a recursive, centre-embedded structure. This result suggests that the human ability for recursion might partly if not entirely originate from fundamental processing constraints already present in non-human primates and that the critical distinction between animal communication and human language should more likely be found in working memory capacities than in an ability to produce recursive structures per se (p. 180).

Hauser et al (2012) are dismissive of these claims, as they understand them. They write that these and similar studies:

. . . focused on the problem of embedding, virtually all used methods of extensive training, and all mistakenly equated embedding with both recursion and the claim that any evidence of embedding would rule out earlier claims of human uniqueness. [I]n one study of starlings and one on baboons, subjects were trained for months in tens of thousands of reinforced trials to learn a pattern of embedding that was comparable to that tested on tamarins. Both species learned this pattern, with limited generalization to novel patterns. The researchers concluded that recursive computations are not unique to humans, and so our competence can be explained by non-linguistic processes. For at least four reasons, however, these results do not inform our understanding of human language competence: (i) recursion, as realized in the language faculty, is a set of properties defining the generative procedure, not its output, and so should not be equated with embedding . . . (ii) human language acquisition does not involve training with reinforcement; thus, even if the results showed parallel competences, the acquisition process and underlying computations would be entirely different; (iii) even if animals can process embedded structures, the generalization results show that the capacity is limited to the training level, and pales relative to human competence, especially if one removes some of the working memory constraints; (iv) as the Chomsky hierarchy perspective reveals, embedding is far too weak to explain human language competence, and thus, even strong evidence in animals would contribute little to our understanding of human language evolution. (p. 5)

These criticisms all have a point but in certain respects miss the mark. Concerning (i), it is not clear that the authors criticized equate recursion with embedding; rather their claim seems to be that the embedding is accomplished by a recursive operation “wherein two sentences, a_1b_1 and a_2b_2 , each composed of two ordered elements (a and b representing the first and second element, respectively) are two objects already constructed” that are put together by this operation into the “sentence $a_1a_2b_2b_1$ ”, a_2b_2 becoming “embedded” between the two elements of a_1b_1 . “An example of such embedding in English is ‘The antelope [a_1] the lion [a_2] ate [b_2] ran like a snail [b_1]’” (Gentner, Margoliash, & Nusbaum, 2006, p. 180). The authors’ inference that their primate subjects were applying the same syntactic operation as a human speaker of English may be weak, but they are not equating recursion with embedding nor the generative procedure with its output. Point (ii) is certainly correct; but is it relevant? The assumption is that the authors criticized are trying to show that since the competences of birds and baboons are (as Hauser et al seem to admit) “parallel” to those of humans, the “acquisition process and underlying computations” must be the same. But this

is surely not claimed for the acquisition process, and it is nowhere claimed that the underlying computations are the same, only that they are similar, in the sense of being recursive. As for (iii), admitting that even if animals can process embedded structures, “the generalization results show that the capacity is limited to the training level, and pales relative to human competence” reveals the assumption that the authors criticized claim or imply that their birds and baboons have general syntactic competences approaching those of humans; but no such claims are made: if anything, those authors speculate as to why, if their subjects can use recursive processing (which they do claim, at least tentatively), their competences do *not* approach those of humans. And finally, as to (iv), it assumes that the authors criticized suppose (a) that embedding “explains human language competence” and (b) that their findings contribute substantially “to our understanding of human language evolution”; but these authors suppose neither. What is virtually their sole contention is that non-human animals can employ a recursive syntactic operation to generate new grammatical objects (“symbols”, “structures”, or even “sentences”) out of pairs of such objects, given a rule of compositional syntax. That remains as the principal point about recursion that is of interest to us here in connection with orca vocalizations.

Finally, after having looked at studies involving birds and social primates in this discussion of recursion, we move in closer to home. Bottlenose dolphins, another member of the delphinid family, showed comprehension “for all of the sentence forms and sentence meanings” of an artificial language “that could be generated by the lexicon and the set of syntactic rules” that were presented to them in a 1984 study (Herman, Richards & Wolz (1984, p. 129). Without specific instruction, a dolphin performed two tasks indicated to it in a conjoined sentence. The dolphin usually responded by performing both of the tasks in the order that the two sentences were conjoined, but, the dolphin also executed the tasks in reverse order, performed either one of them, and in one case repeated them both twice. And in one case, the dolphin combined the tasks into a conjoined response; when being given the sentence: “PHOENIX BASKET TAIL-TOUCH PHOENIX BASKET UNDER”, the dolphin touched “the basket with her tail flukes while in an inverted position”. It also spontaneously responded “appropriately to the linking of actions” in structurally novel sentences. (p. 187). Herman et al. (1984) wrote that since the dolphins understood *modifiers* in these sentences, this, in principle, could allow for sentences with an unbounded number of words by adding modifiers before an object name.

But why “in principle”? It is significant that, as we saw noted above by Suzuki, Wheatcroft and Griesser, (2019), “All reported known cases for meaningful [syntactic] combinations in animals involve only two meaningful units.” (p. 6) Assuming this as a general truth until such time, if any, as it may be shown to be false, this might indicate that non-human animal syntactic computation is based upon a compositional operation that can merge two non-composite elements into a composite structure but cannot merge composite structures with anything. Whether this is even a possibility is unclear, but if such *were* the case, then this operation would not be iterable, and hence not recursive. It would still provide an animal with a certain amount—albeit limited—of compositional syntax. But it would not mean, for instance, that a creature that could generate a new sentence from a given sentence by applying a modifier could, even in principle, produce sentences with an unbounded number of words by adding modifiers before an object name. At the other end of the possibility spectrum, so to speak, the heretofore observed two-unit limitation would be compatible with non-human animals having the recursive operation Merge available for syntactic computation but being unable to utilize it because of, for example, paucity of working memory—the latter suggestion, as we saw, was made by Rey, Perruchet & Fagot (2011), but

pooh-pooed by Hauser et al. (2014) in response (although they themselves make related remarks in both Hauser et al. (2002, pp. 1570 & 1577) and Hauser et al. (2014, p. 5)). If a recursive operation like merge were available, but not useable, one could say that, “in principle”, an animal could generate sentences with an unbounded number of words—say by adding modifiers before an object name—but, alas, not in practice.

A complication, which cannot be followed up here, is that Herman et al. (1984) were studying their dolphins’ ability to *understand*, but not to generate, sentences that were lexically or structurally novel. It is not clear that the two-unit limitation applies to comprehension as to syntactic generation. Herman et al. (1984) remark (p. 194) that:

Premack (1976) could find no evidence for the *production* of structural novelty by his apes, a point emphasized by Fodor et al. (1974) in their critique of the accomplishments of the chimp Sarah. However, Premack (1976, p. 15) does report that the chimpanzee “can *comprehend* five or six sentence forms structurally different from any on which it was trained” (italics added).

But how important is recursion, that is, the ability to produce and comprehend an unlimited number of combinations constructed out of simpler elements, *for the purposes of symbolically mediated thought and vocally mediated communication, planning, social organization, and coordinated action*? Surely, in any organism, the extent of the flexibility, creativity, and variety of syntactically structured symbolization and vocalization that is required for such purposes is limited by the physical, developmental, and psychological make-up and capabilities of the organism and what can be done with these in the environment, or environmental niches, in which the organism lives. The natural gifts of our species that enable us to extend our physical, developmental and psychological capabilities by artifice and technology and to modify our natural environment to an extent unknown to any other organism are what creates a space of utility—and arguably, of evolutionary advantage—for recursively generated language (internal and external). Even so, we could probably do with generative principles that were not unlimited in their creative scope. And it is not even certain that, even with recursive generative grammar, the creative scope of language is unlimited *functionally*; in fact, it is unlikely that it is.

A lack of recursion in non-human animals, does not need to imply the inability to engage in such things as vocalization-mediated cooperative planning, making new structures out of existing structures, describing novel situations, as well as having two-way vocal “conversations” that are not simply stereotyped and might include the ability to describe previously undescribed things to conspecifics and be understood by them. Perhaps even lacking recursion, the killer whale symbolization faculty might yield the capacity for thought, organizing action, interpretation, planning, creativity, and the externalization of internal symbols and their assignment “to sensory data in perception” (Chomsky, 2010). If the number and variety of possible combinations of call and whistle sequences is large or open-ended enough, the various things that human language is supposed to allow *Homo sapiens* to achieve, might still be achieved to the extent that the physical and psychological make-up of the organism, and its marine surroundings, allow without the symbolic function being based upon a recursive syntactic operation.

3.3. Semantic aspects of vocalizations

It is hard to imagine that orca vocalizations lack semantic content: the pairing of a sign (in this case sound) with meaning (Hauser et al., 2002). It seems at least unlikely that all of the complex sounds would just be made without any meaning behind them, or that they would all be comparable to such behavior as singing in humans. But do vocalizations have meaning in somewhat the same way human language does; can they be used to describe things? Or are vocalizations signals without specific meaning? And do the meanings of call sequences depend on both the “meanings of the component calls and their syntactic order”, as in phrases or sentences of human language? (Suzuki, Wheatcroft & Griesser, 2019, p. 1)

If the hypothesis that orcas have an inherited, genetic, *syntactical symbolization faculty* is rendered plausible in the light of our survey of orca vocalizations. And if its generated internal symbols are externalizable by becoming coupled to vocal expressions assigned to “sensory data in perception” (cf. Chomsky, 2010, p. 1)—or other contributions of whatever sort of conceptual-intentional module that an orca might have, yielding syntactically structured *symbolic vocalizations* that are not wholly stereotypical—then doubt is cast upon the degraded view of the semantics of non-human animal vocalizations shared by Chomsky and many of his collaborators insofar as it is applied to relatively complex and sophisticated vocalizing organisms, such as orcas.

But, according to Hauser et al. (2014), the sounds [and evidently also gestural externalizations] of killer whales and other non-human animals “refer, at best, to directly observable objects or events, with great uncertainty about the precise meaning, and no evidence for signals that map to abstract concepts that are detached from sensory experiences” (p. 4).

Such is, however, not the view of C. R. Gallistel. Gallistel is an oft-cited favorite of Chomsky’s, yet his work is not discussed in either Hauser et al. (2002) or in Hauser et al (2014) and is referenced only once, in passing, in the former. In Gallistel (2011), “Prelinguistic Thought”, he writes, strikingly:

I review evidence from the animal cognition literature suggesting that the construction of abstract representations that support complex inferences is widespread. It is found even in insects. This widespread symbol processing capacity supports the construction of complex data structures (symbolic propositions). In vertebrates at least, there is evidence that the representation of actions takes the predicate-argument form characteristic of human language. Thus, the symbol processing capacity underlying the thoughts expressed in human language appears to be evolutionarily ancient. What is unique to humans is the ability to translate these private representations into a communicable symbol system of comparable representational power. . . . Chomsky (1988) has suggested that both language and the capacity for abstract thought rest on the evolution in humans of a computational capacity that is absent in nonhuman animals. Language and abstract thought may, for example, be manifestations of a uniquely human capacity to construct symbolic structures by recursion (Hauser, Chomsky, & Fitch, 2002). . . . I argue that findings in the animal cognition literature suggest that species with which humans have not shared a common ancestor since the Cambrian era represent the experienced world at a high level of abstraction. Their

behavior is routinely informed by complex inferences drawn from these representations. These nonlinguistic representations appear to involve symbolic structures, that is, multiple symbols stored in memory in such a way as to encode experienced relations among the entities to which the symbols refer. Actions appear to be represented as functions (predicates) that have arguments (i.e., agents, objects) as to-be-bound variables, just as do verbs in spoken language. (pp. 253-254)

Hauser et al. (2002) agree that “A wide variety of studies indicate that nonhuman mammals and birds have rich conceptual representations . . . Studies using classical training approaches as well as methods that tap spontaneous abilities reveal that animals acquire and use a wide range of abstract concepts, including tool, color, geometric relationships, food, and number.” But these remain almost entirely “internal”:

. . . there is a mismatch between the conceptual capacities of animals and the communicative content of their vocal and visual signals . . . For example, although a wide variety of nonhuman primates have access to rich knowledge of who is related to whom, as well as who is dominant and who is subordinate, their vocalizations only coarsely express such complexities. (p. 1575)

Gallistel agrees that there is a “mismatch”; but, as we shall see in the next section, he argues that it is nevertheless the case that non-human animals may succeed in externalizing, and communicating to conspecifics, abstract thoughts and inferences, some of which rest upon shared knowledge that has been acquired by abstracting from complex environmental contingencies. If he is correct, then, put in terms of Chomsky’s account of language in the wider sense—that is, comprising the whole of FLB, which includes FLN—the implication is that species-specific conceptual-intentional systems have long been present in those non-human animals to which it makes sense to attribute systems of that kind. We do this for orcas, and Gallistel does it “for vertebrates at least”, and even insects, although they are all pre-linguistic. Moreover, on Gallistel’s view, that kind of system as it exists in “higher” non-human animals, and perhaps many others, is much more like the human conceptual-intentional system than has generally been imagined.

Gallistel says in conclusion:

It would appear that animals have represented the experienced world at a highly abstract level in a richly structured symbolic system for eons and that the human infant is heir to this powerful and versatile representational system. What is unique in humans is the machinery for mapping what they represent in the privacy of their own brain into a *communicable* system of symbols of similar power and versatility to the private system. In that, the human far outstrips the bee. (p. 260)

And no doubt the killer whale. Nonetheless, if Gallistel’s picture is correct, and if our hypothesization of an orca *symbolic vocalization faculty* is on anything like the right track, then we may view the killer whale as a creature that understands the world in which it lives, which is a social world, a world of conspecific vocalization, a world inhabited by other creatures besides killer whales to which it must relate in various ways, and a world which it conceptualizes, symbolizes, and reasons about in some fashion. Gallistel maintains that an

orca would have much to talk about, if only it had “a *communicable* system of symbols of similar power and versatility to the private system”. But there, orcas fall short, as do other non-human animals. However, falling short, even very short, does not mean failing completely. And moreover, each species that finds itself in this position falls short *in its own way*. Or so Gallistel argues.

Evidently, then, orca vocalizations—or a significant proportion of them—have semantic content. In the study mentioned earlier, Herman et al. (1984), bottlenose dolphins, cousins of the killer whales, were able to learn the syntax and lexicon of an artificial language, including which whistles refer to which objects. Being able to understand what a signal refers to does not seem to be a rare feature in animals; killer whales may be kept in pools and trained to do certain tricks when they are given a certain sign, and this is something that a dog for example can also learn. It is a different question however, whether an animal like the killer whale actually uses signals that refer to something specific to communicate with their conspecifics. Bottlenose dolphins actually do use signature whistles as individually distinctive tags or “names”, for themselves and each other (King & Janik, 2013). They seem to transmit and understand identity information from the structural characteristics of a sound, “independent of the signaler’s voice or location” (Janik, Sayigh & Wells, 2006, p. 8295). However, there is as yet no evidence of killer whales using individual signatures.

Although a similar feature has not been observed in killer whales, Ford (1991) suggests that variations in the standard format of a call are individualized and depend on the context, likely conveying “information about the identity and behavior state of the vocalizing animal, as do changes in the frequency of use of different calls” (p. 1480). Ford also speculates that certain calls may refer to certain activities or “specific features in the environment (as in some primate vocalizations)” (for references to primate studies see Ford, 1989, p. 742), although no sound was associated exclusively with a particular context. Vocalizations likely also express (and therefore refer to) at least some basic emotions, such as fear, joy, anger and pain. Even a dog that has very simple ways of vocalizing, is capable of expressing fear and pain by squealing, joy by barking and anger by growling. These are ways for an organism to respond to their environment that aid the organisms survival.

There likely is an interrelation between how structurally complex and variable a signal is, and how much information that signal can potentially carry. Riesch et al. (2008) write that the ability to combine stereotyped vocal signals into longer specific sequences of signals “increases the range of information that can be transferred between individuals” (p. 1822). For example, modulations, recombinations and frequency of call use, may change the meaning of vocalizations for the animals. Calls seem to become less stereotyped at close-range and during socializing (Ford, 1989), and more stereotyped at a longer range when maintaining contact. At close proximity, vocalizing behavior includes more of combining stereotyped calls into longer sequences and altering them through modulation. This could indicate that more information is transferred or that the information changes. (Thomsen et al., 2002; Riesch et al., 2008).

Finding out what calls “mean” can be a challenge. For example, during brief capture for the purpose of tagging, five killer whales produced highly variable calls, and “most individuals produced more than one call type” (Van Parijs, Leyssen & Similä, 2004, p. 558). It is difficult to say whether these were general signals of distress, warning signs for others, or whether they communicated specific information to the group on the context and situation of capture. Killer whales might use vocalizations to construct meanings in a very different way to how

humans do with language. For example, a multiloop, i.e. a repetition of the same call type (Riesch et al., 2008), may have the same meaning or a different meaning every time it is repeated, or the whole multiloop may have an independent meaning, depending on how many sequences it contains.

It is possible that the semantic features of calls and whistles are indistinguishable from the functions of vocalizations, in other words, that sounds function to accomplish something but do not refer to anything specific. For example, if the sounds of killer whales have meanings, a certain kind of whistle or whistle sequence could mean something like “come here”, or “food”. But it is also possible that vocalizations do not have a semantic aspect in this sense. And some signals are probably used more as tools, for example, echolocation clicks that are used for observing the environment, and the “herding call”, a specific kind of pulsed call, which is produced by killer whales in Iceland and Norway “to manipulate herring into dense schools during feeding” (Filatova et al., 2015b, p. 2012; (Simon, Ugarte, Wahlberg & Miller, 2006).

Hauser et al. (2014) argue that with a few exceptions, individual animals “only produce single utterances or gestures, never combining signals to create new meaning based on new structures”, and there is “no evidence of complex syntactic composition derived from an inventory of discrete morphological elements” (p. 4). Whether or not killer whales are the exception Hauser et al. (2014) are referring to (it is likelier birds), combining signals seems to be a very important aspect of their vocalization, and they seem to combine discrete morphological elements, as may be seen from our survey of orca vocalizations. We do not know of course whether these combinations are based on shared rules, and what shared rules would even mean in the case of killer whales. But the sequences of vocalizations that killer whales produce, may not be linear sequences made up of pairings of sound and meaning. Instead, vocalizations could be interpreted as the feelings they evoke, or only have an interpretable meaning when given in full sequences. We will revisit this topic further on, in relation to the question as to how orca vocalization might have evolved.

4. Functional aspects of orca vocalizations

Killer whales use acoustic signals in remarkably diverse ways. And we must survey, at least selectively, some of the functions of killer whale vocalizations in their interactions with one another and with other aspects of their environments. What do vocalizations accomplish for killer whales? When coordinating behavior for example, are whistles or calls used as signals or instructions? For instance, does an individual make a sound to inform others of its presence and (physical) position in the group? Or can a killer whale individual instruct its conspecifics by telling them what to do, in a certain situation, like during foraging or hunting?

Understanding trait functions is central to understanding the evolution and development of a trait, because function can explain at least in part why a certain trait has evolved. The functional perspective for studying communication in organisms consists in “[l]ooking at a trait in terms of its effects on survival and reproduction”, in Hauser’s words (Hauser, 1996, p. 2), a very Darwinian view. Here, we will broaden the approach to include the effects of the vocalizing trait upon socialization and cooperative behaviors, because the level of complexity of vocalization, and the social structure of killer whale communities, suggests that much of social organization, cooperative action, and pod dynamics is (at least in part) vocalization-mediated. Vocalization, like language, is a phenotype that exists in the nexus of the organism and the environment and involves selection across generations and plastic responses within generations. In the present section, we will also list the behavioral categories used to study the function of vocalization.

In any species, interpreting the functions of acoustic signals “requires information on the social and environmental contexts in which the sounds are used” (Ford, 1989, p. 727). Specific vocalizations must be distinguished by their temporal emission pattern from the other vocalizations that the animal produces (Riesch et al., 2008). When humans learn, we also learn through context, but the context may only be interpreted from the other things that are said, and may not in any way be apparent from the behavioral context of what is said.

There can be great differences in vocalizing between social and behavioral contexts (Ford 1989). But vocalizations may not be very strictly determined in relation to immediate contexts, or at least general contexts that we are able to interpret and distinguish from the outside, without understanding the context of a call in a very detailed way. Changes in vocalizations can happen “without any obvious change in behavior” (Ford, 1989, p. 733), as well as occur in a variety of behavioral contexts (Filatova et al., 2015b, p. 2011). Most calls in a pod’s repertoire “are produced in every behavioral circumstance in which the pod is alert and active” (Ford, 1991, p. 1480). Only a few sounds have been linked to specific activities, such as “the herding call”, as well as “excitement calls”, which have a certain kind of modulation pattern, and seem to be used by killer whales in high-arousal states, such as aggressive behavior (Filatova et al., 2015b, p. 2012).

4.1 Communicative vocalization

One of the most basic functions of human speech—spoken language—is that of conspecific *communication*. We can recall Gallistel’s recently quoted conclusion that “What is unique in humans is the machinery for mapping what they represent in the privacy of their own brain into a *communicable* system of symbols of similar power and versatility to the private system. Hauser et al. (2002) and Hauser et al. (2014)—both have Chomsky as a co-author—speak of human language as little else than a system for communication; rather oddly, since Chomsky said and wrote in 2011 (in “Language and the Cognitive Science Revolution(s)”, a lecture given at the Carleton University, April 8, 2011) that “you can use language for communication, you can use other things for communication, most language use is not for communication. So, they’re just different topics.”

Few would deny, however, that even if “most language use is not for communication” that communicating is one of the most central functions of human language and speech. However, it is unusual to be informed as what exactly is meant by *communication*; the meaning of the term varies from author to author and context to context, without announcement. For the purposes of our discussion, we need to specify what we will mean in this place by *communication* if we want to ask seriously whether orca vocalizations include communicative utterances.

Like many theorists, Chomsky often gives the term communication a rather thin meaning.

The language faculty is often equated with “communication”—a trait that is shared by all animal species and possibly also by plants. In our view, for the purposes of scientific understanding, language should be understood as a particular computational cognitive system, implemented neurally, that cannot be equated with an excessively expansive notion of “language as communication”. Externalized language may be used for communication, but that particular function is largely irrelevant in this context. Thus, the origin of the language faculty does not generally seem to be informed by considerations of the evolution of communication.

A communicative utterance for him often seems to amount to nothing more than a vocal signal to which a conspecific auditor would normally, or typically, respond in a certain way. (The restriction to conspecifics is for the sake of simplicity only in the present context.) An avian mating song that functions as an attraction signal would be an obvious example; and both in our earlier survey and our discussion later in this chapter provide many examples of orca vocalizations that are communicative in this sense.

There is nothing wrong with this thin notion of communication. However, we propose here to use as well a rather thicker notion of communicative utterance, one that is useful in connection with Gallistel’s discussion. Without attempting to give an overly refined account, we will say that a communicative utterance is one that symbolically expresses a thought, representation, or understanding of the utterer—what the utterer “represents in the privacy of its own brain”, in Gallistel’s language—and transmits it to a conspecific auditor. What differentiates Gallistel from many other biolinguists is that, for him, there *is* something that an utterer represents in private, call it a “thought”, which may be even an abstract thought, that could possibly be transmitted to an auditor through symbolic vocalization in such a way

that the auditor would understand what is communicated; and this is so for non-human communicators as well as humans. What he thinks that non-humans lack, as we saw, is a robust machinery for mapping their thoughts into a communicable system of symbols. But they may have *some* machinery.

Even bees, with their very tiny brains, have some machinery, although they are not vocalizers. They communicate by dancing: performing the so-called wagggle dance”, which has been investigated by Gallistel, among others. Gallistel’s findings, or more precisely his interpretation of them, is remarkable. Although Gallistel (2011) is in large part devoted to bees, that are non-vocalizers and in countless ways different from killer whales, the relevance of what Gallistel has to say to our unfolding discussion of orca vocalizations and the topic of communication justifies adding to what we have already related; and as there is evidently no better, or quicker, way of doing this than quoting selectively from Gallistel’s text, it is hoped that the reader will tolerate a long quotation without losing the thread of our discussion. What we count as points of emphasis are italicized. Here is some of what Gallistel says about what bees communicate (in our thick sense) through the wagggle dance, and what lies behind it (Gallistel, 2011 pp. 254-257; italics added):

A major function of language is to locate events in space and time: “here,” “there,” “then,” “now,” and “soon.” *The abstract representation of space and time is broadly spread among the animalia.* Commonly studied species of birds and insects navigate in part by dead reckoning, which is the real-time estimation of one’s position by integrating one’s velocity with respect to time. In its most basic form, this is not a complex computation. . . . There are substantial measurement challenges in implementing this computation because the result depends critically on the accuracy of the speed and direction estimates. . . . That said, *it is hard to see how it could fail to be a symbolically mediated activity of the brain.* The essence of the activity is the adding (in the arithmetic sense) of symbols for one’s most recent displacement (change in position) to the symbols that represent one’s earlier estimate of position. . . . The locus of neural activity is taken to represent location, speed, and direction. These loci of activity are unequivocally symbols; that is, they refer and they are operated on to generate other loci of activity that also refer.

Dead reckoning requires a means of determining compass direction (direction relative to the earth’s axis of rotation). Many animals, including bees and birds, prefer to use the sun for this purpose. The sun is so far away that its compass direction does not change as the animal moves. However, its compass direction changes continuously throughout the day as the earth rotates. To use it as a directional referent, *an animal must know the solar ephemeris, that is, the direction of the sun as a function of the time of day. The local solar ephemeris is a spatio-temporally contingent aspect of experience; it varies as a function of both latitude and time of year, so it must be learned.*

The learning of the solar ephemeris by bees has been studied using brooder-reared bees whose life-time experience of the sun’s location can be experimentally manipulated. The results illustrate two of Chomsky’s most influential contentions . . . : the poverty of the stimulus in learning and the resulting necessity for problem-specific structure in learning mechanisms . . . Bees that have seen the

sun only in the late afternoon when it is declining in the west represent it as being in the east in the morning. Bees in Germany represent the sun's direction at midnight as due north, although they have never seen the sun in the north nor at midnight. Thus, *what bees learn from their limited experience of the sun's direction at different times of day—a complete 24-hour solar ephemeris—transcends what is justified by their experience (the poverty of the stimulus)*. Bees (and very likely other animals) appear to have a genetically specified parameterized function that embodies what is universally true about the solar ephemeris (it has a 24-hour period and is in the east in the morning and the west in the afternoon). The values of the parameters of this function are adjusted on the basis of minimal experience with the location of the sun relative to local terrain features at a few different times of day. This explains the extreme rapidity with which bees learn this complex function. *They do not learn the function itself; they learn only values for its parameters. The inherited function plays the role that the universal grammar plays in Chomsky's theory of language acquisition.*

A solar ephemeris function represents the direction of the sun relative to some local terrain features as a function of the time of day. *This would seem to require what computer scientists call data structures, which I take to be what linguists and philosophers call symbolic statements. In both cases, there are symbols referring to different aspects of the experienced (or potentially experienceable) world.* The arrangement of the symbols encodes relations between the referenced aspects of experience.

Foraging bees communicate to their fellow foragers the compass direction and distance of a rich food source from which they have just returned. They do so by means of a “dance” performed on the vertical surface of the comb, inside the hive, out of sight of the sun . . . The dance is in the form of a figure 8, the key component of which is the wagging run through the central link between the two loops. The angle of this waggle run with respect to vertical symbolizes the direction of the source relative to the sun, while the number of waggles symbolizes its distance from the hive. *This communication relies on the bees' shared knowledge of the solar ephemeris.*

[I]t is probably more accurate to say that what the bee dance communicates is not compass direction and distance but rather map coordinates. The navigation of ants and bees depends on both dead reckoning and piloting. Piloting is navigation by reference to recognizable landmarks (Gallistel, 1990). It requires the encoding of landmark appearance so that a terrain feature may subsequently be recognized, and location so that the recognized landmark may be used to estimate the location of points of interest remote from it. At least two recent experiments give reason to believe that the different points of interest (e.g., food sources) and salient terrain features that may be used to locate them *are arranged on a cognitive map and that the information conveyed by the dance of a returning forager specifies a point on this map (that is, map coordinates).*

Menzel et al. . . . taught selected foragers to come and go from one source, then had them observe the dance of another forager returning from a different source.

When the selected foragers subsequently found the previously visited source empty, they flew directly from it to the location they knew of only secondhand (from the dance of another forager), but only when the angle subtended by the rays from the hive to the two sources was below some critical value. This result has three important implications: 1) Bees attending the dance of a returned forager locate the indicated location on their map; 2) bees can set a course from any location on their map to any other; and 3) in doing so, they take angles and distances between possible destinations (hive or other source) into account. *These latter quantities only arise when they consider the relations between two or three locations recorded on their map at different times in the past.*

Many of Gallistel's views as expressed here are controversial. Nonetheless, they are based upon what appear to be sound studies by himself and others and are plausibly argued. Accepting as a working hypothesis Gallistel's analysis of what makes bee communication possible through the waggle dance, it would be hard to imagine that orcas could not have thoughts or representations—some of them abstract—that they have some possibility of communicating through symbolic vocalization. As implied in Chapter 2, such communication would be mediated by our hypothesized *orca syntactical symbolization faculty*, at least distantly analogous to the human FLN (hypothesized by Chomsky) and providing an underpinning for our hypothesized *orca symbolic vocalization faculty*, at least distantly analogous to the human FLB (likewise hypothesized by Chomsky). We repeat that the analogies are very distant, and we make no claim that orcas have language or speech. But the distance of these analogies does not mean that they cannot be instructive.

4.2. Some behavioral functions of orca vocalizations

Orca communicative vocalizations in both the thinner and thicker senses of “communicative” generally serve functions other than communication that, however, depend upon the communicative vocalizations. And in the case of other vocalization-mediated functions, the vocalizations may not be communicative, in either sense. And last but not least, various functions may depend upon communications that are non-vocal: gestural communications for instance (as in human signing).

Many killer-whale studies aim to understand the function of vocalizations by associating calls with behavioral categories. Listed below are the some of the behavioral categories mentioned in the literature, in no particular order, with notations about what is said about vocal behavior during these behaviors. Most studies have paid attention to only a few of these categories; for example, slow-travel is always not distinguished from travel. Some of the behaviors that are described may also overlap.

4.2.1. Slow-traveling

Dive sequences are synchronized, and the animals move in the same direction at a speed of 3–6km/h (Deecke et al., 2005).

4.2.2. Socializing

The animals show social displays such as “swimming on the back, rolling over each other, flipper and fluke slapping [and] breaching” (Filatova et al., 2013). Animals chase each other and thrash together at the surface. Sexual interactions, belly flops, and dorsal-fin slaps are common. Individuals may also play with inanimate objects or ride the wake of passing vessels. Ford (1989) reports that “[m]ost of these activities were especially prevalent and vigorous among younger whales” and that “[a]dults often milled slowly or rested in the vicinity of socializing juveniles” (p. 732). Saulitis et al. (2005) observed that 73% of vocalizations occurred during socializing, a majority of those being whistles, and that whistles were never heard from lone whales. Ford (1989) reported an increase in variable and aberrant calls during socializing activities, and that whistles were “heard in direct proportion to the amount of socializing activity in the pod” (Ford, 1989, p. 741). Saulitis et al. (2005) also found that two pulsed calls were emitted significantly more often during socializing than during other behaviors.

Whistles emitted during socializing could be expressions of emotion such as joy. Even if this is done symptomatically, it could still have a descriptive element to it. For example, in humans, joy is usually not expressed out loud unless there is someone to hear the expression. And when another person is present, one might let out a shriek of joy to inform another person of this emotion, even if the one expressing joy is not consciously thinking “I will now express to this other person that I am joyous”. When young killer whales whistle while playing, they may communicate something specific to each other about the situation, or the whistles could also be similar to the screams small children let out when they chasing one another while playing for example.

4.2.3. Surface-active

During surface activity, whales express frequent physical contact between group members, as well as “occasional aerial and percussive behaviours including breaches, tail-slaps, pectoral slaps and spyhops.” Whales frequently change direction, typically moving “at speeds of less than 6km/h, and do not surface in synchrony”. (Deecke et al., 2005, p. 398). Deecke et al. (2005) observed that vocal rates are highest during this behavior, but did not consider surface-active behavior as socializing, so these two behaviors likely overlapped.

4.2.4. Milling

The animals move at “speeds of less than 3km/h and lack a clear direction. The dive sequences of individuals in the group are irregular and not synchronized and there are no aerial or percussive behaviours”. (Deecke et al., 2005, p. 398). Milling “often occurs during other activities such as feeding on marine mammals, resting, foraging and socializing” (Saulitis et al., 2005, p. 1022).

4.2.5. Traveling

All members of a group move in the same direction at the same speed (Filatova et al., 2013). Swim speeds exceed 6km/h, group members surface in synchrony and the animals are “usually within a few body lengths of each other” (Deecke, Ford & Slater, 2005, p. 398).

Animals tend to be “less dispersed than when foraging” (Ford 1989). Whales that hunt marine mammals tend to stay quiet while traveling, for example, Saulitis et al. (2005) found that traveling transients emitted on average of less than 1.2 calls every 20 minutes. Staying quiet while traveling is a plastic response to the environment and context of transients, in which they need their prey not to hear them.

4.2.6. Foraging and hunting

Killer whales are carrying fish in their mouths, swimming non-directionally, at varying speeds and “with sudden changes in direction” (Filatova et al., 2013). Ford (1989) observed this to be the most common activity. Vocalization is used to achieve successful cooperation during hunting and foraging behaviors (Van Opzeeland, Corkeron, Leyssen, Similä & Van Parijs 2005). Vocal behavior during foraging depends on prey type. Piscivorous whales do not quiet down during foraging (Yurk et al., 2010), but those that hunt marine mammals do, to avoid eavesdropping by potential prey (Deecke et al, 2005). For example, Guinet (1992) observed very quiet short distance contact calls and “a few isolated clicks” from killer whales that were hunting marine mammals. Saulitis et al. (2005) reported that whistles “which have frequencies well within the hearing range of transient killer whale prey” were not heard during foraging.

Whales possibly need to keep making clicks in order to keep track of their surroundings, which would explain the few clicks that Guinet (1992) observed during hunting. The “quiet short distance contact calls” (Guinet, 1992) while hunting could be used, either to give others information like “I hear something”, “I am on this side”. They could also be instructions such as “go faster” or “go slower”. Or, there could be a sound that means “fish” for example that can be used to inform others, when one has either seen or found fish by echolocation.

Icelandic killer whales use a specific pulsed call as a vocal tool in foraging. This call is used to manipulate the schooling of herring, and it is made shortly before an underwater tail slap is given to debilitate the fish. The more herring in a tighter space, the more fish will be debilitated by a tail slap. The low-frequency call is below the optimal hearing range of killer whales, but in the most sensitive hearing range of the herring. (Simon et al., 2006). This adaptive foraging technique is probably passed down to younger generations by teaching it to them, possibly giving them a selective advantage in the long-term.

This kind of flexibility in foraging and hunting behaviors exists, because of the ability to use vocalizations in many different ways and adapt them to changing situations. To achieve the adaptive benefits, behavior often needs to be coordinated, for example, the whole group needs to stay quiet to avoid eavesdropping by potential prey (Deecke et al., 2005).

4.2.7. Milling after kill (typically of a marine mammal)

In addition to regular milling, aerial and percussive behaviors are often present. “This behavior ends when the whales increase their swim speed and move away from the site of the kill.” (Deecke et al., 2005, p. 398). Deecke et al., (2005) reported calls rates to be the second highest after surface-active behavior. It is interesting that after a kill, killer whales do not just eat their prey, but that this behavior includes aerial and percussive behaviors, and high call rates. These behaviors possibly express or “celebrate” excitement and joy about the fact that there is food to eat. They could also be expressions of power, in an “look what I did” kind of way, if a kill has been made.

Deecke et al. (2005) suggest that vocalizations function to delineate “social relationships during the sharing of prey” (p. 403). But is this done by interrupting when one animal is eating too much or when its not yet its turn? For example, older members of the group might have to defend some (possibly younger) group members from others that might be hogging food. Or, are killer whales able to be more specific when they are possibly controlling these situations? We do not know whether killer whales have signature whistles, but if they have sounds for identifying group members, it is possibly that after a kill, the grandmother for example might vocalize something that means “This is for killer whale X”.

In the northeastern Pacific, marine mammal hunting transients have less complex whistle repertoires than piscivorous residents, and they producing whistles only during surface-active and milling after kill-behaviors (Riesch and Deecke, 2011). and producing pulsed calls (Deecke et al., 2005) and echolocation clicks (Barrett-Lennard et al., 1996) significantly less frequently than residents. However, when wanting to find each other, transients use very loud calls (Saulitis et al., 2005). This is an example of a population of killer whales responding to changing environments and context, which likely is beneficial for their survival in the long run.

4.2.8. (Group-)resting

The animals stay joined together “in a tight grouping”, either staying in the same place or moving slowly with “highly regular and coordinated dives” (Filatova et al., 2013). Ford (1989) observed that although the entire pod was usually underwater and at the surface together, “members of maternal subgroups maintained close physical association and tended to coordinate their movements” (p. 732). During resting, killer whales are mostly silent, or sometimes emit a few echolocation clicks” (Filatova, Fedutin, Nagaylik, Burdin, Hoyt, 2009, p. 40). Being silent clearly suggests that the animals are resting or sleeping, and likely emitting some echolocation clicks to stay somewhat aware of their surroundings. Also, is the time and place of resting decided somehow together, or does the matriarch (grandmother) decide this? And is there a vocalization that means “rest”, that a killer whale can make to their group, letting the group know that this now it is time to rest?

4.2.9. Beach rubbing

Animals interrupt their foraging sessions to visit the shoreline and rub themselves on pebble beaches as well as an underwater shelf. During rubbing, the animals dive to the bottom and roll their “lateral, dorsal, and ventral surfaces against the pebble shelves for 0.25 – 1.5min before surfacing again”. This can be “accompanied by resting and socializing among nearby animals.” (Ford 1989, p. 732). During beach rubbing activities, variable and aberrant calls increase (Ford 1989). Since these vocalizations also increase during social events, this could suggest that beach rubbing is something of a social activity.

4.3. The different functions of echolocation clicks, pulsed calls and whistles

Clicks are generally used as biosonar signals in odontocetes (Ford 1989). They are used for detecting information from the environment, predominantly for “sensing objects such as prey in the environment”. The frequency content and source level of clicks seems to vary depending on the type of prey that is being pursued. (Holt, 2008, p. 6). Killer whales also travel and forage “without discernibly echolocating, suggesting that passive listening [also] provides cues for prey detection and orientation” (Barrett-Lennard, Ford & Heyse, 1996, p. 553). Passive listening may also be passive echolocating, in other words using natural echoes in the environment to sense details in it.

In pulsed calls and whistles, there is a lot of phenotypic variation. Discrete, group-specific pulsed calls are the most commonly observed sound type in all long-range behavior categories. Holt (2008) reported that more than 50% of calls were pod-specific discrete calls. At close-range, variable calls and whistles increase (Thomsen et al., 2002).

Pulsed calls are used most often during foraging and traveling, possibly for maintaining social cohesion among pod members, when other sensory information is not available or is lacking (Holt, 2008; Ford, 1989; Miller, 2002). Ford (1989) writes that most discrete calls contained components and features that “enhance their recognizability over long distances and background noise, as well as their potential for accurate localization” (for references to studies discussing noise localization see Ford, 1989, p. 741). Discrete calls “can be intense” and are used proportionally most often “during behaviours where animals are widely spaced out such as traveling and foraging” (Riesch et al., 2008, p. 1822). We do not know whether calls that are used to maintaining contact and social cohesion are signals or whether they have some kind of informational content, like a description or instruction of some kind. Contact calls could similar to car horn, in the sense that even though they function to inform other of one’s presence, the sound itself does not contain any other meaning.

Whistles have a relatively short range of detectability compared to other vocalizations and seem to be the most used sound during close-range social behavior, and not used as much during other behaviors (Holt, 2008; Thomsen et al., 2002). The variable complex structure of whistles seems to suit the purpose of coordinating interactions at close range (Thomsen et al., 2001). Whistles are relatively quiet compared to other sounds and are “only sporadically emitted during long-range exchanges when whales are dispersed (Thomsen et al., 2002, p. 406). Riesch et al. (2008) reported that whistles were used almost solely in close-range interactions among individual killer whales, and suggest that whistles are possibly used at least in part for private communication, to limit the number of eavesdroppers. Private communication might function for example, to inform other group members of a possible food source, without the members of another hearing. However, since groups have different dialects, it is not clear whether the other group would understand the whistles anyways.

Whistles are possibly used for communication between clans that “otherwise use different communicative signals”. (Riesch et al., 2008, p. 1823). It may be useful, for example, to share whistles between interacting and interbreeding groups (Riesch, Ford & Thomsen, 2006). Riesch et al. (2008) observed that whales emitted elaborate series of stereotyped whistles during socializing, and animals that had no overlap in their repertoire of pulsed calls

used “essentially the same set of stereotyped whistles”. (p. 1823). This kind of feature could suggest that there is information sharing and interpretation going on. But it could also be, for example, a way to show friendliness to other groups.

Elaborate whistles, and the use of same stereotyped whistles when socializing with certain other groups, could suggest that these sounds have some informational content, in the sense that they are describing something. It is possible though, that these are just used to “mark” group members, and using the same stereotyped whistles with certain other groups is just a way of acknowledging some kind of connection.

Whistles are also linked to “male-only social interactions” that can happen rather frequently during social traveling or socializing and involve “at least one adult male and one or more adolescents”. They may serve as breeding-related competitive interactions, in which whistles may be used to signal motivation, for example, long and complex whistles sequences signaling competitive motivation, and shorter and simpler whistles representing a relatively lower motivation for competition. It may also serve to use whistles instead of calls for these interactions to keep them private, “to prevent or minimize attraction by rival males”. (Riesch et al., 2008, pp. 1827–1828). Male-only interactions may also function to strengthen relationships between male killer whales of different ages or develop male-specific social skills (Rose, 1992). For example, competitive interactions might be practiced before they actually happen, by older males simulating these situations with younger males.

4.4. Function, cooperation and socialization

Vocalizing has been suggested to maintain and create social and group cohesion, coordinate group behavior and to negotiate social relationships (Ford, 1989; Filatova et al., 2015b).

Distinct, group-specific repertoires distinguish groups from one another, and so they function as a way for killer whales to recognize, find and track each other (Filatova et al., 2015b). Dialects that distinguish different pods from each other not only help to avoid inbreeding (Saulitis et al. 2005), they may work as a “badge” that both affiliates animals to a certain group, and functions as a way for them to be accepted by that group, giving animals a “continued access to the benefits of group living”. Pods are comprised of “several overlapping generations”, and therefore likely have “strong cultural traditions”. “The overall range of the pod, the timing of its movements to coincide with the distribution of its migratory prey, cooperative foraging strategies, and social activities may all be dictated by tradition”. For example, certain northern resident pods have conducted beach rubbing at a site on Vancouver Island “almost daily during the summer months since at least 1973 ... yet southern resident pods have no such tradition”. (Ford, 1991, p. 1480).

In Kamchatkan, killer whales that were played calls of different pods remained silent and only turned their direction of movement toward the boat half of the time. But when they were played calls of their own pod, in all of the eight cases, whales started calling in response, and in seven of the cases they also changed their direction of movement towards the boat. (Filatova & Fedutin, 2011). This kind of observation suggests that group cohesion is indeed very important for killer whales. We do not know whether the animals were able to associate the playback call with a specific animal, and whether, if this animal was actually present, that would have caused confusion in the animals. It seems however that hearing the call of a family member was something that could not be ignored.

Vocalizations may also be used to share knowledge, especially from older individuals to younger whales. Matriline units are led by post-reproductive females that take their position as the leader of their group after menopause, in their late 30s or early 40s. Having grandmothers around has been found to improve the survival of their grandoffspring. (Nattaras, Croft, Ellis, Cant, Weiss, Wright, Stredulinsky, Valcroze, For, Balcomb & Franks, 2019). If knowledge is shared, is it shared descriptively, such as “do not go over there” or more simply “danger”? Can a grandmother actually tell her descendants things like “there is fish over there”, or again more simply “fish”? Or is knowledge shared just by acting and letting a calf or younger killer whale observe? Simply leading the matriline to certain important locations and showing how to hunt for example, would be sharing knowledge as well. If we wanted to study whether there is a vocalization that refers to food or fish for example, we would need to observe a certain sound or sound sequence repeatedly in a situation in which it could confidently be associated with the presence or potential presence of fish or food. This sound or sound sequence would likely be needed to be observed in different individuals that vocalize in the same dialect.

Even if vocalizations are descriptive, we do not know whether they are descriptive in the same way as human language is. For example, is there a certain syllable or combination of syllables that directly refers to an emotion or something in the environment? Or is a certain syllable or combination of syllables combined with elements similar to tone in human language to give them a signification? And does a certain sound always refer to the same thing, or does it depend on the context or potentially the emotional state of that situation? And does symbolic vocalization have the possibility of innovative description for novel situations?

The identity of accompanying whales (Weiss, Symonds, Spong & Ladich, 2007; Filatova et al., 2013) and the number of pods present in a given situation also affects what sounds are produced. Low-frequency monophonic calls (Filatova et al., 2013) and whistles (Riesch & Deecke, 2011) seem to be important for close-range, intra-group coordination and communication, socialization, and private communication. When more than one pod is present, biphonic and high-frequency calls increase significantly, independent of behavioral context (Filatova et al., 2009), and dominant call types of each pod relatively decrease (Foote, Osborne & Hoelzel, 2008). Do the animals make less group specific calls because they start sharing information with members of the other groups? Or do they start making biphonic and high-frequency calls as signals or tools that helps them maintain contact with their own group members, to avoid getting separated from them? Biphonic calls have two independently modulated frequency components, which may “increase the probability of call type recognition for the sounds that are degraded during the transmission through water and masked by background noise” (Filatova et al., 2009, p. 42). Higher frequency harmonics on the other hand have more directionality, which helps to coordinate the position of family members, when several pods are mixed (Miller, 2002, Filatova et al., 2013).

Filatova et al. (2009) suggest that since the proportions of monophonic and biphonic calls do not seem to be connected to behavioral context or type of activity, other than to the presence of different pods, these discrete calls are possibly not just “activity markers”, instead “their functions are more complex”. It is also possibly that it is the sequences, rather than specific isolated calls that could be associated with certain activities (p. 42). If calls are not just activity markers, they could possibly contain information. Lone whales that are probably in search of conspecifics have been observed to emit several different types of

loud, long and discrete pulsed calls with high-frequency components (Saulitis et al., 2005). These calls possibly contain “multiple pieces of information”, such as information of the caller’s sex, motivational state, or distance from the receiver. Multiple calls may also make long distance communication more effective. (Saulitis et al., 2005, pp. 1025–1026).

If calls contain information, is it descriptive in the sense human language is? Do certain sounds refer to certain pieces of information, like “I am alone” or “I am scared”? Or are these pieces of information conveyed through something more close to the tones in human language. For example, if a lone whale is afraid, so they give out the same call structure they would if they weren’t afraid, and does only the perceived tone change unintentionally, because of a different emotional state? Also, are lone whales able to communicate their distance from the receiver by first examining the distance through echolocation, and then actually describing it vocally? Or does the receiver possibly understand the distance by examining how silent or loud the incoming call sounds?

Another question is whether killer whales can use vocalization creatively. Can a killer whale, after it has learned its local repertoire socially, use what it has learned creatively? Is there a fixed amount of possible combinations killer whales can make using the vocalizations they learn socially? Are these combinations also learned by listening to others, or are they partly made up and changed? Can killer whales produce new combinations when faced with new situations, or in some other way adaptively change vocalizations and vocal sequences to better fit situations, when different circumstances arise in their social environment, or in the environment otherwise? And are conspecifics able to interpret these changes in a way that corresponds with the intent to of vocalizing individual?

4.5. Expressing emotion and the psychological aspects of vocalization

One of the functions of vocalization might be to express emotion. At least some of “the ways in which killer whales modify their vocalizations” seem to “reflect their emotional state” (Graham & Noonan, 2010, pp. 16–17). Calls appear to include information on the emotional state the caller, and some calls have been linked to specific emotions (Ford 1989). Some expressions of emotion, such as excitement, distress or aggression may be universal or at least used by several populations among killer whales. For example, the V4 call, also known as “the excitement call” may be an innate signal of emotion. It has has been linked to motivational expression or high arousal behavior in Pacific killer whales. Rehn, Filatova, Durban and Foote (2010) suggest that V4 is used by “socially and reproductively isolated” Pacific killer whale populations “independent of cultural tradition or ecotype”, all of which had “discrete culturally transmitted vocal traditions”. These types of innate expressions of emotion possibly evolve through ritualization (Rehn, Filatova, Durban & Foote, 2010, p. 1), which in the study of animal behavior refers to “a selective process that allows for the enhanced communication of evolutionarily advantageous information and emotional states (Stephenson, 2015, p. 11). In this selective process, expressions of emotion become highly stereotyped and exaggerated, because they facilitate social communication (for references to studies exaggerated expressions of emotion see Rehn et al., 2010).

Excitement calls increase for example after the birth of a calf (Miller et al., 2004). They have higher variation than long range call types, which could be because of differences in

individual arousal or context (for references to studies discussing arousal and context see Rehn et al, 2010). Ford (1989) for example observed certain stereotyped calls in both high-arousal and low-arousal contexts. Rehn et al. (2007) divided V4 calls into six sub-classes, and associated them with close-range socializing that was possibly agonistic or playful in nature. The six sub-classes of calls were possibly produced in distinct, specific emotional states, or may indicate a difference in the degree of emotion (Rehn et al., 2010). Rehn et al. (2010) explains that in many species, "[g]raded vocal exchanges" are "associated with affiliative interactions", which may be used to "reaffirm relationships" after "periods of dispersion and separation" (for references to studies on graded vocal exchanges see Rehn et al., 2010). However, it is not necessarily the case that killer whales express different degrees of emotion only after a periods of separation. Considering the highly social environment of killer whales, and their likely sophisticated cognitive abilities, it is possible that emotion is a regular part of everyday life, and expressing it in degrees happens often and without a specific context.

It is difficult to say whether an excitement call for example, expresses emotion symptomatically or descriptively that is, whether is a reaction to a certain emotion, or whether it is used to explicitly express to others that "I am excited". Also, we do not know whether emotional states are described in more detail, for example, are killer whales able to vocally express the reason for their excitement? Or, if this information is interpreted by others, do they just interpret the reason from the context? Also, can killer whales describe an emotion or whatever they are being vocal about to conspecifics, so that their conspecifics understand it? Can they, for example, tell conspecifics about a situation that is happening or has happened to another animal that has not witnessed it?

In the Crozet archipelago, 72% of the time after capturing an elephant seal, killer whales emitted long distance contact calls that were characterized by excitement. This call led to the arrival of the "most distant members of the group, along with whales of other group coming from several kilometers away" (Guinet, 1992). How did the other group members that arrived from several kilometers away understand these calls? Did they understand that a successful kill had been made, or did they just recognize that something important was happening, when they heard their own dialect characterized with motivation? Were these killer whales able to think of a possible scenario of a successful kill?

Baron-Cohen (2008; 2020) views the ability to think of possible scenarios a uniquely human capacity and a prerequisite for empathy. According to Baron-Cohen, language is needed for this, because thinking of possible scenarios means thinking of conditional statements of others and how they might be feeling (Baron-Cohen, 2008; Baron-Cohen, 2020). Baron-Cohen seems to view language as the only way to think of conditionals and possible scenarios, but it would seem that linguistic representation is rather one example of a more general ability to do this. In other words, language is just one of the media for manifesting this ability. Thoughts can be abstract or visual thoughts without any linguistic elements in them. For example, I can have a visual thought of a scenario of killer whales feasting on an elephant seal without integrating language into that thought in any way. I can also think about this scenario in linguistic terms, and express them through language, but it is not the only way to think about or describe this scenario.

Also, feeling empathy is often just an immediate emotion that arises from witnessing someone else go through something, or expressing a certain emotion. If one sees another person crying, they might just right away feel anxious or sad for them, without any linguistic

thought crossing their mind at all. This type of feeling is called *affective empathy* in empathy research, as opposed to *cognitive empathy* (Yu & Chou, 2018). Innovative research by American psychologist Russel T. Hurlburt, using descriptive experience sampling (DES) “provides provocative descriptions of phenomena such as ‘unsymbolized thinking’—thoughts that occur in awareness without words, images, or any other kind of symbols” (Hurlburt, 1997, p. 941 and cf. pp. 945-948); but there is no evidence that those humans whose thought is unsymbolized, and thus not in the form of “inner speech” (perhaps 70-80%) suffer from any lack of empathy towards others; and children act in empathic ways a very young age, before they have learned to use language (Liddle, Bradley & McGrath, 2015).

There is also evidence of empathy in animals (Bates, Lee, Njiraini, Poole, Sayialel, Sayialel, Mossa & Byrne, 2008; Pérez-Manrique & Gomila, 2018). For example, in a study on spotted dolphins it was reported that adults brush calves slightly with their pectoral flippers to calm them, after calves emitted distress vocalizations similar to excitement calls (Herzing, 1996). This behavior suggests that these animals have the ability to understand others’ emotions, and to empathize, whether or not thinking of possible scenarios is a part of this process. Killer whales are likely to have ways of detecting and understanding the emotions of conspecifics that we are unable to understand. For example, since echolocation clicks make it possible to “see through” objects, whales can sense how fast another animal’s heart is pumping and can attribute significance to this. It is possible that whales interpret the emotions of conspecifics and prey animals in part through echolocation.

Aggression may not be particularly common in killer whales. Graham & Noonan (2010), who observed killer whales in captivity, reported aggression to be generally rare between conspecifics, and in wild animals that are not affected by the distress of captivity it is possibly even rarer. But in captive killer whales, when there were instances of aggressive chase, a consistent vocal pattern was observed, and it “differed markedly” from another pattern which was recorded during non-aggressive control periods. In addition, three call types occurred only during chases, and had similar acoustic features as the V4 call mentioned earlier. The animal that was the target of aggression expressed signals with rising frequencies which were likely signals of the distress of subordination. (Graham & Noonan, 2010). It is possible that these sounds were innate signals of distress, similar to yelping or whimpering, but they could also contain descriptive elements in them that contain information about the distressed animals emotional state, or the situation in general. These calls might not be directed at the agonistic party, but they could also be calls for help, aimed at a killer whale outside of the situation, or made in the hopes that another conspecific hears them, even if there is actually no other animal in the pool. This kind of plea for help could just be a signal, or it could even mean “help”.

Graham and Noonan (2010) believe that during agonistic chases, aggressors produced aberrant calls by using both chase-related and aggression-related call types and adding certain features to them. Graham and Noonan (2010) compare this to the changes in tone of voice in humans, where a different tone can indicate a change in the emotional content of what is said, even when the words do not change (Wurm et al., 2001). The variations in frequency and amplitude observed, may be “universal characteristics of agonism in killer whales in the same way” that a certain tone-of-voice indicates agonism human language. (Graham & Noonan, 2010, pp. 12–13). This might mean that if another conspecific heard these calls, they might make a connection between the chase and aggression related call

types, and be able to interpret that an agonistic chase was going on. The added features might also be interpreted and understood as a certain degree of emotion in the vocalizing animal.

5. Evolutionary questions concerning killer whale vocalization

In our introduction, we announced that we meant to explore vocalization in killer whales with an eye to developmental and evolutionary issues. But by now, the reader should have noticed that this was really a very indeterminate announcement and could not have been otherwise. For, as Chomsky would be the first to say, if you ask questions about how and when and why something evolved, the first thing that you have to make clear is what that something is. We chose to base our approach upon Chomsky's account of language, because this has been taken by many writers, including Chomsky and his associates as a ground for speculating about the evolution of language (see, in particular, Hauser et al. (2014) and Bolhuis et al. (2014)). But, in addition to having to have a clear account of language to work with, one also has to have a clear idea of the evolutionary question or questions for which one will search for answers. What is it that we are asking whether, how, when and why it evolved?

Bolhuis et al. (2014) outline two ways in which “evolutionary analysis might be brought to bear on language”:

First, evolutionary considerations could be used to explain the mechanisms of human language. For instance, principles derived from studying the evolution of communication might be used to predict, or even explain, the structural organization of language. This approach is fraught with difficulties. Questions of evolution or function are fundamentally different from those relating to mechanism, so evolution can never “explain” mechanisms. For a start, the evolution of a particular trait may have proceeded in different ways, such as via common descent, convergence, or exaptation, and it is not easy to establish which of these possibilities (or combination of them) is relevant. More importantly, evolution by natural selection is not a causal factor of either cognitive or neural mechanisms. (para. 7)

The second, more traditional way of applying evolutionary analysis to language is to attempt to reconstruct its evolutionary history. Here, too, we are confronted with major explanatory obstacles. For starters, language appears to be unique to the species *H. sapiens*. That eliminates one of the cornerstones of evolutionary analysis, the comparative method, which generally relies on features that are shared by virtue of common descent. Alternatively, analysis can appeal to convergent evolution, in which similar features, such as birds' wings and bats' wings, arise independently to “solve” functionally analogous problems. Both situations help constrain and guide evolutionary explanation. Lacking both, as in the case of language, makes the explanatory search more difficult. (para. 8)

We find both of these statements rather obscure and unhelpful. We will not discuss them further but will refer back to them selectively in the sequel. Instead, we shall turn to a specific question that arises out of Chomsky's account of language as we have recounted it.

5.1. May the evolution of language be equated with the evolution of FLN?

The focal questions of Hauser et al (2002) and Hauser et al. (2014) concern how and when and why language evolved; those are the authors' overarching and all-consuming concerns. From their point of view in these works, comparative animal studies are significant principally to the extent that they contribute to the understanding of the evolution of language, which these authors consider to be an exclusively human phenomenon. And "language" here means, for them, FLN, or even more specifically, the advent of Merge as the central computational operation in syntactical and grammatical processing (these authors being computationalists) together with the mappings to the conceptual-intentional and sensory-motor interfaces. Although "language" really refers, on Chomsky's own account, to FLB—for language would be attributed only to a creature possessing FLB; and when an organism has FLB, then it has language; unless and until it has FLB, it does not have language—the interest of Hauser and his colleagues, in the evolutionary question concerns almost exclusively FLN. This narrow focus seemingly detracts the attention of these authors away from what might be called the "language counterparts" of non-human animals, and renders these researchers rather emphatic skeptics concerning the possibilities of symbolic representation and expression, and expressive creativity and plasticity, among non-human creatures. This is not to say that such skepticism is entirely unwarranted, but one gets the impression that anyone taking such possibilities seriously is thought by these authors to be on the way to attributing language and speech to non-human animals, which is surely not the case among those serious researchers who accept the general characterization of language developed by Chomsky.

Some indicative wordings (italicized below) from the section on comparative animal behavior in Hauser et al. (2014) reveal this exclusive focus:

Researchers claim that songbirds and nonhuman primates exhibit features of communication that parallel human linguistic communication. [Examples follow.] These observations, generated from behavioral as well as neurobiological evidence, are interesting [?], *but do not guide understanding of language acquisition in humans . . .* (p. 4)

Though . . . studies [of talking birds and signing apes] are of potential interest to understanding the acquisition of specialized, artificial skills—akin to our learning a computer language—*they do not inform understanding of language evolution.* (p. 4)

[Certain] studies have explored the possibility that nonhuman animals produce vocalizations or gestures that are like our words—that is, symbolic or referential—and with the capacity for combination based on some syntactic principles [Examples follow.] *The question of interest is whether these seemingly*

modest claims about animal signals help us understand the evolution of our capacity to represent words, including not only their referentiality but their abstractness, their composition via phonology and morphology, and their syntactic roles. (p. 4)

[A number of] studies . . . focused on the problem of embedding, virtually all used methods of extensive training, and all mistakenly equated embedding with both recursion and the claim that any evidence of embedding would rule out earlier claims of human uniqueness. . . . The researchers concluded that recursive computations are not unique to humans, and so our competence can be explained by non-linguistic processes. For at least four reasons, however, *these results do not inform our understanding of human language competence . . . (p. 5)*

For now, *the evidence from comparative animal behavior provides little insight into how our language phenotype evolved. The gap between us and them is simply too great to provide any understanding of evolutionary precursors or the evolutionary processes (e.g., selection) that led to change over time. (p. 5)*

Not to be misunderstood: there is nothing wrong with restricting oneself to a specific research question. Our complaint is that, in this case, this single-minded focus winds up distorting even the discussion of that research question, not to mention the related questions concerning the evolution of counterpart animal competences and the “machinery” that lies behind them.

If the faculty of language and speech is viewed as FLB, and not merely as FLN, then questions about the evolution of the faculty of language and speech should be questions about the evolution of FLB. And if, as Chomsky seems to believe, the so-called “peripheral” systems of FLB—the cognitive-intentional system and the sensory-motor, or phonological system—are independent systems that could have evolved separately, then questions about the evolution of the faculty of language and speech, FLB, should be questions about the evolution of each of the component systems and, further, about the evolution, or the development, or at least the advent, of the integrated system comprised of these three (and perhaps other) elements.

Why do Hauser and collaborators not concern themselves overmuch with the evolutionary advent of FLB or its individual “peripheral” components, but for the most part only with FLN? They explain that:

An overarching concern in studies of language evolution is with whether particular components of the faculty of language evolved specifically for human language and, therefore (by extension), are unique to humans. Logically, the human uniqueness claim must be based on data indicating an absence of the trait in nonhuman animals and, to be taken seriously, requires a substantial body of relevant comparative data. More concretely, if the language evolution researcher wishes to make the claim that a trait evolved uniquely in humans for the function of language processing, data indicating that no other animal has this particular trait are required. . . . Thus, a basic and logically ineliminable role for comparative research on language evolution is this simple and essentially negative one: A trait present in nonhuman animals did not evolve specifically for human language,

although it may be part of the language faculty and play an intimate role in language processing. (Hauser et al., 2002, p. 1572)

We find this not to be a very persuasive (or very clear) rationale for the heavy focus upon FLN in the evolutionary speculations of Hauser et al. (and many others); perhaps it even contains a *non sequitur*. We suspect that something much simpler lies behind this focus to which voice is not explicitly given, perhaps because Hauser and colleagues have overlooked its assumption and have never brought it into the forefront of their own thinking. The simpler thing is this: according to the plausible, but speculative, scenario in which Merge (and other aspects of FLN, which are only loosely and vaguely described) became a fixture of the human genotype considerably later than the appearance of *Homo sapiens* as a species, that genotypic transition represents the evolutionary interval wherein human beings acquired language. What supposedly happened at that juncture, as we recall, was that a genetic mutation (a “small rewiring of the brain”) forming FLN, occurred in a few individuals and eventually spread to become a part of the genome; and from that time onward, humans had language. So, is not that genomic (and genotypic) change—the advent of FLN—precisely what we should identify as “the evolution of language”?

We think this a misleading framing of the issue, to the extent that that one has represented the language faculty (= language) to be a composite, biologically embodied system of interrelated biologically embodied systems (FLB) where each of the component systems is claimed to have its own, independent evolutionary history. Following Chomsky, Hauser and collaborators suppose that the conceptual-intentional system and the sensory-motor (or phonological) systems in the area of FLB “peripheral” to FLN both evolved, i.e. came into the human genotype, evidently in retention from ancestors of *Homo sapiens*, prior to—and perhaps very long before—the advent of FLN. FLN was simply the last of the components of FLB to evolve. So it seems that the evolutionary advent of FLB should be thought to have happened piecemeal—the separate evolution of the phonological system, the separate evolution of the conceptual-intentional system, and, finally, the evolutionary advent of FLN—rather than being conceived of as a single development. That would seem to be the proper way of looking at things, if one assumes Chomsky’s account of the composite nature of FLB and the evolutionary independence of the components. If one paints the west wing of a house, and then the east wing, and lastly the porch, it would be misleading to speak of painting the house as if it were equivalent to painting the porch.

And if this be recognized, then we should also note that FLN is an element of the faculty of language only because it is interconnected with the “peripheral” elements of FLB in the way that Chomsky surmises. So if an otherwise human-like creature lacking these peripheral biosystems were to undergo the same kind of “rewiring of its brain” by genetic mutation that Chomsky speaks of as the evolutionary advent of FLN, the result might arguably be an in-built computational device (for which the organism might develop a use), but it would not be a *language* faculty in the narrow sense, or indeed in any sense. It could only be considered such in systematic interconnection with the so-called “peripheral systems” that are components of FLB.

We shall return to the questions raised above in §5.6.

Meanwhile, the reader might be impatient to know what, if anything, all this might have to do with evolutionary questions about our hypothesized *orca symbolic vocalization faculty*. Simply stated: since that hypothesis is to the effect that the vocal externalization of symbolic

representations in killer whales might be explainable as deriving from interconnected component systems, each of them a counterpart to one of the three component systems of FLB, being misled in the discussion of the evolutionary advent of human language and speech is likely to mislead us in our attempt to speculate plausibly about the evolutionary advent of the orca faculty from which the vocal externalization of symbolic representations derives.

5.2. Leaving “language” aside

Re-winding to the issue of five paragraphs ago, we must point out that Hauser et al. (2002) are aware that their perspective on the evolution of the component systems of FLB is not the only plausible one. “Given the definitions of the faculty of language, together with the comparative framework,” they say, “we can distinguish several plausible hypotheses about the evolution of its various components.” (p. 1572). They distinguish three such hypotheses, subscribing to the third:

Hypothesis 1: FLB is strictly homologous to animal communication. This hypothesis holds that homologs of FLB, including FLN, exist (perhaps in less developed or otherwise modified form) in nonhuman animals . . . According to this hypothesis, human FLB is composed of the same functional components that underlie communication in other species.

Hypothesis 2: FLB is a derived, uniquely human adaptation for language. According to this hypothesis, FLB is a highly complex adaptation for language, on a par with the vertebrate eye, and many of its core components can be viewed as individual traits that have been subjected to selection and perfected in recent human evolutionary history. . . . The argument starts with the assumption that FLB, as a whole, is highly complex, serves the function of communication with admirable effectiveness, and has an ineliminable genetic component. . . . [P]roponents of this view conclude that natural selection has played a powerful role in shaping many aspects of FLB, including FLN, and, further, that many of these are without parallel in nonhuman animals.

Hypothesis 3: Only FLN is uniquely human

[W]e hypothesize that most, if not all, of FLB is based on mechanisms shared with nonhuman animals (as held by hypothesis 1). In contrast, we suggest that FLN—the computational mechanism of recursion—is recently evolved and unique to our species. According to this hypothesis, much of the complexity manifested in language derives from complexity in the peripheral components of FLB, especially those underlying the sensory-motor (speech or sign) and conceptual-intentional interfaces, combined with sociocultural and communicative contingencies. FLB as a whole . . . has an ancient evolutionary history, long predating the emergence of language, and a comparative analysis is necessary to understand this complex system. By contrast, according to recent linguistic theory, the computations underlying FLN may be quite limited. In fact, we propose . . . that FLN comprises only the core computational mechanisms of

recursion as they appear in narrow syntax and the mappings to the interfaces.
(Hauser et al., 2002, pp. 1572-1573)

The statement, particularly of Hypothesis 3, is puzzling, since it treats FLB as *disjoint* from FLN, whereas they said originally that “FLB *includes* an internal computational system [FLN] combined with at least two other organism-internal systems, which we call ‘sensory-motor’ and ‘conceptual-intentional.’” (pp. 1570-1571, italics added)

But we need not pause over these hypotheses, for our objective here is quite different from that of Hauser and colleagues. We are not wondering about the evolutionary advent or background of language and are thus not in the position of having to choose how “language” is to be construed in the context of evolutionary questions as they are construed by Hauser et al. (2002; 2004).

Our working view, based upon what has come to light about orca vocalizations, is that contemporary killer whales emit and receive *symbolic* vocalizations—meaningful vocalizations that serve various functions and mediate various activities including communication in both the thicker and thinner senses.

Not all killer whale vocalizations are symbolic in the intended sense; that is, not all have meaningful content, any more than all human vocalizations do. If someone gives a yelp of pain, the yelp is a vocalization that is a signal of pain but lacks meaningful content. The yelp may (intentionally or unintentionally) signal pain—and may thus communicate pain in the thinner sense—without communicating through descriptive content, as would the utterance, “I am in pain”. In the terms we are using, the yelp would not be a symbolic vocalization; the descriptive sentence would. We spoke earlier of various orca “calls” that were, or might be, expressive of emotion, such as “excitement calls”. And we there raised the question whether these are more like yelps that signal excitement, which may affect the behavior of auditors (who may understand them as revealing excitement) and may mediate the activity of a pod though lacking content, or whether they might be symbolic expressions descriptive of the emotion that could communicate excitement in the thicker sense. (Note that the latter might at the same time work as would a non-descriptive signal.)

The killer whale clicks that are used for echolocation lack content and are therefore not symbolic vocalizations in the sense intended here. They are nevertheless vocalizations that mediate behavior—for instance, stalking prey—and serve one or more functions. We might say that they have significance for an orca that understands them as indicators of the presence and distance of prey, but that is not their *content*, even if it is their *significance*. (Let us understand significance as attributed, but not inherent, content.)

We should also not forget that, just as orcas may emit symbolic expressions vocally, they may also emit symbolic expressions that are either non-vocal or not entirely vocal. Our concern herein has been and will be limited to vocalizations. It is likely that what we have said and will hereafter say about vocalizations would be applicable to non-vocal externalizations. But we will not follow up that possibility in the present work.

5.3. The specific focus of our evolutionary inquiry

Let us at this point become as clear and specific as we can and declare (if it is not already apparent) the focus of our evolutionary inquiry herein to be the evolutionary roots of orca *symbolic* vocalizations that could include the questions of how and why the orca symbolic vocalization faculty, hypothesizing that there is one, became a heritable characteristic of killer whales, but that could focus upon other questions as well. Answers to these questions that have any sort of scientific plausibility will be speculative and uncertain at best; and of course, as we have set the discussion up, they rest upon certain hypotheses. But our suggestions may be, and are meant to be, testable in various ways. And if our hypotheses should begin to look suspect, the reasons for that may show us the way to better hypotheses, or may convince us to frame our discussion in different terms.

Since our hypothesized “machinery” for orca symbolic vocalization, mirroring Chomsky’s hypothesized machinery for human language, comprises a composite system with several systems as its components—counterparts (however distant) of the biologically embodied components of FLB (one of which is FLN)—we maintain, as argued above, that any pretended description of the evolution of the whole, which we have labeled the *orca symbolic vocalization faculty* must describe the evolution of each component, together with an explanation, if such is available, of their systematic interrelationships. Let us review these briefly.

One of these hypothesized components is the (perhaps distant) counterpart of the conceptual-intentional element of FLB, call it the *orca conceptual-intentional system*. The literature on animal cognition suggests that this is a symbol-processing capacity that reputedly constructs abstract representations that support complex inferences, to paraphrase Gallistel. It likewise supports the construction of complex data structures (we rehearse Gallistel, 2011, pp. 255-258, esp. p. 255), or symbolic propositions. And in vertebrates at least, the representations of actions may take “the predicate-argument form characteristic of human language” (Gallistel, p.253). Hauser et al. (2002; 2014) are surprisingly sanguine about the parameters of *conceptual-intentional systems* in non-human, “pre-linguistic” animals. They seem to agree with Gallistel that the *conceptual-intentional* capabilities of non-human animals may, in some cases, rise to nearly human levels. This is incautious. Our own feeling, expressed earlier, is that these capabilities, although they may exist, are species-specific. And we have very little, if any, idea of what having these capabilities is like as seen from the perspective of an animal who has them. So when we talk about *conceptual-intentional systems* in various non-human, “pre-linguistic” animals, we are talking about corresponding systems that are, to varying degrees, similar in form or function and that may either be *analogous* or *homologous* in the sense in which these terms are used in evolutionary biology.

Another of these hypothesized components is the denatured counterpart of FLN, which we have called the *orca syntactical symbolization faculty* (perhaps a better label might be found). Insofar as it is capable of doing so, this system is supposed to syntactically structure and re-structure the various kinds of representations, symbolic propositions, and lexical items that are created in the *conceptual-intentional system* and to send instructions to the *phonological system* for vocally externalizing these structured representations. Our earlier survey of orca vocalizations has shown—and most researchers who write within the general Chomskyan framework agree—that this *orca syntactical symbolization faculty* is limited in comparison to the human FLN, as comparable faculties have proven to be in all known non-

human animal vocalizers. Although it can perhaps be pushed by training, as our survey indicated, the *orca syntactical symbolization faculty* cannot spontaneously combine more than two representational elements, meaning that it is limited in its powers of symbolic flexibility or creativity; or so it has been claimed, as we saw earlier, by Suzuki, Wheatcroft and Griesser (2019) and some others. This may be because its basic computational operation is not Merge (if we speak the language of computationalists), which is the operation supposedly basic to FLN and supposedly accounts for the infinitely creative nature of human language; or, its operation is Merge, but its computational power is limited by factors, such as a paucity of working memory in the organism (as we recall was suggested by Rey, Perruchet & Fagot (2011)), that render it *functionally* finite and non-recursive. (FLN itself may also be functionally non-recursive albeit with far fewer restrictions.) However, just because it is limited, does not mean that the *orca syntactical symbolization faculty* is utterly impotent or simply non-existent. It may still exist and do the kind of job described above, only far less robustly than FLN. This seems to be a possibility overlooked by Chomsky; but in fact it seems that it would have to exist for orcas to be capable of symbolic vocalization, imagining that this capability requires “a particular computational cognitive system, implemented neurally”.

Chomsky thinks that prior to the evolutionary advent of Merge in humans, the perceptual and motor mechanisms belonging to FLB were at least “possibly preexisting”; indeed, he goes much further:

. . . virtually all of the antecedent “machinery” for language is presumed to have been present long before the human species appeared. For instance, it appears that the ability to perceive “distinctive features” such as the difference between the sound *b*, as in *bat*, as opposed to *p*, as in *pat*, might be present in the mammalian lineage generally . . . The same holds for audition. Both comprise part of the externalization system for language. Furthermore, the general constraint of efficient computation would also seem plausibly antecedent in the cognitive computation of ancestral species. The only thing lacking for language would be *merge*, some specific way to externalize the internal computations and, importantly, . . . “atomic conceptual elements” . . . (Bolhuis et al. 2014, para. 12)

Granting that what would be required for language (FLB), “the ability of any child to learn any human language” would be Merge (FLN), we suppose that in orcas, and indeed in pre-linguistic humans, there would also be, prior to the advent of language in *Homo sapiens*, a counterpart to FLB that would permit orcas, pre-linguistic *Homo sapiens*, and, say, *H. neanderthalensis* to vocalize symbolically to some limited extent. The reason that Chomsky overlooks (as it seems) this possibility is evidently because he doesn’t think that non-linguistic animals can express themselves symbolically, i.e. can externalize, or perhaps can even have, symbolic “thoughts”. We do not find Chomsky to be completely consistent on this matter. But his associate, Ian Tattersall, whom he admires, seems clearly to suppose that symbolic cognition comes only with language (see Tattersall, 2008); Chomsky (2004) remarks that “Tattersall takes language to be virtually synonymous with symbolic thought.” (p. 3) Randy Gallistel would hardly agree:

The abstract representation of space and time is broadly spread among the animalia. Commonly studied species of birds and insects navigate in part by dead reckoning, which is the real-time estimation of one’s position by integrating one’s

velocity with respect to time. In its most basic form, this is not a complex computation. It rests on the principle that if you have been moving northeast for 100 seconds at an average speed of 1 m/s, then you are now 100 meters northeast of where you were 100 seconds ago, so if you knew where you were then, you know approximately where you are now. There are substantial measurement challenges in implementing this computation because the result depends critically on the accuracy of the speed and direction estimates. However, the computation itself is of modest complexity. That said, it is hard to see how it could fail to be a symbolically mediated activity of the brain. The essence of the activity is the adding (in the arithmetic sense) of symbols for one's most recent displacement (change in position) to the symbols that represent one's earlier estimate of position. If there is a proposal for a machine that can do this without symbols that refer to position and velocity (or displacement) and machinery capable of combining these symbols arithmetically to yield a new symbol that refers to the new position, I have never heard of it. The models for the process that I know of, including neural net models . . . are symbolic models. The locus of neural activity is taken to represent location, speed, and direction. These loci of activity are unequivocally symbols; that is, they refer and they are operated on to generate other loci of activity that also refer. In my opinion, they are not very good symbols, but symbols they certainly are. (Gallistel, 2011, p. 254)

The uncertainty on this issue may derive from the vagueness and polysemy of the notions of *symbol* and *symbolic*; and we are as guilty as anyone in leaving this notion pretty much undefined. But we nevertheless side with Gallistel, finding the flat denial of symbolic cognition and expression to animals to be unrealistic and difficult to sustain.

Turning finally to the counterpart of the third component of FLB, let us label the hypothesized counterpart, in killer whales, of the phonological (sensory-motor) element of FLB, the *orca phonological system*. This is the vocal system that makes it possible for orcas to make sounds, structured by the *orca syntactical symbolization faculty*, that have symbolic content. This makes it possible for orcas to *communicate* in the thicker sense, but also in the thinner sense, and also to produce symbolic vocalizations for other purposes than communication. The range of symbolic vocalizations that an animal can produce are limited by the repertoire of discriminable sounds that it can produce and by its ability to structure combinations of sounds syntactically.

An orca symbolic vocalization faculty

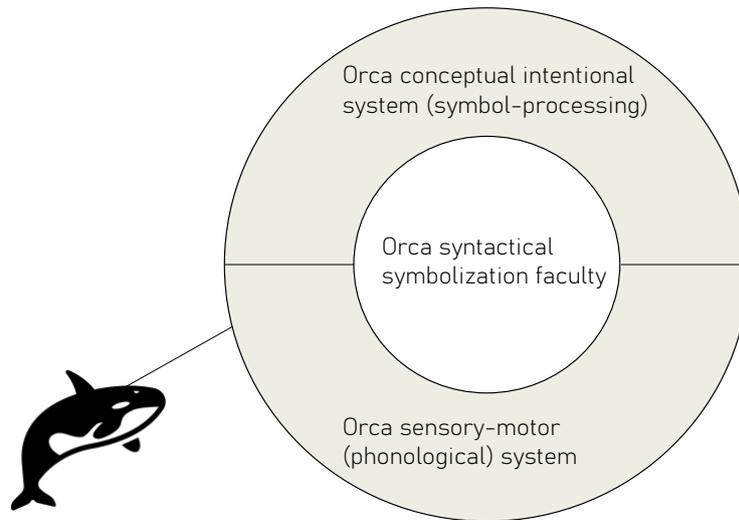


Figure 2. A schematization of the orca symbolic vocalization faculty, a hypothesized counterpart to FLB, which includes the orca syntactical symbolization faculty, a counterpart of FLN. Image by author.

Our survey of orca vocalizations showed that orcas have a repertoire of sounds that they can emit vocally: clicks, whistles, and pulsed calls, interestingly with dialectical nuances, on top of a limited capacity for structuring their utterances syntactically. Human syntactic capacities are greater. It is for these reasons that Gallistel would say, as we saw, that orcas (along with all known nonhuman animals) lack “the machinery for mapping what they represent in the privacy of their own brain into a *communicable* system of symbols of similar power and versatility to the private system” (Gallistel, 2011, p. 260).

5.4. On the evolution of the orca symbolic vocalization faculty

Now, if we argue that Chomsky and his associates should properly pay attention to the evolution of the component systems of FLB, what of the evolution of the orca component systems just discussed and thus of the *orca symbolic vocalization faculty* that is the hypothetical counterpart of language in the sense of FLB? Let us note two things that Chomsky thinks are the case for language but that we cannot assume for orca symbolic vocalization.

First, as we related in Chapter 2, Chomsky speculates, based upon archeological evidence, that FLN and Merge appeared around 50 thousand years ago (Chomsky and associates mention varying figures for this, all in the range of 50-100 thousand years), long after the emergence of *Homo sapiens* as a distinct hominid species, and that this made it possible to combine syntactically formed symbolic structures into new ones without limit, giving human individuals the advantages of planning, complex thought, interpretation, and the ability to create possible worlds mentally. At first, Chomsky thinks, humans likely could not use language for communication, since the language faculty was present only in a few individuals, so that language remained internal. (Thus language did not evolve for the sake

of communication.) But after the language faculty had become a fixture of the human genotype, it became possible to use this system for communicating with conspecifics, and the internal symbolic ability was externalized. Humans were then able to use the abilities Merge gave them in their speech and communication with others. (Chomsky, 2010). No parallel facts can be assumed with respect to orcas. We have no evidence of a “Great Leap Forward” at any point in the species history of killer whales. (Although it must be added here, that the “Great Leap Forward” is becoming an increasingly controversial hypothesis, with evidence of tool use abilities and symbolic behavior emerging of the Neanderthal human). And we have seen reason for thinking that orcas can communicate vocally, in the thicker sense, without language (but with a counterpart of FLB, including a counterpart of FLN).

And second, we have little reason to assume that any of the three component systems of the hypothesized *orca symbolic vocalization faculty* could have existed, or evolved, separated from the others in any orca or orca ancestor.

If we consider first the *orca conceptual-intentional system*, it would appear to be a system of the sort that is, according to Gallistel—apparently with the agreement of Hauser et al. (2002; 2014) and many students of animal cognition—“evolutionarily ancient” (rehearsing Gallistel, 2011, p. 253). Animals, Gallistel asserts, “have represented the experienced world at a highly abstract level in a richly structured symbolic system for eons” (p. 260); “[S]pecies with which humans have not shared a common ancestor since the Cambrian era represent the experienced world at a high level of abstraction” (p. 253). Evidently, the evolutionary appearance of this kind of system far antedated the evolutionary appearance of orcas, and the presence of the orca variant came into the orca phenotype through the ancestral line. It is not clear that the presence of comparable systems in a variety of lines of descent can be traced to any common ancestor. If they appeared in many different lines of descent by convergent evolution, that would be a powerful indication that the possession of such a system is highly advantageous to many types of animals from the evolutionary point of view and is promoted by natural selection in species that differ markedly from one another in body design, natural habitats, food sources, prey and predators, modes of reproduction, developmental traits and trajectories, modes of interaction with conspecifics, and so on (see Hendry, 2017). The same thing is true of many forms of cognition, such as sense perception, to which symbolic representation and intention (motivation) are surely linked; and it seems obvious that the power to represent the experienced world in a structured symbolic system is a cognitive power, if anything is.

Thus, we may say that the evolutionary emergence of the *orca conceptual-intentional system* begins with the appearance of such a system as a novelty in the heritable characteristics of an ancient—and surly very ancient—orca ancestor. However, that evolutionary event would not be the correct one to identify as “the evolutionary advent of the *orca conceptual-intentional system*”, because that system, like all such systems, is species-specific. To speak of a system or faculty of structured symbolic representation is to employ a very thin (and in this case, rather opaque) description that makes it possible to bring a range of very different cognitive abilities under one hat. Except for being apt for this thin (but not empty!) description, the symbolic representational powers and systems of animals are highly diverse, and each is species specific. Without considering the specifics of each, and the functions that it supports for each particular kind of creature with its own particular kind of body, its own developmental trajectory, in its own sort of habitat, and its own mode of life, we cannot fit individual examples into an evolutionary account; for instance, we cannot show in what

ways a specific system gives creatures of a given species evolutionary advantages, making it apt for selection.

So the evolutionary advent of the *orca conceptual-intentional system* seems have been an element of the evolutionary advent of *Orcinus orca*. The relevant evolutionary event (really a lengthy transitional process of some complexity) is the appearance of the *orca species* of which the *orca conceptual-intentional system*—in the form of a heritable biologically embodied faculty—is an integrated element. An important aspect is that the *orca conceptual-intentional* evolves in synergistic connection with the *orca phonological (sensory-motor) system* and the *orca syntactical symbolization faculty* as well as other cognitive (and also non-cognitive) systems—as an *organ* in the context of an *organism*. This surely shapes the design of each of the functionally interconnected systems. The question then of how and why the *orca conceptual-intentional system* evolved is the question of how and why *Orcinus orca* evolved with just that sort of *symbolic representational (conceptual-intentional) system*, and the attempt to answer those question requires us to look at each part as a functional component of an organism.

Much the same thing is to be said about the *orca phonological system*. *Orcinus orca* evolved from ancestors that vocalized, but the vocal system of orcas differed from that of its near ancestors just as its body topology—its internal and external organs—and its natural behaviors differed from theirs. Again, it is important that the *orca phonological system* evolved as an element of the orca heritable make-up and in interconnection with the *orca syntactical symbolization faculty*, the *orca conceptual-intentional system*, and other functional elements of the organism considered as a systematic whole. To the extent that the species evolved under the influence of natural selection, what was selected was a certain package of functional elements that, working together in the organism's environment, were advantageous for the flourishing and continuation of the species, that is were selectively advantageous for robust reproduction in the niches that members of the species have created and exploited. Distribution of subpopulations exploiting different niches may result in rapid divergence of ecotypes with various demographic consequences; for an interesting study pertaining to killer whales, see Foote et al (2016).

5.5. Two kinds of evolutionary accounts

What we have discovered by following out the line above, is that there are two different sorts of evolutionary inquiry that need to be followed in examining the evolution of the *orca symbolic vocalization faculty* and comparable systems in other organisms, aimed at answering two different evolutionary questions. First we can ask why, when, and how a composite system evolved that—when brought under a thin description that puts many such systems, comparable in particular, and basic, respects while being highly divergent in others—is present in a large class of organisms, such as vertebrates or mammals, belonging to a common evolutionary tree, and even perhaps present in a large class of organisms, such as insects or cephalopods, belonging to different evolutionary trees.

Thus, the *orca symbolic vocalization faculty* is a specific instance of what may be called a *symbolic externalization faculty* that is evidently found generally in vertebrates and mammals, presumably following lines of descent from very ancient common ancestors, and in insects and other taxa by convergent evolution. As we said earlier, if a certain type of system continues persistently along ancient lines of descent or appears in many different

lines of descent by convergent evolution, that indicates that the possession of that system “is highly advantageous to many types of animals from the evolutionary point of view and is promoted by natural selection in species that differ markedly from one another in body design, natural habitats, food sources, prey and predators, modes of reproduction, developmental traits and trajectories, modes of interaction with conspecifics, and so on.” An evolutionary account would try to show why such a system is so widely advantageous in a manner that is favored in natural selection. It would try to demonstrate why such a system would serve as a solution to a “problem” that a large number of diverse organisms share in common.

If one can show this about what we have labeled a *symbolic externalization faculty* then we have an evolutionary explanation of the *orca symbolic vocalization faculty* which is one such system, and carries with it the selective advantages that that type of system has generally. This pertains to the *symbolic externalization faculty* that orcas have, but the selective advantages are not specific to orcas. That is to say that such an evolutionary account would explain why orcas have a *symbolic externalization faculty* but would not explain why the species-specific *orca symbolic vocalization faculty* is as it is—for instance, why it is a *symbolic vocalization faculty* as opposed to a *symbolic externalization faculty* where the externalization works through gestures perceived visually or by other, non-vocal media. We are reminded by Bolhuis et al. (2014) that, even concerning language it is a “misconception” to suppose that:

. . . language is coextensive with speech and that the evolution of vocalization or auditory-vocal learning can therefore inform us about the evolution of language . . . [S]peech and speech perception, while functioning as possible external interfaces for the language system, are not identical to it. An alternative externalization of language is in the visual domain, as sign language; even haptic externalization by touch seems possible in deaf and blind individuals . . . Thus, while the evolution of auditory vocal learning maybe relevant for the evolution of speech, it is not for the language faculty per se. (para. 2)

We have focused our evolutionary investigation upon the hypothesized *orca symbolic vocalization faculty* and so are interested in an evolutionary explanation as to why the *orca symbolic externalization faculty* is, at least in part, a *vocalization faculty*, without overlooking the possibility, or rather what seems to be the fact, that orcas may also externalize symbolically otherwise than by vocalizing. In his discussions of language, Chomsky similarly concentrates for the most part upon *spoken* language, and thus talks about the phonological system as a component of FLN. But, as the quotation just above shows, we should not be misled by the fact that so much of the discussion is about spoken language; for language, in the sense of FLB, will include an externalization interface (or more than one), but not necessarily, or exclusively, one that is vocal.

The second kind of evolutionary account that we might aim to give is of the *orca symbolic vocalization faculty*: a particular, species-specific system. That is to say, we might try to find out how and why the *orca symbolic vocalization faculty* came to have the characteristics that it has; characteristics that may, or do in fact, differ from the *symbolic externalization faculties* that we find in other species. One is the characteristic just mentioned: that it is a faculty of *symbolic vocalization*. Another is that orca vocal utterances have the phonetic form that they have: clicks, pulsed calls, and whistles; these are unlikely to much resemble

the vocalizations of the Mesonychids, hyena-like, carnivorous terrestrial mammals of perhaps 60 million years ago that are thought to be ancestral to orcas and other cetaceans. Another is that orcas learn to vocalize in the “dialect” of the pods to which they belong; this developmental characteristic is uncommon among vocalizing animals and is likely not descended from remote orca ancestors. And so on. The approach to finding this type of evolutionary explanation will for the most part consider the functions that these species-specific characteristics have and, to the extent that these functions can be shown to be advantageous for survival and reproduction, can be explained in terms of natural selection.

This type of evolutionary explanation is also fitting for heritable elements that arise within a species phenotype subsequent to its original appearance, such as FLN or the Merge operation within the *Homo sapiens* phenotype. On Chomsky’s account, FLN is just the sort of species-specific innovation in the human genotype as we have been talking about. It seems to us that it would be best viewed as a developmental innovation in whatever counterpart of FLN existed in “pre-linguistic” *Homo sapiens*. Chomsky doesn’t view the matter in that way, apparently because he doesn’t believe in, or hypothesize, any such counterpart. That may seem strange, since we saw Chomsky saying, in §5.3, that “virtually all of the antecedent ‘machinery’ for language is presumed to have been present *long before the human species appeared*” (Bolhuis et al. 2014, para. 12; italics added); but that “machinery” evidently doesn’t include a limited system for syntactic structuring and re-structuring symbolic “expressions” and for mediating between conceptual (symbolic) and externalizing interfaces or “systems”. If the event that introduced Merge consisted in a “minor rewiring of the brain” through a small, random mutation, as Chomsky supposes, might there not have been a pre-existing system with relevant, if relatively inchoate, functions that got rewired? That seems more likely than that some new system was introduced *ab initio* through a re-wiring that was unconnected with any pre-existing system. (This is not the “slow evolution” view that Chomsky denigrates in Chomsky (2004), p. 7.) The abilities that Chomsky attributes to pre-linguistic *Homo sapiens*, or to *Homo neanderthalensis*, are miserable indeed.

5.6. Still another framing of evolutionary accounts

Both kinds of evolutionary accounts described in §5.5 concern the evolution of functional structures; this is invited by taking Chomsky’s biolinguistic approach to language as a model. FLN and FLB are functional structures: physical structures, or biological organs, that endow their possessors with certain abilities, such as those of speaking and reasoning, and planning and inventing and cooperating, mediated by spoken language. But this perspective is not limited to linguistic or cognitive abilities. Animals can digest their food because they have digestive systems, which are functional structures, consisting of functional substructures, such as stomachs and intestines: biological organs that do things. The functions made possible, and supported by, these structures, are not to be confused with the structures themselves.

Chomsky is not clearly in agreement with this last statement. He says such things as “to talk of the mind is to talk of the brain at a certain level of abstraction” (paraphrase from numerous sources). So, for Chomsky, to have language, or vision, or digestion is evidently to have bodily structures that potentiate the activities or actions, or behaviors of seeing, or speaking, or digesting or the abilities to see, to speak, or to digest; and to talk of seeing, or speaking, or digesting, or the corresponding abilities, is to talk of those structures “at a certain level of abstraction”. We think that this way of looking at things makes for obscurity in framing

evolutionary explanations, at least if one is not cautious. Abilities or types of activities may be spoken of as evolving—the evolution of language, the evolution of vision, the evolution of digestion—but if “biological as opposed to cultural evolution” (Hauser et al., 2014, p. 2), as these authors conceive it, is meant, then they need to be careful, because, from their perspective, biological evolution, strictly speaking, is the evolution of biological structures, organs, and organisms—changes that express genetic changes; changes in genotypes that result from, or are preserved by, natural selection, taking into account the mutual influence of development and phenotypic variation upon one another, and the mutual influence of environmental change and phenotypic evolution upon one another. (Hence a change of this sort brought about artificially, say by genetic engineering, should not be described as an instance of evolution.)

Since Chomsky thinks that talking about abilities or types of activities is the same thing as talking about the structures or organs that potentiate them “at a certain level of abstraction”, he moves without remark between the type of evolutionary account directed at describing or explaining changes in, or the appearance of, biological *structures* to (what we consider to be) another type, directed at describing or explaining changes in, or the appearance of, *abilities* or *types of activities*. The difference is widely papered over by speaking, as is commonly done, of “traits”, because a trait, according to common understanding, is “a morphological, physiological, or behavioral feature of an organism”. (We do not imply that there is anything wrong with speaking of traits, if one does not lose sight of the fact that the term covers several different kinds of feature.)

Bolhuis et al. (2014) announce that, “It is uncontroversial that language has evolved, just like any other trait of living organisms” (para. 1). Perhaps so, but it might be uncontroversial just because it is left rather open-ended just what’s meant in saying that “language has evolved”. Bolhuis et al. (2014) go on immediately to say what the point of their announcement is: “[O]nce—not so long ago in evolutionary terms—there was no language at all, and now there is, at least in *Homo sapiens*” (para. 1). Here, it seems to us, they are thinking of the language “trait” as the *ability to use language* or the *activity of language use* (a “behavior”) rather than the biological structures that potentiate it. If you are talking about the advent of language in *Homo sapiens* on the evidence of the archeologically apparent “great leap forward”, you are talking about what *Homo sapiens* could all of a sudden *do*, not speculating about the biological structures that potentiated this ability or those actions (even if you assume, as a scientist, that there must be some physiological change, and some such structures, that would explain the new ability). Thinking of language as an ability or type of activity that appeared all of a sudden, you will think of “the evolution of language” as simply its appearance in the repertoire of some organism.

That Chomsky and his associates sometimes think of language in the way just mentioned rather than as “a particular computational cognitive system, implemented neurally” may explain the narrow, and apparently illogical, focus on the advent of FLN that we questioned in §5.1 above. For if the focus of interest is on the evolutionary acquisition of an ability to engage in a type of activity, and if language in this sense appeared suddenly, and unpredictably, in the human behavioral repertoire, then it is reasonable that that appearance will be the event for which we may search for an evolutionary explanation. One obvious candidate for such an evolutionary explanation will exploit the assumption that this dramatic change in the behavioral repertoire of *Homo sapiens* reflects an evolutionary change in the underlying “machinery” (a term that Chomsky often uses, and that we find revealing): the neurological structures that potentiate the behavioral abilities. This will, of course, invite an

attempt to give an explanation of the evolutionary advent, or changes in, these structures. Viewing FLN and, indeed, all of the presumed components of FLB as neurally embodied structures—parts of the “machinery” that potentiates linguistic abilities and behaviors—it is nevertheless the case that the neural development of which the behavioral developments are expressions is, if Chomsky’s account is more or less correct, the evolutionary advent of FLN, so that that may be taken logically as a focal event in “the evolution of language”, and we can attempt to explain what that development consisted in (this is not, in itself, an evolutionary mode of explanation, but is likely necessary to giving one) and why and how it came about (which—if the explanation is framed in terms of natural selection, taking into account, as we said just above, the mutual influence of development and phenotypic variation upon one another, and the mutual influence of environmental change and phenotypic evolution upon one another—*will* be an evolutionary mode of explanation).

That is, in some part, the approach that Chomsky and his associates have taken with respect to their discussions of “the evolution of language”. But identifying a trait (say, a cognitive trait, although the point is generalizable) as a certain type of behavioral ability or functional activity, as opposed to identifying it as a certain type of (hypothesized) biological “machinery”—“a particular computational cognitive system, implemented neurally”—are importantly different as objects of explanation, whether evolutionary explanation or otherwise. The reason is that what we might identify as “the same” functional activity in different organisms on the basis of a given set of performance criteria (or “tests”) could turn out to be potentiated by very different biological structures (“machinery”) in different organisms. So the evolutionary advent of that functional activity within the animal kingdom might, in the first place consist of several different events in different ancestral lines, identifiable independently of whatever we know, or don’t know, about the underlying biological structures that potentiate it, and these, when investigate it, might prove to be analogous or not. We could not assume that “the same” structures underlie “the same” functional activities; and whether it will be true or not that they do depends upon what standard of sameness or similarity that we use for each: functional activity or biological structure.

If “language” is understood to be a certain sort of ability or functional activity, rather than an embodied “system”, then is it an instance of the ability to structure symbolic representations syntactically and to externalize and comprehend them, the sort of ability that humans might share with orcas, and bees, and many other animals (accepting differences in modes of externalization and the possibilities for syntactical structuring)—or not? If we say no on the grounds that it does not have the power that Merge supposedly gives to human language, then it evolved in but one species and not even at the point of evolution of that species as such (assuming the wider Chomskyan scenario) and is of a unique sort. Then we can explain this evolutionary event on the basis of another evolutionary event, namely the sudden appearance of a certain heritable neural structure, which is not a functional activity but a potentiator of such. The explanation of that evolutionary event, if one can be found, would be of a different kind than the first.

But we are not driven to answer our question negatively; and much depends upon which criteria we choose to apply, what we seek to explain, and in what terms. Our criteria for identifying something as an instance relevant functional activity might not have the power deriving from Merge built into them. Then the functional activity that we call “language” might be counted as an instance of the ability to structure symbolic representations syntactically and to externalize and comprehend them—an ability present (perhaps long

present) in the pre-linguistic world, and not unique to humans. Yes, but isn't language a very special, and, as it happens, unique instance of that more ancient functional activity? Surely it is. But every evolutionary variant of a trait of this kind is new and species-specific—unique in that sense. Then we might try to search for the neural structures that potentiate the more widely defined functional activity; and these will be considered generically analogous (as we outlined in §5.5, cf. §5.1), but specifically different. Evolutionary explanations can be searched for both for the genetic similarities and for the specific differences.

6. Orca symbolic vocalization from an evolutionary perspective

In the light of what we have discussed in Chapters 3, 4, & 5, we should now answer two questions before going further: (1) What is it exactly that we propose to discuss from an evolutionary perspective? That is, what is it exactly about which we will try to explain how and why it evolved? And (2) which of the types of evolutionary account or explanation discussed in Chapter 5 will we employ? It should be clear to the reader that the answer to question (2) is dependent upon our answer to question (1).

But before we engage with these questions, we will raise here, and answer, an additional question, question (3), which is: what is meant by evolution? In §5.6 above, we responded to the announcement of Bolhuis et al. (2014) that, “It is uncontroversial that language has evolved, just like any other trait of living organisms” (para. 1) by remarking that it might be uncontroversial just because they leave unspecified just what’s meant in saying that “language has evolved”. In that context, we were concerned with the question whether the “language” that was said to evolve was being thought of as an *ability* or *type of activity* or rather as a *neurally embodied physical* (computational) *system*. But here we may also raise the question, “Upon what understanding of evolution is it asserted that ‘language has evolved’?” What idea of how the evolutionary process takes place is to be assumed?

Chomsky’s idea of the mechanics of evolution is basically that of the so-called “Modern Synthesis” in evolutionary biology (Müller, 2007), which focuses on the correlation of phenotypic character variation with statistical gene frequencies in populations. However, in one place (Chomsky, 2010) he asks how true some “simple evo-devo theses” might be for language and finds that there are some similarities between the evolution of language as seen from his biolinguistic perspective and as seen from the more recent view known as the ecological, evolutionary and developmental (eco-evo-devo) account of evolution.

Chomsky does not make his ideas in that direction very clear, and we will not concern ourselves further here with those particular speculations. What we do want to make clear is that at this point in our discussion we will be speaking consistently from our own perspective, and not Chomsky’s, as far as the processes mechanics of evolution are concerned. Our viewpoint is the ecological, evolutionary and developmental account of evolution as we understand it, and this is implicit in our discussion below concerning the evolution of orca vocalizations. The eco-evo-devo perspective stresses that phenotypic variation in populations results from the development of individual phenotypic differences (the individuals that form the population) within generations. The development of each individual is influenced in concert by inherited factors (including genetic and non-genetic ones) and direct environmental effects (phenotypic plasticity). Variability in the development of phenotypes due to integrated effects of plasticity (eco-devo) and/or inherited effects (evo-devo) provides phenotypic variation in populations for natural selection to act on (eco-evo) (Müller, 2007; Hendry, 2017, Skúlason et al., 2019). This last indicates the

connection with Darwin’s insight concerning natural selection as the “guiding force” in evolution. This picture of evolution is our answer to question (3), and we now return to the further consideration of questions (1) and (2).

Question (1) received something of an answer in §5.3. There, we declared the intended focus of our evolutionary inquiry to be “the evolutionary origin of orca *symbolic* vocalizations: the questions of how and why the orca symbolic vocalization faculty, hypothesizing that there is one, became a heritable characteristic of killer whales.” But we subsequently revealed some ambiguities in that declaration that Chapter 5 requires us now to resolve.

Taking aspects of Chomsky’s account of language as a possibly helpful schematic model, we have arrived—partly by hypothesis and partly with a view to what empirical studies have shown, or seem to have shown, about orca vocalization and other relevant matters—at a working hypothesis that includes the following points: (i) that, in addition to vocalizing non-symbolically, orcas vocalize symbolically; this is an ability or functional activity; (ii) orca symbolic vocalization is potentiated by a particular computational cognitive system, call it the *orca symbolic vocalization orca faculty*, implemented neurally (we adopt the computationalist perspective without comment); (iii) this is a heritable, embodied (physiological) functional system, a counterpart to the FLB in humans; (iv) the *orca symbolic vocalization faculty* is a composite system, made up of (or analyzable into) the *orca conceptual-intentional system*, the *orca phonological system*, and the *orca syntactical symbolization faculty*, which is the counterpart of the human FLN; the function of each element is the counterpart of the corresponding elements of FLB; (v) the principal computational operation of the *orca syntactical symbolization faculty* is not functionally recursive, so its syntactic structuring power is not unbounded, but is bounded in species-specific ways; (vi) the *orca symbolic vocalization orca faculty* is a species-specific instance of what we may call a generic *symbolic externalization faculty*, which is “broadly spread among the animalia”, analogously or homologously, and is “evolutionarily ancient” (cf. Gallistel, 2011); (vii) the *orca symbolic vocalization faculty* is itself a sub-faculty of the species-specific *orca symbolic externalization faculty*, that potentiates the externalization and comprehension of symbolic representations in orcas, including non-vocal symbolic externalizations, if any; (viii) the species-specific orca systems and faculties evolved as elements of the evolution of the orca species.

One can ask questions about how and why any of the abovementioned *systems* or *faculties* evolved—all of these being assumed to be neurally embodied computational systems, physiological “machinery”, potentiating various sorts of functional symbolic activities. And one can likewise ask how and why these functional symbolic activities evolved, which is a different sort of question. Seeking answers to any such questions from the evolutionary perspective amounts to trying to show how and why the relevant systems or activities are either selected by, or preserved by, natural selection, taking into account the mutual influence of development and phenotypic variation upon one another, and the mutual influence of environmental change and phenotypic evolution upon one another. This is what might be called the generic answer to our question (2); specific answers will derive from our answer or answers to our question (1). The possible answers to question (1) are many, and in a work of this length, we must make a parsimonious decision. Since the present study rests upon the survey of orca vocalizations undertaken in Chapter 3 and the account given in Chapter 4 of the ways in which these vocalizations function in the lives and activities of orcas, we will narrow our commitment to trying to give an account of “the evolutionary roots of orca symbolic vocalizations” that addresses the questions of how and why the items on

our survey that are arguably *symbolic*—these being particular functional activities or behaviors—became, or simply are, heritable parts of the natural repertoire of orcas. In focusing upon this, however, we will need to take into our discussion many aspects of orca vocalizations more generally; not merely their symbolic vocalizations. But many other things that might have been asked about will have to be left for another day.

Thus, the initial framing of our evolutionary accounts will be of the sort described in §5.6. But since the things that we attempt to account for will be fine-grained instances of orca functional activities, rather than the generic activity of *orca symbolic vocalization per se*, this will make our accounts rather different in structure than Chomsky’s corresponding account of human spoken language (the human ability to speak and to interpret speech and the human activity of speaking and interpreting speech; see §5.6).

6.1 The evolutionary roots of orca symbolic vocalization

If we are to discuss the evolutionary roots of orca symbolic vocalization we must first examine a wider domain of traits than symbolic vocalization. One basic trait is simply that orcas vocalize. This trait exemplifies what we called an ability, functional activity or behavior, so the initial perspective of an evolutionary account would be that described in §5.6. The trait described simply as *vocalization* is common to a very wide range of animals that belong to varied and divergent lines of descent. In nearly all cases, it is quite uncertain at what point vocalization appeared in a common ancestor for a given branch of the evolutionary tree, but it appears in general to have been very early. More significantly, this thinly described trait has evidently persisted through evolutionary descent in different lines, which indicates that it must have been advantageous from the standpoint of natural selection to animals with extremely different lifestyles, body plans, vocal organs (nascent or developed), behavioral repertoires, developmental characteristics, environments, and habitats.

One can presumably say much more about the way in which vocalization gave its possessors evolutionary advantages by focusing upon *specifics*, that is to say, upon specific species or varieties of organisms living in specific circumstances, but there would seem to be little hope of, or purpose to, trying to find some global benefit to account for the persistence of this trait through the evolution of species. But if we look specifically at *orca* vocalization, we can try to account, from an evolutionary perspective, for some of the particular features that it exhibits; these may be considered traits in themselves.

It is not clear which animals exhibit *symbolic* vocalization, in part because, as we remarked previously, there is no very clear, common idea of what symbolic vocalization, or what other forms of symbolic externalization, are. We do not assay to clarify that idea definitively in this thesis but will add a few pertinent reflections here.

In connection with *communication*, we made a distinction between thicker and thinner senses of that notion. We suggested that vocal communication in the thicker sense involved the vocalization’s having *content* that a conspecific auditor could interpret, in the sense of understanding that content; a human example would be if someone said, “I am in pain”. If the vocalization were, on the other hand, a yelp or a moan, that might *signal* to a conspecific auditor that the vocalizer was in pain although the auditor did not *describe*, or communicate in terms of semantic content, its condition; this we said was communication in a thinner

sense. We suggested there that the thicker communicative vocalization was symbolic, whereas the thinner communicative vocalization was not. (See earlier discussion in §5.2.)

Now if we continue to accept that very tentative suggestion, we need to add something to it here, which is that the suggestion may pertain to the *utterances* in question, but not to the *interpretation* or *reception* of the utterances by an auditor. In a creature that has a symbolic vocalization faculty, that faculty is responsible not only for *externalizing* (that is to say vocalizing) symbolic representations, or “thoughts” in the form of utterances, but in *interpreting* utterances symbolically—as if they had semantic content—whether the utterances externalize such content or not. So it is a function of a symbolic vocalization faculty to interpret a heard utterance like a groan in terms of a “thought”—“Ah, that creature is in pain”—although that thought was not externalized by the groaner. In that way, vocal communication in the thinner sense may also be considered symbolic.

The key point is that symbolic vocalization (or other forms of symbolic mediation) is an *interactive activity among conspecifics and has two sides*: the externalization of “thought”, or semantic content, and the interpretation of vocalizations, which involves either the “reading” of their content or the attribution of such content (significance), or both. We see no reason why Chomsky, or anyone willing to consider symbolic interaction in both linguistic and pre-linguistic animals, would have any deep objection to this; niggling objections are another matter that must be left out of consideration here. However, Chomsky and his close associates only really talk, in any detail, about one side of a two-sided, interactive activity—the externalization, vocal or otherwise, of symbolic representations. The interpretive side remains mostly in darkness and ill-described, even if recognized. But robust awareness that symbolic vocalization is a two-sided, interactive activity is needed for the purposes of the discussion that follows.

The symbolic interpretation of perceived external contingencies that, as we have just maintained, is an integral part of symbolic interaction is of great importance far beyond the province of symbolic vocalization. The translation of observed behaviors into symbolic representations or “thoughts” by animals that think symbolically is interestingly discussed by Gallistel (2011); at the risk of taxing the patience of the reader, we find it enlightening on a key issue to quote at some length once more from his article, “Prelinguistic Thought” (pp. 258-259):

Data structures [or “what linguists and philosophers call symbolic statements”] integrating diverse aspects of single episodes are implied by the results of a lengthy series of experiments on the cache memory in food-caching jays done by Clayton, Emery, and Dickinson (2006). Jays cache food by burying single beakfuls in locations spread over square kilometers. The jays that Clayton and her collaborators work with make thousands of these caches as winter approaches. During the winter, they survive by harvesting the food from them, itself an astonishing feat of spatial memory. They are like squirrels in that regard but on a grander scale.

Clayton et al. exploit the fact that these birds are omnivores and, like us, they like some foods much more than others. They tend to harvest first the foods they like best. There is, however, the problem that some foods rot much more quickly than others; a fresh meal worm is delicious, but a rotten one is inedible. Clayton et al.

have capitalized on this to demonstrate that jays remember *where* they cached *what* and *when*, *who* was watching, and *whose* cache they are emptying. When it comes time to retrieve the caches, they go first to the ones that contain what they like most, unless they made that cache so long ago that its particular contents will have rotted. In making the latter judgment, they compare the time elapsed since they made the cache to what they have subsequently learned about how long it takes for the kind of food they put in that cache to rot.

Experienced jays are sensitive to whether another jay is watching when they make a cache. If they make some caches while another jay watches and some when no other jay is present, they return later and selectively retrieve and rebury the caches made while another jay was watching. What is most interesting from a linguistic standpoint, and perhaps also for those interested in the ontogeny of moral thought, is what makes a jay an “experienced” jay, that is, a jay suspicious of the intentions of other jays. Jays that have never plundered the cache of another jay are insensitive to the presence or absence of another jay when they make their own caches. Only birds that have plundered the cache of another are sensitive to this variable (Emery & Clayton, 2001). This result reveals a behavioral consequential distinction in the bird’s memory between caches it made and caches made by others. The roots of the possessive would seem to lie here.

More generally, these results imply the existence of a complex data structure in the memory of jays. It must represent different kinds of food, different points of time in the past, different temporal intervals (rotting times and times elapsed since a point in the past) different locations, different observers, and different agents (self or other)—in a way that captures the connection of all these variables to a single episode.

The generalization from a jay’s own behavior to the likely behavior of others seems to me of particular interest for the light it sheds on the relation between thought and natural human languages. I would suggest that the jay’s generalization is most readily understood if one assumes that in the thought of a bird, as in, I believe, every language, the symbol for an action is independent of the agent and the direct and indirect objects (<*I*>**take** <*your*><*food*>, <*you*> **take** <*my*> <*food*>). The inferences that birds draw from their own behavior to the possible behavior of others suggest to me that this way of representing actions predates by hundreds of millions of years the emergence of natural human languages.

Here, the presence of nearby jays, rather than the vocalizations of nearby orcas, is represented in the form of “symbolic statements” (data structures) and incorporated into a strategic action plan nested in a larger, very complex data structure that includes generalization from the jay’s own behavior. What is operative here is, at the ground level, what we called the “interpretive” aspect of symbolic activity; externalization is not the primary point.

If orcas have a symbolic vocalization faculty that enables them to externalize their symbolic representations vocally and to interpret orca vocalizations symbolically, whether or not they

are externalization of symbolic representations, how and why did these vocalizing and interpretive activities and behaviors become heritable characteristics of orcas? Why did the ability to symbolize arise, and why was it favored by selection? Did it happen analogously to Chomsky's account of the advent of the language faculty—first as a random, non-adaptive mutation that occurred without selective pressures? And did this mutation “stick around” because it provided an advantage for the individual in which it happened, giving it simplest and most efficient computational algorithm for thought, planning, and other such cognitive activities? And was it only later externalized into vocalization, when it became beneficial to use this ability for communication?

Or, alternatively, is the symbolization faculty based on a more complicated and less “economical” process than the one humans possibly have? And would this lack of efficiency be the reason why killer whale vocalizations are not as complex as human language? Moreover, if Merge is the most “economical” way to make complex structures into new ones, as Chomsky maintains, and recursion does not exist in other animals, what does this imply about killer whales? If killer whales have the ability to make new structures, but do not have recursion, do they therefore have an alternative kind of ability to create new structures? Why would this type of ability arise?

Or rather, could a symbolization faculty evolve gradually? Did vocalizations along with the cognitive abilities of killer whales and their social environment, gradually become more complex? Dor and Jablonka (2010) suggest, for example, that language in humans evolved as a gradual improvement in the cognitive abilities that made symbolic thinking also possible. Fox, Muthukrishna & Shultz (2017) speculate that, like human cognition, cetacean cognition possibly arose adaptively “to provide the capacity to learn and use a diverse set of behavioral strategies in response to the challenges of social living” (p. 195).

Whether or not symbolic vocalization evolved gradually or through a sudden mutation, why was it favored for selection? How did the ability to symbolize, to communicate these symbolizations to others, and to interpret vocalizations, aid in survival and reproduction?

It is difficult to answer these questions; but one thing seems pretty clear, which is that this trait, considered as an ability, activity or mode of behavior, appeared originally in very ancient ancestors of the orcas, perhaps in a piecemeal fashion, and was inherited by orcas from their proximate ancestors. In short, we suppose that it did not appear originally in orcas in the way that Chomsky supposes that language and speech appeared originally in *Homo sapiens* at a later time than the appearance of the species itself. We suppose that the *orca* version of symbolic vocalization, with the characteristics that differentiate it from the orcas' proximate ancestors, appeared when the orcas appeared as a distinct species, as part and parcel of that species evolution.

To the extent that the evolution of *Orcinus orca* can be accounted for by natural selection, what was selected was a certain organism that had a certain package of abilities, activities, or modes of behavior that, as a whole, made that organism apt for selection, i.e. a package that was selectively advantageous for the flourishing and continuation of the species—for robust reproduction in the environmental niches that members of the species created and exploited. Not all of the abilities, activities, or modes of behavior in the package were necessarily advantageous in this way, but, if we find that it was historically persistent in the orca ancestral line, we can assume that symbolic vocalization as such was advantageous to orcas and their ancestors from the standpoint of natural selection. What remains to be

accounted for, if we are able to do so, are the species-specific features of *orca symbolic vocalization* that, we have been supposing, appeared with the appearance of orcas as a species. The supposition just mentioned, by the way, has been made for the purposes of simplification and is rebuttable. It is entirely possible that *orca symbolic vocalization* has evolved during the history of the orca species and is not as it was when the species originally appeared in the course of evolution. If we find evidence of such evolutionary changes, then they would be events to be accounted for from an evolutionary perspective.

We note here that much of what has been said in the last two paragraphs mirrors our discussion, in §5.4, of the evolution of the neurally implemented structures hypothetically underlying orca symbolic vocalization, here considered as an ability or activity. Indeed, the points made in §§5.4-5.6 need to be kept very much in mind in reading the present chapter, which continues the thread of Chapter 5.

In approaching questions concerning the species-specific features of *orca symbolic vocalization*, we will look at the symbolic vocalization phenotype as a nexus of the organism and the environment that is the result of phenotypic variation, selection across generations and plastic responses within generations, a perspective that can also be applied to the language phenotype. We should keep in mind that the natural environment of killer whales is one that includes vocalization as an important part, a part that is created by, and that in turn influences, orca vocalization. The natural environment of killer whales is also one that is importantly social, and, indeed, the interactive vocalization environment is a part of the larger social environment. It may be that, as Gallistel (2011) claims—based upon extensive research of his own and of others on animal cognition—very many animals, on various branches of the evolutionary tree, have thoughts in the form of symbolic representations (even abstract representations) and can use these to plan and make inferences (like the jays studied by Clayton et al. (2006)), but symbolic interaction (externalization and interpretation) with conspecifics (like the bees investigated by Gallistel and many others) seems to be most highly developed among social animals, and in fact social and symbolic interaction (considering the latter as a distinct sort of activity) are evidently interdependent, for obvious reasons. Hence it seems likely that social and symbolic interaction evolve in tandem.

Following Müller (2007), we can look for some answers to three “eco-evo-devo” questions: (i) How does the orca vocalization environment interact with developmental processes? (ii) How do changes in the vocalization environment influence phenotypic evolution? (iii) How does developmental evolution affect the vocalization environment? The following three subsections propose some answers these questions. We must note, however, that answers to these three questions overlap, so it is not possible to deal with each of them in entire separation from the others.

6.1.1 How does the environment of killer whales interact with developmental processes?

How do vocalization and symbolic vocal interaction develop in a calf, and what role does its environment play in the developmental process? Similarly to humans, orcas learn vocalizations socially rather than inheriting them genetically (Ford 1986; Filatova et al., 2015; Abramson, Hernández-Lloreda, García, Colmenares, Aboitiz & Call, 2018). Therefore, the social environment, which is, as we said, importantly an environment of

vocalization, plays a crucial role in the development of vocal repertoires and skills. For example, a calf will not learn the dialect of an absent parent (Ford, 1991). There must also be some internal capacity in killer whale calves, which is triggered by vocalizations of conspecifics and makes it possible for them to develop their vocal repertoires and learn the dialects of their group automatically, because vocalization skills develop through simple social exposure (like language skills in humans). This would also be a capacity to understand symbolic interaction and to attribute semantic content (significance) to non-descriptive vocalizations. Killer whales do not need explicit instruction to acquire their various vocalizing skills; rather all the information about sound, structure, and possibly meaning, that they need for this purpose derives from the vocalizations themselves.

Chomsky maintains that language is the result of the development of language in a child and the long-term evolution of that child's genetic ability to learn a language, while Hauser et al. (2014) argue that, in nonhuman animals, sounds or gestures are innately specified. Given our references, the latter seems not to be true of all non-linguistic animals. In orcas (and there are even better examples) vocalization, including symbolic vocalization, is the result of the development of a group-dialect in a calf and the long-term evolution of the genetic ability of a calf to learn those vocalizations. As a child will learn any language if exposed to it, independent of its parents' mother tongue, so a killer whale calf has the capacity to learn repertoires of vocalization and to acquire the dialect of its particular family group.

Adult animals possibly influence the development of vocalization by changing their vocal behavior to help a young killer whale learn to vocalize. In the days following a birth of a calf, family-specific call types were observed to occur much more frequently than usual, possibly facilitating "the learning process of this 'acoustic family badge'", helping the calf recognize and maintain cohesion with family members" (Weiss et al., 2006, p. 627). Aberrant calls that were characterized by excitement also increased after a birth, which Weiss, Ladich, Symonds and Spong (2006) suggest were either excitement calls of family members, or the undeveloped stereotyped calls made by the calf. Using more family-specific call types and excitement calls could serve a similar purpose to infant-directed speech or "baby talk" in humans, which combines exaggerated vowels with a happy emotion, supporting language acquisition and development (Kalashnikova, Carignan & Burnham, 2017). If orcas use *infant-directed vocalizations* to aid the development and learning of the pod's dialect, this might be done knowingly, at least to a certain degree. However, it is worth noting that, even in humans, infant-directed, high-pitched speech is often performed almost reflexively, without a conscious intent to teach language to an infant.

It is possible that an orca calf learns to vocalize primarily through vertical transmission from its mother (Filatova & Fedutin, 2011). Ford reported that a captive-born calf "learned and reproduced only the calls of its mother, and apparently ignored the different repertoires of calls used by other conspecific individuals held in the same pool" (Ford, 1991). Together with the "accumulation of errors in call learning across generations, call innovation and call extinction", vertical transmission may have produced different dialects in sympatric pods (animal groups of the same or overlapping geographical areas) (Ford, 1991, p. 1454). But, although killer whales learn their family's dialect young, the entire "lexicon" of orca vocalization is not necessarily acquired "by the end of the early juvenile period", as Hauser et al., (2014) claim is the case in signal-using nonhuman animals (p. 4). Orcas remain able to learn new sounds horizontally as adult animals and include those sounds into their repertoires (Filatova, Burdin, Hoyt, 2010). Horizontal learning leaves open the possibility for intraspecific communication between groups with different repertoires, to facilitate

sharing and cooperation. (Filatova et al., 2010). If animals were only to learn through vertical transmission, group repertoires might eventually evolve to be so different that only intragroup communication would be possible.

A calf may also be affected by social “pressures” in its learning environment. For example in the populations of transient killer whales, calves probably learn silent behavior by observing adults, and may also learn to be silent “the hard way”, if a prey animal escapes from them because they were too loud. Also, adults—not least a calf’s mother—likely want to build a connection with the calf, pushing it to learn vocalizations. It might also be selectively beneficial for calves to start vocalizing as early as possible, since navigation, finding food, socialization and maintaining contact with the pod are all central to survival. So, cognitive abilities that facilitate rapid learning of vocalization are likely favored by selection. “Seaworld” (*Sound in the Sea*, n.d.) reports that, in captivity, calves vocalize within days of birth in “loud, high-pitched calls that bear no resemblance to adult-type calls”; and at about two months of age, “a calf produces its first pulsed calls with similarities to adult-type calls”. However, calves live in close contact with their group and, at least in captivity, mothers may nurse their young for up to two years (Ford, 2002). Therefore, it is also possible that learning to vocalize very early does not have a great impact on their survival in other than in the likely rare circumstance in which a calf loses contact with its group and would be able to call out for them, making it easier for group members to find it.

6.1.2 How do changes in the vocalization environment influence phenotypic evolution?

Orca vocalization has evolved, and develops, in an underwater environment, where sound travels very efficiently (Urick, 1983), about 4 times faster than in air (“Understanding Ocean Acoustics”, n.d.). Because of this, and often poorer visibility underwater, the acoustic channel is evidently much more important for marine animals than it is for terrestrial animals (Filatova et al. 2013). The land-mammal ancestor of killer whales almost certainly vocalized in some way, similarly to most current land mammals, but probably quite differently from orcas. It is doubtful that such ancestors used echolocation, which would have been less effective than in an aquatic environment and probably evolved once the ancestors of cetaceans moved into water and became amphibious or fully aquatic. The ability to echolocate would then have become advantageous for finding food or for detecting predators at a distance. The early ancestors of killer whales were quite small compared to modern killer whales (Thewissen, Cooper, George & Bajpai, 2009), and it is entirely possible that they had natural predators. However, since baleen whales do not echolocate (Pavid, 2020), this ability might have not evolved until the earliest diverging odontocetes appeared and started to use it for foraging and hunting. (Coombs, Clavel, Park, Churchill & Goswami, 2020). Although echolocation pings do not have semantic content as such, they may have *significance* (attributed content in interpretation) for an auditor—“object ahead”, or “prey ahead”—and qualitative differences among reflected pings might vary their significance.

Selective environmental pressures may have influenced the developmental structures that make vocalizing possible and render it effective in an animal’s environment, such as the marine environment of orcas, because an individual that can make a clearer or stronger sound may have had an advantage in survival and reproduction.

The cognitive abilities that make communicating and interpreting vocalizations possible, and the social environment, may have pushed one another forward in evolution, through natural selection. For example, an individual with slightly better cognitive abilities, might have made the social environment somewhat more complex. And an individual with slightly better cognitive abilities might have an advantage in reproduction, eventually making these abilities a part of the heritable characteristics of killer whales.

If the ancestors of modern orcas developed phenotypic abilities that made communication possible in a thick sense—imbuing vocalizations with semantic content—rather than only in a thin sense, then these may have been selected for. For example, taking the example from the Crozet archipelago (see §4.5), where killer whales from other groups moved to the location of a successful kill when hearing long distance contact calls, it would be advantageous to know what those calls are about: whether, for instance, there has been a successful kill of an elephant seal and there is enough food to share. Moving several kilometers takes energy, and so it might be important to move only in response to long distance calls when there is a good reason to, disclosed by content, and not each time such calls are heard, especially if they originate from members of another group. But this would require the ability to emit a variety of contact calls, each with a different symbolic significance that could be interpreted by auditors.

In the social structure that killer whales have, there are large differences between how close individuals are to one another within that structure. Matriline groups stay together for life, while other groups interact with each other only occasionally, and others never. And even in a matriline group, orcas seem to have preferences for certain individuals over others, interacting most actively with individuals of a similar age and the same sex. In a socially complex structure like this, in which individual relationships as well as relationships between groups differ from one another, it makes sense to have some way of managing these differences as well as understanding them and communicating them to others, and, for killer whales, symbolic vocalization seems to be an important medium for accomplishing this.

It seems plausible that this would have happened over time, with social relationships and social communication and the ability to symbolize developing gradually. The more efficient communication is, the more ways of cooperating with each other there might be. And with more ways of cooperating come better chances at survival. With the amount of energy killer whales need, hunting in the ocean is probably a task that could not be achieved as efficiently as required without echolocation and some form of sharing of information. Staying in one place and waiting for prey animal to come close enough to see them in water, might not even be a sufficiently efficient hunting technique to sustain one orca, let alone a pod.

Why then are orcas not solitary animals that eat fish to survive, and thus do not need the help of a pod to hunt down a larger animal for instance? Possibly they might have been. But in their early evolution, living in groups may have been advantageous, and once it became possible for them to share information and communicate, it would have become even more advantageous. Moreover, as their cognitive abilities increased, they probably became emotionally needful of having other orcas close to them, further driving forward the evolution of efficient communication.

If we look at some of the examples from our survey of the vocalizations of modern orcas, we can see the environment as constantly influencing the vocalization phenotype and the phenotypic evolution of vocalizations. For example, which groups killer whales interact with

will affect which vocalizations are incorporated into their repertoires through horizontal learning. Learning the calls of other pods may influence mating preferences, therefore affecting phenotypic evolution. Horizontally learned calls may also be passed on socially to other group members and generations, further affecting how those individuals interact with other groups.

We also discussed how transient populations stay silent most of the time, very likely to avoid eavesdropping by prey animals, while residents and offshores vocalize most of the time. In these different ecotypes of killer whales, both the environment and their behavior of (what prey they hunt) have an effect on how vocalizations are used. This has made the repertoires of mammal-eating transients very different from their fish-eating conspecifics. It also seems plausible that this type of behavior requires a level of planning and thinking, which could also further affect phenotypic evolution.

6.1.3 How does developmental evolution affect the vocalization environment?

Certain developmental structures appearing, such as the fat pad that connects the lower jaw to the middle ear (Thewissen et al., 2009) possibly increased the efficiency of sound for cetaceans. This pad of fat was present in remingtonocetids, an early aquatic cetacean (Nummela, Thewissen, Bajpai, Hussain & Kumar, 2004). Pakicetids, the earliest cetaceans, already had skull structures and a lower jaw that implies a different kind of path of the nerves going to the eyes and nose than are seen in other land mammals, which again suggests that their sense organs were different (Thewissen et al., 2009). In modern cetaceans, the jawbone acts as a sound receptor, transmitting sounds to the ear canal and auditory nerves (Ocean Today, n.d.). But, for simple echolocation, these special of structures are not necessarily needed, since there are even accounts of humans who acquire this ability to a surprising degree (Norman, Dodsworth, Foresteire & Thaler, 2021).

Other odontocetes, namely sperm whales and bottlenose dolphins are known to have complex vocalizations, which seem to also be quite sophisticated, like the vocalizations killer whales use. Two important increases in the brain size of cetaceans appear to have occurred, first in Archaeoceti, and second, when delphinids arose, around 15 million years ago (Marino, McShea & Uhen, 2004). It is possible that after this time, in a common ancestor of bottlenose dolphins and killer whales, the abilities for mentally combining existing structures creatively took a leap forward. This would not need to involve the introduction of unbounded Merge as a computational operation, but it could well betoken the development of a different sort of internal ability for increased complex thought, planning and the creative combining of structures and elements: a “symbolization faculty”.

If an internal ability to symbolize arose in the ancestors orcas, and once it did, it might have given rise to vocal externalization, since killer whales would have already had the ability to vocalize at this point, assuming that there land-dwelling early ancestors already did. And a similar event might have happened, for instance, in bottlenose dolphins and sperm whales. Vocal externalization may have become beneficial because this behavioral strategy increased “the reliability and efficiency of intrapod communication” (Ford, 1989, p. 743); and the development of group dialects possibly enhanced the effectiveness of this system (Cohen, 2012). With more efficient communication, social relationships have the chance to become more complex, further emphasizing the advantage of complex vocalizations.

When the vocalizing and communicating abilities of orcas or their ancestors became more sophisticated, it likely increased their chances of survival, and could have even played an important part in putting orcas on top of the marine food chain. For example, the ability to control vocalizations and stay silent when hunting a marine mammal, could have been instrumental in making it possible to keep hunting marine mammals.

Currently, vocalization seems to influence which individuals and groups orcas interact with, since there is a correlation between the amount of group interaction and call similarity. Having similar calls might make communication more efficient, and intrapod communication might be more efficient than communication between different pods. Clans, for instance, are defined as groups of pods that interact, and that have something in common in their vocal repertoires. The groups that individuals and groups interact with because they have something in common in their vocal repertoires, will likely affect mating choices, and by way of that, affect phenotypic evolution. And the phenotypic evolution of vocalization or other phenotypic evolution that affects vocal behavior, will feedback straight into the environment, through the vocalizing behavior of orcas.

7. Conclusion

In this thesis, we have studied killer whale vocalizations and what we have called the orca vocalization and symbolic vocalization systems, and their possible evolution. We have done this by comparing what we have called the relevant contingencies of human language, with vocalization, and by positing hypothetical counterparts of the elements comprising Chomsky's biolinguistic account of language and tracing out the implications of viewing the orca vocalization systems, and their evolution, on the basis of that platform.

We started off by explaining Chomsky's biolinguistics account of language, an account which we chose to use in this thesis as our definition of language, including FLB and FLN. We then moved on to survey studies on orca vocalizations, and discussed their possible functions and their syntactic and semantic properties, as well as what they possible tell us about the psychology of killer whales. We said that orcas could plausibly have an *orca syntactical symbolization faculty*, a counterpart to the human FLN that Chomsky postulates, but does not, viewed as a computational system, rest upon a functionally recursive operator. We also noted, that having the ability to mentally symbolize something, and having the ability to successfully externalize that in order to interact symbolically with conspecifics, are two different things. If orcas have a symbolization faculty that they are able to use in their own way to make sense of their world, reason and symbolize, their ways of communicating these private thoughts and feelings to conspecifics do not match the abilities of humans to do so.

Although we decided early not to criticize Chomsky any more than necessary or discuss alternatives to the views that we were adapting to our purposes—simply because that would have entailed a book-length discussion on its own—we did find that there were obscurities in Chomsky's account that made the evolutionary issues to be addressed uncertain; and, in consequence, we tried to clarify those issues (§§5.3-6.1, intro.) This revealed some limitations on the extent to which evolutionary questions concerning symbolic vocalization in orcas (or orca vocalization more generally) could not follow a counterpart of the path that Chomsky envisions for language. Moreover, it raised some questions about the latter (see, in particular §5.3), which were, however, not pursued, in favor of sticking to our topic. It proved important to distinguish between *generic* traits (whether neutrally implemented computational structures or modes of activity), such as *symbolic representation* or *vocalization*, that have been present in diverse lines of descent from a time very long before the advent of orcas as a species, and the *species-specific orca expressions* of these traits, which evolved either along with the emergence of the species or by subsequent evolutionary development within the species. Concluding that there is, in the present state of knowledge, very little (although not nothing) that can be said about the evolutionary origins of the generic traits that orcas inherited from their proximate ancestors that does not amount to

speculative hand-waving, we concentrated instead on the species-specific orca versions of selected traits, in particular symbolic interaction through the vocal medium. It is in this domain that the eco-evo-devo approach to evolutionary and developmental questions is particularly apt. Significant uncertainties, of course, remained.

7.1 Some uncertainties concerning orca symbolic interaction, vocal and otherwise, and its evolution

Assuming that orcas interact symbolically, in a manner that surpasses the denatured account of Hauser et al. (2014), we do not yet know to what extent this ability makes it possible for killer whales to think, plan, interpret and be creative. The waggle dance performed by bees and the use individual tags or “names” by bottlenose dolphins are quite clear examples of communication in the thicker sense and of the use of abstract symbolic representations and sophisticated calculation, but we do not yet have equally clear examples of orca symbolic communication (vocal or otherwise) in the thicker sense. It can anyway be difficult to draw the line in some cases between communication in a thin sense and communication in a thick sense if we focus upon interpretation rather than upon externalization (see the introductory discussion in §6.1). To return to the study from the Crozet archipelago reporting that a long distance call characterized by excitement often resulted in other groups coming to the area from several kilometers away we may ask: Do long distance calls just signify something important, or may they signify food? And if they signify food, is there a specific call that actually tells the receiver that there is food available; or is this communicated in a thinner, more indirect way?

Orca dialects can be seen as symbolic, in a thin sense, of the group that they are used by, since they help orcas recognize their own group members. In §4.4, we talked about a study in which orcas that were played calls of different pods only turned their direction of movement toward the boat half of the time, but when they were played calls of their own pod, they turned their direction toward the boat in seven of the eight cases. Filatova and Fedutin (2011) believe that the reactions to playbacks of calls of other groups were diverse enough to be explained by the various social relationships between different groups and group members. However, whether or not these different calls symbolize the many complexities in social relationships, we do not know yet.

We also do not know, whether vocalization is based on a simple algorithm that generates all vocalizations, or whether they are produced by a different kind of computational ability that generates a relatively large “package” of sound sequences and combinations of elements. Looking at the elements of human speech, such as sentences, we see a code-like operation of combining elements into longer sequences and changing the order of elements in a sequence to get a different meaning or “result”. And a supposed mutation that gave humans unbounded Merge, might be the most efficient way to conduct the computational operation humans use in language.

It seems that, as with language, we can only speculate about how vocalization evolved, both as a set of neurally embodied structures and as a set of abilities or type of behavior. Our current knowledge does not seem to suffice for explaining, other than speculatively, symbolic vocalization as a trait that evolved either by natural selection, or alternatively without selective pressures. Studying the evolution of symbolic vocalization seems to run into similar issues that Hauser et al. (2014) describe as “challenges in the study of language evolution.”

First, we have not been able to assess the comparative landscape of human language. Studies have assessed the computational and perceptual capacities and language learning in other animals, but almost no evidence of vocal learning, a babbling phase, sensitive periods or inductive leaps—all typical features of human language—has been found in other animals. Even if orcas have these characteristics and go through these periods and phases, they are too distantly related to us to help in evaluating the comparative landscape. In other words, we cannot understand the evolution of orca vocalization or human language as connected processes, even if they were or are similar to each other. Second, different fields of sciences have their limits. Current paleontological evidence of features in bony structures, anatomy, aural abilities and the genome of *Homo neanderthalensis* will not tell us much about how language as an internal machinery or external activity emerged, or about the possible selective pressures behind their evolution. Mathematical models tend to include assumptions that cannot be tested empirically, and therefore, they do not explain how language originated or help understand the difference between the biological capacity and its adaptive or non-adaptive functions. And molecular biology has not told us much about how and what genetic factors and mechanisms are responsible for language and its evolution, what the developmental processes behind language development are, and what for example, are the neurobiological processes of recursion (Hauser et al. 2014). Therefore, we simply do not yet have enough knowledge to build an evolutionary account of language.

In the case of killer whales, assessing the comparative landscape is even more complicated because we do not yet understand vocalizations. And bottlenose dolphins learning the grammar of an artificial language does not ultimately tell us much about their own, natural vocalizations. Fossil evidence of bony structures, anatomy and aural abilities of the earliest killer whale *Orcinus citonensis* from the Pliocene Epoch (*Britannica*, The Editors of Encyclopedia, *Killer whale*) will not tell us how it vocalized, or about the internal systems that were connected to this ability. Considering the fact that orcas live in the ocean, it is also possible that there is fossil evidence that we are currently unable to find simply for practical reasons.

When it comes to humans, we can look for archaeological evidence of symbolic behavior or tool use. But since killer whales have fins instead of hands, their possible cognitive abilities for symbolic behavior would likely not manifest themselves in the creation of symbolic artefacts. Also, the internal ability for tool use does not necessarily mean that this ability will be used in practice. For example, a population of bottlenose dolphins in Shark Bay,

Australia, uses marine sponges as foraging tools (Smolker, Richards, Connor, Mann & Berggren, 1997), but there is no evidence of tool use in other populations of dolphins.

We also do not know much about “how neurobiological systems link to ... ‘language-like’ communication” (Hauser et al., 2014, p. 14) in killer whales, what genetic factors and mechanisms are responsible for vocalization and its evolution, or what developmental processes are behind the development of vocalizations, and what are the neurobiological processes behind it. Hauser et al.’s (2014) points about human language address some important issues that need to be addressed in killer whales as well, before we can claim to understand the evolution of their symbolic vocalizations.

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