Darwin and the Golden Rule: How to Distinguish Differences of Degree from Differences of Kind Using Mechanisms

Forthcoming, *Biology & Philosophy*

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In *The Descent of Man*, Charles Darwin proclaimed that "the difference in mind between man and the higher animals, great as it is, is certainly one of degree and not of kind." (Darwin, 1871, vol. 1, p. 105). This claim is quoted approvingly by contemporary animal experts such as Frans de Waal (2016, p. 1). Similarly, Mashour and Alkie (2013) debate whether the difference in consciousness between humans and other animals is one of degree and not kind.

Such contentions prompt difficult questions.

- Semantic: What does it mean to say there is a difference only of degree and not of kind?
- Epistemological: How can scientists legitimately judge whether differences are of degree or of kind?
- Ontological: What is the real difference in the world between matters of degree and matters of kind?

This paper proposes answers to these questions by analysis of mechanisms, which are combinations of connected parts whose interactions produce regular changes that include emergent properties.

The resulting answers are relevant to important issues concerning complex systems. Hegel (1969) and Engels (1947) emphasized the transition from quantity to quality as a fundamental principle of change, and Robert Carneiro (2000) advocates it as a mechanism of social evolution. The distinction between quantity and quality is the same as the distinction between degree and kind: changes in degree are quantitative whereas changes in kind are qualitative. In contemporary discussions of complex systems, there are many terms that signal a shift from changes in degree to changes in kind, including *tipping point*, *phase change*, *critical transition*, *nonlinearity*, *inflection point*, *catastrophe*, *singularity*, and *discontinuity*. Specific fields use terms that indicate changes in kind and not just degree, for example, *punctuated equilibrium, ecological threshold, regime shift*, *crisis, revolution, Gestalt switch*, and *paradigm shift*. Hence answers to the semantic, epistemological, and ontological questions about degree/kind are important for issues that range beyond animal behavior. For example, current fears about climate change see our planet as approaching a tipping point where quantitative increases in global temperatures will have irreversible qualitative consequences such as devastation of many coastal areas (Lenton et al., 2019).

To defend himself against critics who maintained that human minds did not evolve by natural selection, Darwin (1981, vol. 1, p. 35) set out to show that "there is no fundamental difference between man and the higher mammals in their mental faculties." He recognized two major challenges to this claim in the high intelligence of humans and their moral sense. He argued that the social instincts of lower animals developed into the occurrence of praise and blame among early humans, which eventually developed into moral principles such as the Golden Rule: "To do good unto others – to do unto others as ye would they should do unto you, the is the foundation-stone of morality" (Darwin, 1981, vol.1, p. 165). This rule is culturally much broader than the Christian version that Darwin knew, as variants can be found in ancient China, India, and other societies (Gensler, 2013).

I will argue that the Golden Rule refutes Darwin's claim that there are no differences in kind between the minds of humans and the minds of non-human animals. After a review of ideas about mechanisms and emergence from contemporary philosophy of science, I consider recursion as a property that marks an emergent difference in kind that is special to human minds. The Golden Rule and some other ethical principles involve recursive representations that are beyond the capabilities of the most cognitively advanced animals such as the great apes, dolphins, and elephants. However, recognition of differences in kind in the development of human minds is compatible with Darwin's main hypothesis that they evolved by natural selection. I follow the usual practice of using "animal" as short for "non-human animal".

The major point of this article is refutation of Darwin's claim about differences between human and animal morality. My argument depends on a new analysis of the degree/kind distinction based on mechanisms, emergence, and recursion.

1. Mechanisms and Emergence

Google Scholar gets more than 10 million hits for the term "mechanism" across many fields of science and technology. Contemporary philosophy of science recognizes the importance of mechanisms to scientific explanation (Bechtel, 2008; Craver and Darden, 2013; Glennan, 2017; Thagard, 1999, 2019b). Terminology varies for the ingredients of mechanisms as shown in the first row of Table 1, but in general mechanisms are combinations of connected parts whose interactions produce regular changes that result in behaviors, functions, or other phenomena. For example, the heart is a combination of muscular walls and valves that interact to pump blood through the body. The parts and interactions in mechanisms cause changes as indicated by terms such as “result in”, “produce”, and “is responsible for”.

Interpretation of the regularity of mechanisms is controversial (Craver and Tabery, 2017). By “regular” I do not mean “universal” because complex systems involve interacting causes that make patterns of change stochastic. For example, heart mechanisms pump blood but can be disrupted by unpredictable events such as clots and aneurysms. For the purposes of this paper, “regular” can be interpreted as “nearly universal”.

	Combination (whole, system, structure)	*Parts (entities, components)*	*Interactions (activities, operations, functions)*	*Changes*	*Results (behaviors, functions, phenomena)*
Mental mechanisms	mind	represent-ations	inferences, associations	new or modified representations	thinking
Neural mechanisms	brain	neurons	excitation, inhibition	firing patterns	brain function
Molecular mechanisms	neuron	genes, proteins, neuro-transmitters	chemical reactions	properties of neurons	neural firing

Table 1. Mechanisms relevant to explaining intelligence across species. In the first row, the parentheses show the range of terminology used in philosophical discussions of mechanism, reviewed in Craver and Tabery (2017), Glennan (2017), and Thagard (2019b). The rest of the rows describe the ingredients of mental, neural, and molecular mechanisms.

Table 1 sketches the main mechanisms responsible for intelligent behaviors including moral judgments such as applications of the Golden Rule. To use this rule, people need representations of themselves, others, actions, and wanting, along with inferences that compare what people want for themselves with how they treat others. Psychology is converging with cognitive neuroscience to consider how such representations and inferences are performed by neural mechanisms such as firing patterns in diverse brain areas (Anderson, 2007; Eliasmith, 2013; Thagard, 2019a). In turn, cognitive neuroscience leans heavily on increasing understanding of how molecular mechanisms such as neurotransmitters control neural firing (Kandel et al., 2012).

Normally, mechanisms exhibit changes in degree rather than kind. For example, hearts increase their beating rates in response to exercise or psychological stress, and neurons increase their firing rates because of increased excitation by other neurons. Sometimes, however, hearts develop rapid and irregular beating constituting atrial fibrillation. Similarly, hyperexcitable neurons can produce too much firing leading to epileptic seizures. Stimulants such as caffeine and cocaine increase heart rates and neural firing in ways that temporarily generate qualitative changes in conscious feelings of energy and confidence.

Such differences in kind arise from emergence, where there is a change in the properties of a whole combination that is not simply the aggregate of the changes in its parts, because the change in the whole results from the interaction of the parts (Bunge, 2003; Holland, 1998; McClelland, 2010; Thagard, 2019b; Wimsatt, 2007). There are many scientific phenomena that exhibit such emergence, for example H_2O molecules that are liquid at room temperatures whereas their atomic parts are gases. The underlying mechanism for molecular formation is covalent bonding from the sharing of electrons, but molecules end up with properties that are not the aggregate of the properties of atoms and their constituents. Some philosophers advocate alternative conceptions of emergence (O'Connor, 2020; Povich and Craver, 2017).

I propose that the degree/kind and quality/quantity distinctions can be understood based on mechanisms that exhibit emergence. Simple mechanisms exhibit only changes in degree that are the aggregate of the changes in their parts, for example when the motion of a human body is just the sum of the motions of its components. In contrast, when the interactions of parts produce changes that do not just sum the changes in their parts, then the whole combination gets novel properties not found in the parts. Hence water molecules can be liquid at room temperatures, whole hearts can pump blood in a way that individual muscles cannot, and groups of neurons firing interactively can represent aspects of the world that single neurons do not.

What constitutes a kind? Some philosophers have maintained that natural kinds have essences that objects possess in all possible worlds (Bird and Tobin, 2017), but essences and possible worlds are immune to empirical analysis. More scientifically, natural kinds can be viewed as clusters of properties resulting from underlying mechanisms (Boyd, 1991; Glennan, 2017). Then the very notion of a kind, not just differences in kind, depends on an understanding of mechanisms. However, claims about the existence of a natural kind are stronger than claims about the existence of difference in kind. For example, male and female chimpanzees are members of the same species but have different sexual behaviors.

If the difference between degree and kind is a matter of emergence, then Darwin's claim about human minds amounts to the contention that they do not have any emergent properties compared to animal minds. Much continuity undoubtedly occurs between human and animal minds. The molecular mechanisms such as genetics and neurotransmitter operation are fundamentally the same, and neural firing operates with the same parts and interactions. Many experiments suggest that animals use a wide variety of mental representations such as concepts and cognitive maps (Reznikova, 2007). Perhaps human brains are just larger than those of most animals, making human intelligence and morality matters of degree rather than kind as Darwin claimed.

We need to distinguish different claims about kinds and emergence:

C1. All emergent properties of mechanisms yield differences in kind.

C2. Differences in kind are always the result of emergent properties of mechanisms.

C3. All mechanisms with emergent properties yield novel natural kinds.

C4. Natural kinds always possess emergent properties of mechanisms.

Evaluating claims C2, C3, and C4 would require a comprehensive survey of natural systems that display combinations of kinds, mechanisms, and emergence, far beyond the scope of this paper. I only require C1, which gets support from examples already given (water molecules, heart systems, and neural representation), and many more could be generated. Moreover, the view of emergence as involving properties of wholes that are not properties of their parts suggests differences in kind, but the vagueness of "difference in kind" prevents C1 from being analytically true. Attention to mechanistic emergence eliminates this vagueness.

How emergence produces kind differences is clear from the case of water molecules consisting of two hydrogen atoms bonded to an oxygen atom. In this mechanism, the initial parts are atoms and the connections are the electrostatic bonds between a hydrogen atom and an oxygen atom that produce water molecules, which also constitute parts. These molecules are weakly connected to each other by electrical bonds between the positive hydrogen atoms in water molecules and their negative oxygen atoms. These weak connections cause interactions that produce the regular behaviors of liquid water, in contrast to the gaseous behaviors of unbonded hydrogen and oxygen. Being liquid is an emergent property of the mechanism of interactions of water molecules, and generates the novel difference-in-kind of water as H_2O, which is also a natural kind.

2. Recursive Thinking is Emergent

Many claims that humans are unique with respect to behaviors such as tool use, communication, and culture have been refuted by careful observations of animals. But the claim that only human thought is recursive is maintained by numerous researchers (Corballis, 2011; Fitch, Chomsky, and Hauser, 2005; Pinker and Jackendoff, 2005; Suddendorf, 2013; Watumull, Hauser, Roberts, and Hornstein, 2014). In mathematics, a recursive function is a procedure that calls itself, as in: factorial(n)=n(factorial(n-1)) where factorial(0)=1. Analogously, a representation is recursive if it refers to representations of the same kind, as in "All the sentences in this paragraph are true" which is a sentence about sentences including itself. Mental recursion is the ability to embed thoughts within other thoughts, for example when I think that you think that I think you are smart. These aspects do not provide a definition of recursion, but a general characterization is provided at the end of this section.

Recursion is not just linguistic as humans also think recursively with pictures, sounds, emotions, and motor behaviors. For pictures, the Droste effect concerns cases where pictures are embedded in pictures as with the Droste cocoa tin that includes a picture of the Droste cocoa tin (figure 1). More generally, experiments show that people can do visual recursion without using linguistic resources (Martins, Muršič, Oh, and Fitch, 2015). Sounds can also be recursive as in complex music such as Bach's fugues (Hofstadter, 1979; Martins, Gingras, Puig-Waldmueller and Fitch, 2017). Nested emotions about emotions are recursive as in Franklin Delano Roosevelt's warning about the fear of fear itself and also in less self-referential examples like longing for love and fear of embarrassment (Thagard, 2019a). Many animals such as chimpanzees and crows use tools, but only humans make tools that make tools such as anvils that form axe blades and 3-D printers that print their own parts.

Figure 1. Recursive picture of Droste's cocoa, in public domain according to Wikipedia.

Animals such as chimpanzees, ravens, dolphins, and prairie dogs communicate with strings of sounds or gestures, but they have never been found to use language recursively (Corballis, 2011). Starlings can be trained to recognize recursive patterns in artificial songs (Gentner, Fenn, Margoliash, and. Nusbaum, 2006), but do not use recursion in their everyday songs and may only be seeming to identify recursive patterns using simple rules (Beckers et al, 2012). In contrast, recursion is found in almost all human languages, with Pirahã as a possible exception (Everett, 2012). In mathematics, recursive functions only began to be used in the late nineteenth century (Odifreddi and Cooper, 2016).

To show that recursion is an emergent property of linguistic and other kinds of representation, we need to identify the relevant mechanisms and properties of whole combinations that are not aggregates of their parts because they result from interactions among the parts. Even in a simple sentence such as "the ball is green", the meaning of the sentence amounts to more than aggregating the meanings of words like "ball", "is", and "green" because "the green is ball" is nonsense even though it has the same parts. Recursive sentences with embedding such as "the ball that was thrown by Sam and caught by Pat is green" are more complicated because the reader needs to keep track of how "that was thrown by Sam" goes with "ball".

Embedding of sentences within other sentences requires more than aggregation of meanings, because it is crucial to consider the interactions among the mental representations of all the concepts used to construct and understand the sentence, including the meaning of embedded sentences. Hence the overall understanding of recursive sentences provides them with novel, non-aggregative properties that qualify as emergent. Therefore, recursive language differs from mere strings in kind as well as degree because the meanings of recursive thoughts depend on interactions with the meanings of the thoughts they embed.

Recursive music, emotions, and tools also have emergent properties. Fugues are structured to return back to the same musical theme, generating expectations and surprises that are not just the sum of the notes. In emotional recursion, fear of embarrassment is not just the sum of fear and embarrassment because it needs to be about embarrassment. This complex emotion is a novel property of a whole human whose parts include emotions and other mental representations that interact to produce something new. Using an anvil as a tool to forge other tools requires visual and motor representations that include using a hammer to hit hot iron on an anvil to make an axe blade. The linguistic description of this function shows how actions about actions generate new properties. Moreover, anvils are themselves constructed from pieces of steel using other tools such as oxygen cutters, introducing further recursion.

How do human brains manage recursion? Simple artificial neural networks lack recursion: a network with a neuron for *ball,* a neuron for *green,* and a synaptic connection between them cannot distinguish "the ball is green" from "the green is ball", let alone deal with "the ball that was thrown by Sam". But computational neuroscience has developed techniques for implementing recursion in neural networks, most simply by allowing feedback connections from output layers back to input layers (Elman, 1990). The tensor product networks of Smolensky (1990) were an early method of using vectors to allow recursion in neural networks.

Currently, the most sophisticated mathematical method for explaining recursion in neural networks is the semantic pointer theory of Eliasmith (2013) that incorporates the holographic reduced representations of Plate (2003). On this approach, the difference between "Sam threw the ball" and "the ball threw Sam" is captured by binding a neural representation of "Sam" to a representation of "subject", "threw" to "action", and "ball" to "object". The resulting vector can be translated into a neural group capable of distinguishing Sam throwing the ball from the ball throwing Sam. Moreover, the same binding techniques can operate recursively to produce bindings of bindings, allowing for more complicated embedded representations such as *Sam threw the ball at Pat because Pat was annoying*.

This neurocomputational account of binding shows how recursion can be performed by mental mechanisms. The parts are neural representations which are patterns of firing in groups of neurons. The connections between these representations are synaptic links between the neurons in the groups. The interactions between the parts go beyond the usual patterns of excitation and inhibition found in all neurons to include neural computations that bind representations into new structured representations that can be subject to further binding. Eliasmith's semantic pointers show how recursion can be accomplished by neurocomputational mechanisms.

How humans evolved a capacity for recursive binding is unknown, but it may have come from increased numbers of neurons in the prefrontal cortex that resulted from a combination of primate evolution and greater energy efficiency through the invention of cooking by *Homo erectus (*Wrangham, 2009; Herculano-Houzel, 2016*).* Computational experiments find that binding requires large numbers of neurons in brain areas where connections converge such as the dorsolateral prefrontal cortex. Hence bindings of bindings are limited which explains why human sentences and other representations rarely have more than a few levels of embedding.

Read (2008) argues that the difference between humans and chimpanzees with respect to recursive thought is qualitative rather than merely quantitative because of limitations in chimpanzee's working memory, amounting to a span of 2-3 objects or concepts rather than the span of around 7 that allows people to think recursively. The historical record is too sparse to say definitely when human ancestors developed sufficiently large prefrontal cortices to support larger working memories, but Read points out that around 50,000 years ago humans developed a technology for producing blades that produce blades. Art and other cultural advances made possible by extended working memory also took off around this time (Coolidge and Wynn, 2005, 2018; Read and van der Leuw, 2008). So a plausible evolutionary story says that expanded working memory, possibly due to mutations in genes controlling brain structure, supported recursion that allowed for more advanced thinking about tools, language, and social interactions. Another possibility (suggested by Chris Eliasmith) is that increases in social complexity such as increased teaching made human memory more efficient and therefore capable of recursion.

Recursive binding produces neural representations with emergent properties. Simple concatenation of neural representations can be performed by synchronizing the patterns of firing in neural groups, but relations and recursion require more than concatenation. Brains are able to form recursive representations for language, music, pictures, and tools because the patterns of firing built out of other patterns of firing result from interactions carried out by binding operations. Therefore, like mental representations, neural representations produced by recursive binding have emergent properties that come with greater syntactic and semantic complexity.

There is no standard definition of the term "recursion", but the concept can be characterized in line with current psychological theories of concepts by specifying standard examples, typical features, and explanations (Murphy, 2002; Blouw, Solodkin, Thagard, and Eliasmith, 2016). Good examples of recursion include mathematical definitions, linguistic embedding, pictures of pictures, emotions about emotions, and tools to make tools. These examples typically have something that is the object of recursion which can be an element, entity, thought, procedure or action. All of these objects have structure that is transformed by self-reference, self-modification, self-action, self-definition or self-embedding. The result of this transformation is a new object with a novel structure. Thus recursion provides an explanation of the construction of novel objects and structures and more generally of the creativity of thought and language (Thagard, 2021).

Recursion is an abstract property of representations and operations on them, not a mechanism. But some highly unusual mechanisms are capable of accomplishing recursion because their parts and interactions generate representations and processes rich enough for self-reference and self-modification. Advanced mechanisms using computational and neural representations have the power to perform recursion as the emergent result of complex interactions of the representations. Then recursion is the product of mechanisms.

The emergent properties that come with the operation of recursion in human minds challenge the claim by Darwin and de Waal that animal minds differ only in degree rather than kind. Moral principles amplify this challenge.

3. Recursion in Moral Principles

Many moral principles do not require recursion. The Ten Commandments of Judaism and Christianity such as “thou shalt not kill” have no embeddings, so recursive language is not needed to understand them. But the Golden Rule that Darwin marked as the “foundation-stone of morality” requires embedding of phrases. The injunction to treat others as you want to be treated embeds “you want to be treated” inside the phrase “treat others as”. The recursiveness of the Rule is even more evident when it is translated into formal logic as: For any persons *x* and *y* and any action *z*, *x* ought to do *z* to *y* if and only if *x* wants *y* to do *z* to *x*. Here "do *z* to *y*" is embedded in the ought phrase, and "do *z* to *x*" is embedded in the want phrase.

Because it requires recursion, the Golden Rule is a counterexample to Darwin's claim that there is no difference in kind between human and animal intelligence. Darwin wanted human morality to be a quantitative extension of the social instincts of animals, and researchers such as de Waal (2013, 2019) have noted behaviors in animals that seem moral in nature. For example, capuchin monkeys seem to have a sense of fairness concerning the distribution of rewards, but such behaviors lack the cognitive complexity of the Golden Rule.

Andrews (2020) argues that animals such as apes have four prerequisites of moral normativity: the ability to identify agents, sensitivity to differences between in-groups and out-groups, capacity for social learning, and responsiveness to appropriateness. These features show that some aspects of morality can be attributed to animals, but do not undermine my claim that recursive moral principles such as the Golden Rule are qualitatively beyond the capabilities of animals. One might suggest that morality is a spectrum in which animals have a large approximation to the abilities of humans, but the emergent property of recursive thought shows a discontinuity that belies the spectrum metaphor.

Other moral principles also have recursive complexity. The ancient Chinese philosopher Mengzi (also known as Mencius) advocated a rule that is less self-oriented than the Golden Rule: treat all others as you treat the people you care about (Schwitzgebel, 2019). This rule requires comparison of other people with the friends and family you most care about rather than with yourself. It has the same linguistic complexity as the Golden Rule, as “you treat the people you care about” is embedded within “treat all others as”. In both cases, meaning emerges from complex interactions among the clauses.

Some other sophisticated ethical principles do not employ recursion. One of the major ethical traditions is Utilitarianism which advocates bringing about the greatest good for the greatest number of people (Driver, 2014). This principle is aggregative rather than emergent because it only requires adding up the good (pleasure and absence of pain) found in the world’s people.

In contrast, Kant’s (1959) categorical imperative requires recursion: Act only according to that maxim whereby you can, at the same time, will that it should become a universal law. This imperative rules out acts such as lying, because you cannot will that everyone lie all the time. In logical terms, Kant’s rule becomes: For any person *x* and action *y*, *x* ought to do *y* if and only there is a maxim *z* to do *y* where *x* can will *z* to be universal. More informally, this becomes the injunction to only do things that moral law can require everyone to do. All these formulations are recursive because they embed “will to be universal” inside “maxim” inside “act according to”.

Like the Golden Rule and the Mencius variant, we cannot expect any animal to follow Kant’s categorical imperative because it requires emergent capabilities of recursive thought. Another Kantian ethical principle is “ought implies can”, which is short for “you are not obliged to do anything of which you are incapable”. This principle is also recursive because it embeds “anything of which you are incapable” inside “you are not obliged to do”, which includes a sentence within a sentence. Thinking it requires a mental representation about a mental representation.

In medical ethics, a common approach is based on the following four principles (Beauchamp and Childress, 2013):

1. Autonomy: Respect people's freedom.

2. Beneficence: Provide benefits to people.

3. Nonmaleficence: Avoid harm to people.

4. Justice: Distribute benefits, risks, and costs fairly.

Principles 2 and 3 are non-recursive, since like the Ten Commandments they simply tell you to be good to people and not to harm them. But the requirement of justice in principle 4 is more complicated because it requires a comparison between the benefits, risks, and costs of different people. It might be formalized as something like: For all persons *x* and y, and all benefits *w* and *z*, if *x* gets *w* and *y* gets *z*, then *w* and *z* ought to be approximately equal. This formulation only roughly captures the principle of justice, but it suffices to show that justice requires recursion, since the benefits (or risks and costs) are embedded within a moral judgment that requires their comparison.

Principle 1 which says to respect freedom appears non-recursive but that depends on how freedom is understood. Isaiah Berlin (1969) distinguished between negative liberty as freedom from external control and positive liberty as freedom to develop fully as a human being. On the second interpretation, respecting people's freedom requires establishing societies in which people can live up to their capabilities and satisfy their needs. Then being autonomous is more than just the absence of interference but requires that people have the opportunities to be what they can be. The principle of freedom becomes something like: act in ways that enable people to run their lives in accord with what they need. Here "what they need" is embedded in "enable people' which is embedded in “ways that enable”. On this interpretation based on negative liberty, the ethical principle of autonomy is recursive and therefore requires emergent mental capabilities not found in animals.

Also recursive are the justice principles of John Rawls (1993, pp. 5-6):

> 1. Each person has an equal right to a fully adequate scheme of equal basic rights and liberties compatible with the same scheme for all.
>
> 2. Social and economic inequalities are to satisfy two conditions: first, they are attached to offices and positions open to all under conditions of fair equality of opportunity; and second, they are to be to the greatest benefit of the least advantaged members of society.

In the first principle, the compatibility requirement requires an implicit embedding of schemes. In the second principle, both conditions qualify allowable inequalities by clauses that refer back to them. Hence Rawls’ principles of justice can only be understood by beings capable of recursive thought.

Animals without recursive thought may possess a basic emotional understanding of simple moral ideas such as avoiding harm, but without recursion they are incapable of grasping more abstract principles such as the Golden Rule, Mencius’ rule, Kant’s categorical imperative, Berlin’s positive liberty, and Rawls’ justice rules. So Darwin was wrong that difference in moral thinking between humans and animals is just a matter of degree. At some point in the evolution of humans from apes there was a critical transition or tipping point where quantitative increases in brain size gave way to qualitative differences in recursive thinking. For dissection of the popular concept *tipping point,* see Thagard (2022), ch. 6.

4. Objections

Darwin could be defended by various objections concerning the nature of the degree/kind distinction, the recursiveness of the Golden Rule, recursive thinking in animals, and the origins of morality.

Darwin's Degree/Kind Distinction Concerned the Supernatural

Perhaps all that Darwin meant by claiming that the differences in mind between humans and animals is one of degree and not of kind is that morality does not have a supernatural origin. On this interpretation, his claim is true because there is no reason to assign a theological cause to the human capacity for recursive thought.

However, search using the Google Books Ngram Viewer shows that the distinction between differences of degree and differences of kind was common in Darwin's era in nontheological contexts. Darwin's own discussion in the *The Descent of Mind* never invokes the alternative of creationist explanations that he effectively refuted in *On the Origin of Species*. The contemporary endorsement of Darwin's claim by de Waal is similarly non-supernatural. So there is no reason to believe that the degree/kind distinction corresponds to a natural/supernatural difference. On my analysis of the degree/kind distinction as based on critical transitions with emergent properties, recursive thinking amounts to a difference in kind.

The Golden Rule Need Not Be Recursive

Perhaps the Golden Rule can be construed as a non-recursive principle of reciprocity such as the tit-for-tat strategy that says you should treat people the way they treat you. This strategy requires only observation and imitation, not thinking about what other people want.

However, the Golden Rule is a far more sophisticated ethical principle than mere reciprocity. Like Kant's categorical imperative and Rawls' justice principles, it requires deep reflection about moral situations that goes far beyond any tit-for-tat strategy through recursive consideration of the wants and needs of others.

Animals Do Think Recursively

Animals lack recursive language, but perhaps they are capable of other kinds of recursion using metatools and same/different judgments. I claimed that only humans have been found to use tools to make tools, but animal researchers have discussed the use of "metatools" by crows and chimpanzees. For example, New Caledonian crows have been observed using a short stick to retrieve a longer stick that can be used to obtain food (Clayton, 2007). However, using a tool to get another tool is iteration, not recursion. The first stick is not about the second stick but is just part of a sequence of steps that eventually produces food. The first stick is not used to make the second stick, but is just part of a generalization: if I move the first stick, then I can reach the second stick. In contrast, when a human uses a blade to make an ax handle, the blade is a tool that is about making a tool, which is recursion.

According to Hayashi (2015), the most complex type of tool use in wild chimpanzees is the use of a wedge stone to stabilize an anvil stone that serves to crack nuts. Again, this process is iterative rather than recursive because the wedge is not used to make the anvil, just to adjust it. Crows and chimpanzees display highly sophisticated planning that does not, however, amount to using tools to make tools.

Another possible example of recursive thought in animals is judgments of sameness and difference. Many animals such as pigeons can judge stimuli to be same or different, but some species such as crows and chimpanzees can also match abstract relations such as when a chimpanzee matches half a glass of water with half an apple (Thompson and Oden, 2000). Do such judgments amount to recognizing a “same sameness” which would be recursive? No: detecting relations between relations is an iterative process where one relational judgment (same or different) is made about another relation (full or empty). Contrary to the human capacity for applying relations to themselves (for example that the concept of sameness is the same as the concept of identity), chimpanzees are merely stringing relations together. Thagard (2021) provides further argument that non-humans are incapable of full analogical thinking.

The proposal that recursive thought resulted from the evolution of increased working memory capacity could be challenged by reports that young chimpanzees have greater memory performance than university students, but these reports were based on flawed experiments (Cook and Wilson, 2010).

My argument depends on the empirical premise that humans are the only species capable of recursive thinking. This premise is subject to observational refutation in the same way that the claim that only humans use tools was refuted by Jane Goodall’s observations of tool use by chimpanzees. But numerous, systematic observations of many species of non-human animals have failed to identify recursion used in (1) language use with embeddings or self-reference, (2) tool use with tools that make tools, or (3) prosocial behaviors based on reflection concerning what other animals want rather than on emotional reactions to their behaviors. We thus have good evidence for the generalization that recursion is unique to humans, revisable based on future observations and experiments.

Recent experiments purport to show that macaque monkeys and crows are capable of recursive sequence generation (Ferrigno et al. 2020, Liao et al. 2022). These experiments employed nested pairs of bracket stimuli and found 2 macaques and 2 crows capable of distinguishing center-embedded structures such as ({}) and {()} with success rates greater than chance. More research is required to show that animals are capable of non-associative learning of recursive sequences of meaningful symbols.

Recursion Misinterprets the Origins of Morality

My account might be misconstrued as claiming that recursive thinking is the origin and basis of morality. There are many competing accounts of the source of human morality. Some theologians view the human moral sense as a gift from God. Darwin, de Waal, and Andrews (2012) see morality as a natural extension of aptitudes that developed in other animals. In contrast, Hauser (2006) and Mikhail (2007) hypothesize that humans uniquely possess an innate universal moral grammar akin that resulted from biological evolution. Yet another alternative is that moral codes are the results of social developments prompted by the growth of large communities that followed the invention of agriculture.

The claims of this paper are much less ambitious than these accounts. I have merely noted that humans have a capacity for recursive thinking not found in other animals and that some but not all moral principles are recursive. I leave theorizing about the biological and social origins of morality to others.

Recursion Affects Moral Reasoning Rather Than Moral Behavior

It might be objected that my argument confuses moral reasoning with moral behavior. Animals may not be capable of recursive moral reasoning, but they display many prosocial behaviors (Andrews and Gruen, 2014; Bekoff and Pierce, 2009; Fitzpatrick, 2017; Micheletta et al. 2012; Monsó, Benz-Schwarzburg, and Bremhorst, 2018; Rowlands, 2015, 2017; Rutledge-Prior, 2019). Such behaviors support the claims of Darwin and de Waal about continuities in thinking and morality between animals and humans.

However, the Golden Rule displays an important difference between the prosocial behaviors of humans and those of animals. Many cultural traditions including Christianity have taught the Golden Rule to their adherents in the expectation that it would produce moral reasoning that improves moral behavior. A recent experiment finds that agents' behavior in an economic environment conforms to the Golden Rule (Costa-Gomes, Ju, and Li, 2019). What is striking about human morality is that moral reasoning including the use of recursive rules can affect moral behavior in ways not achievable by animals. Other candidates for moral discontinuities include impartiality, emotion regulation, and moral self-cultivation (Carron, 2018). Because human prosocial behaviors can be influenced by recursive moral reasoning, they differ in kind from animal behaviors.

5. Conclusion

In order to assess Darwin's claim that animal morality differs from human morality in degree rather than kind, this paper has provided answers to three questions about degree/kind differences. The semantic question is answered by the proposal that the meaning of the differences of kind and degree is captured by mechanisms that undergo changes that are emergent properties of the whole system. The epistemological question of how to identify differences in kind is answered by the following procedure. (1) Identify the underlying mechanisms in the system in question, i.e. the parts and interactions among them. (2) Determine whether the system has emergent properties, i.e. properties of wholes that do not belong to the parts and are not just aggregates of properties of the parts. (3)

Identify those emergent properties as changes in kind. The ontological question about the degree/kind distinction is answered by showing that it depends on real-world mechanisms with real emergent properties.

This mechanistic understanding of the degree/kind distinction transforms assessment of Darwin's claim about morality into the question: Are there aspects of human morality that have emergent properties compared to animal cognition? Recursive thinking is a plausible emergent property, and some important aspects of human morality such as the Golden Rule require recursion. Therefore, human morality differs from animal morality in kind as well as degree.

If future research shows that animals are capable of recursive thought, then my argument fails that recursion refutes Darwin's claim. This failure would not undermine other contributions of this paper: the degree/kind distinction can be rooted in emergent mechanisms, and some but not all ethical principles are recursive.

Darwin thought he had to argue against the existence of fundamental differences in kind between human and animal minds because critics took such differences as evidence against his hypothesis that species evolved by natural selection; only divine creation could provide human minds with special powers of ethical reasoning. I have argued that advanced moral principles such as the Golden Rule show that moral reasoning in humans is a difference in kind because the principles require recursion, but this argument provides no challenge to evolution by natural selection. By introducing rigorous considerations of mechanisms and emergence, we can see high-level moral reasoning as uniquely human but still open to evolutionary explanations.

Acknowledgement: I am grateful to an anonymous referee for helpful suggestion.

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