History of Thought, Book 1

The Co-Evolution of Technology and Cognition in primate species

précis

a. **Volume Summary**

The series starts with an in-depth review of how brain and cognition evolved in the primate lineage from ~80 million years up until humans began to split from the other apes. We do this by using a diversity of living primate species, representing different branching points in the tree of life, to provide a background for understanding modern day human cognition and technology. We apply insights gained from knowledge about our primate cousins to the present and into the near future.

With the theoretical premises as the beacon, the book uses extant modern-day species (lemurs, tarsiers, New World monkeys, Old World monkeys, gibbons, orangutans, gorillas, and chimpanzees) as referential models to shed light on the evolution of primate brains. Modern day primates are not a stand-in for ancestors of millions of years ago. Nevertheless, combined with the available fossil evidence of animals from the past, comparisons of cognitive and neurobiological traits in living species can allow us to infer the sequence of changes that have occurred and to reconstruct a model of evolutionary history. Direct observation of living and breathing primates, furthermore, provides a wealth of data that can inform our understanding of how human brains interact with modern technologies. This dataset is often overlooked as part of the current debates on how and why humans interact with technology the way we do. These debates, when they do look back beyond recorded human history, look at most into just the last few million years of human evolution, for example, from the approach of evolutionary psychology, but do not go further back, and do not often use the opportunity to directly observe or test their hypotheses.

Each of the chapter summaries that follow include a sample chapter observation and modern relevance. For example, we can chart how even minor changes in diet as a result of increased competition for food sources from conspecific species, or changes in habitat due to shifting weather, has direct results on the life histories, techniques and cognition (individual) and culture of a species. Specifically, we see that bonobos and chimpanzees developed radically different cultures and techniques, though they had very similar habitats and biology. The common chimps were geographically isolated from bonobos by the Zaire River, with common chimps sharing the habitat north of the Zaire with gorillas. Introduce the theory that this one variable, gorillas, led to major changes in chimps' culture, because the gorillas would eat the tough fibrous food that chimps would rely on in between preferred fruit feasts. With lower food diversity and stability, chimps developed a more aggressive, male dominated society, because of just this subtle change in food. What happens then, when we radically change the food supply of humans? 100 years ago, humans in a developed country like America generally ate a relatively narrow range of foods that was harvested within 100 miles of where they lived. Modern people, chronologically isolated from their great-grandparents, now have food delivered into their refrigerators by modern grocery stores like Wegmans, with choices including over 70,000 items, many of which have been flown in over the last few days from around the world. What effect might this have on humans' cognition? How does the reduced time spent collecting and preparing food - due to conveniences like grocery delivery and in-store prep or consumers' modern appliances like microwaves - effect the rest of the daily activity budget? What human values are advanced, and which ones eroded, just through different adoption and diffusion of modern food?

This book was written by a unique team of two authors with very different backgrounds: a technologist who has played key roles in several of the most disruptive technologies of the last two decades, and a

biological anthropologist/evolutionary neuroscientist who specializes in primate brain evolution. This collaboration yields insights that are available only when these very different fields inform each other. The end-product is therefore itself also unique: a comprehensive background survey and literature review, combined with practical applied insights of that deep background to modern emerging contexts between technology, brain evolution, and human cognition.

b. Chapter Summaries

Chapter 1 Introduction

A daily human activity budget centered around technology:

- *Dad sits hunched over his desk in his home office, working on a venture capital presentation for his company's main product – an embedded brain device. It's therapeutic to epilepsy and TBI patients, but the VCs who invested in the first round want the future monetization strategies developed a bit further. His watch beeps, informing him that he needs to leave for work early, because traffic on his normal route is already building. He heads for the door, saying his goodbyes to his daughters, who don't hear him.*
- *Daughters are on the floor, in front of the fire, doing homework on their laptops. Both have headphones on, listening to music; one is also absentmindedly playing Minecraft. They glance up and see the back of their dad as he leaves for work, without saying goodbye. 'Oh well', says the youngest; the oldest texts her Mom.*
- *Mom, a program manager at a software firm, is at Starbucks, picking up her mobile order before work. The other customers are all heads down over their phones and a few laptops. Back in her Tesla, in self-driving mode, she briefly answers her daughter's text about what to take to school for lunch, then glances at an email from a coworker about a research study the DoD is doing on the future of work: what does she think the primary human skills will need to be in ten years, when technology and AI expand, and start replacing more skilled workers? Hmmm, she wonders before switching over to her Facebook feed, and briefly glances down the road.*
- *Dad drives home (his presentation went great!) and passes a Google Street View car; he waves at the camera, sticking his tongue out. A few minutes later, a car speeds by, the driver texting at the wheel. He comes home to an empty house (volleyball and soccer practice night:(He heats up a meal in the microwave, and sits down in front of Netflix, scrolling for something interesting to watch. He pauses, as he thinks about Netflix's algorithm for curating and recommending content personalized for him. Hhhmm, he wonders, what makes me watch TV, and drives me to prefer certain shows? What's the biological imperative, the evolutionary adaptation that causes me to interact with TV the way I do, or for that matter, with the other technology in my life? Do those forces influence the technologies I make? Heck – how have all of those past adaptations shaped our use of technology today, and what's the accumulated effect of our so-called conscious adoption of technology, if it is in fact driven by evolutionary impulses that are more complex than 'bright lights and new things cause us to release dopamine'? And how might these forces affect us in the future, as technology continues to accelerate? If I can understand that, can I make technology that is <u>better</u> for people? 'Oh, look – the Game of Thrones finale'; he clicks, and leans back.*

- *Mom is at soccer practice, watching her youngest. Her phone vibrates, and she reads a LinkedIn message from a former colleague– how will universities change in the future, to address the new human skills necessary to team with technology? 'Hmmm…' She looks up at her daughter on the field, and wonders about her and her sister's futures.*

This set of vignettes illustrates how the average modern human day in a developed country has become increasingly immersed in and centered around technologies. Relative to other animals or even humans of one hundred years ago, we have a significantly different daily activity budget, because of this technology. The rest of the chapter outlines the approach and intellectual frameworks that influence this work's perspective from deep history, which necessarily integrates material from a number of domains and techniques.

The main thesis of our book is as follows: the pace of rapid technological innovation in our modern world is not driven by forces inherent in technology itself; it is driven instead by us - the people who create the demand by buying, using, or consuming that technology. This chapter defines how the word "Technology" will be used in an appropriate manner that can be consistently and effectively applied across a range of primate activities that spans from lemur mating signals to a Tinder app on a millennial's iPhone.

This chapter lays out the foundational assumptions of the book, including that humans predominantly interact with and create a demand for technology not based on conscious rational reasons, but due largely to unconscious processes that are heavily affected by inherited predispositions. These processes are deeply rooted in evolutionary adaptations, that evolved in past environments in which they were adaptive and useful. This has led to psychological biases that encourage our interaction with certain technologies, though their modern benefit is unclear.

But the bigger problem is that this root cause for Technology adoption is not widely understood or discussed. As a result, policy planning and other activities around technology deal with second or third order dynamics. Seeking to curb or enhance the effects of technology by blaming technology companies for being unethical, or governments for failing to appropriately regulate technology, or worse, ascribing something inherent in technology itself as the problem, all fail to deal with the actual root cause – our own actions. As the positive feedback loops within the current technological landscape kick in, and technological advances accelerate on a number of fronts including digital, medical, industrial, IoT and defense, this dynamic will only get harder to model but more important to try to understand.

This book sets out to establish a common, accessible inter-disciplinary framework for understanding this dynamic set of feedback loops between how humans think, and how that influences the technology they use, and that technology in turn might be affecting how we think.

The rest of the chapter describes the narrative arc of the book and sets expectations.

Chapter 2 How did we get here?

Introduces the "scaffolding" of the book – evolution of primate cognition of the last ~80 million years; we will layer modern-day evidence, detail and implications throughout the historical journey. Short transitional chapter that re-orients the reader from the introductory chapter to main part of book. Discusses the pros/cons of going so far back in cognitive evolution, and the advantages (and limitations) of the use of and focus on extant primates to infer episodes in evolutionary history. To go back further, such as Dawkins did in The Ancestors Tale, means we

have relatively less time to discuss the rich data set that the primates have to inform our modern experience. While the primate focus is a cohesive organizing force, note that we will occasionally use examples from other orders or families to illustrate a point, or to compare/contrast with primates (e.g. the working memory of crows, or otters' use of rock hammers and anvils as tools).

Chapter 3 Lemurs

80 million years ago (mya)

Introduces lemurs as a diverse phylogenetic group including approximately 100 living species (briefly), how primates differ in biology and behavior from other mammals, the concept of brain size vs EQ, gross brain anatomy, review of lemurs' primary senses, the concept of social systems, role of grooming in support of social structure, and the concept of life history. Then delves into how the cognitive process of anticipation of future events is related to physiological and emotional stress. Reviews how lemurs communicate, a deeper dive into smell (one of their primary systems), relate smell back to human senses, and the fact that primates have far more than 5 senses. Summarize how the factors above yield lemur techniques for interacting with the world, and what factors affect how techniques diffuse within social groups. Concludes by establishing the lemur chapter as foundation of evolutionary traits that make up humans' cognition, noting that unlike models of cognitive evolution that only consider the time since the human-ape split, animals like lemurs and other primates are available for direct examination.

- Sample chapter observation: Discussion of how the most powerful supercomputer in the world today can barely model the real-time thought processes of a mouse brain, let alone the more sophisticated lemur brain. Given the 'high performance computing" of this lemur organ, this emphasizes how much processing occurs in the primate brain, below the level of abstract formalized thinking that we often presume dominates the modern human consciousness.
- Modern relevance: A large percentage of modern human brain is driven by unconscious thought processes that are so sophisticated that the world's best supercomputer can't begin to model it. These unconscious processes can be influenced by conscious thought, but we really begin to understand modern thinking when we peel back the conscious layers, and understand the layers that have been around the longest. We carry not only "human" brains, but also "primate" brains, much of whose circuitry was laid down 10s of millions of years ago.

Chapter 4 Tarsiers

67 mya

Introduces tarsiers as a group of species (briefly), and as taxonomic suborder of haplorhines how they contrast with anthropoids, and how that branch relates to human evolution. Introduces how haplorhines and anthropoids have differences over other animals in diet, eyesight, mating, and relatively fine motor skills. Review of tarsier characteristic in each of these categories. Introduces bipedalism and sexual dimorphism. Reviews tarsier social system and communication. Summarizes? tarsier techniques, how the factors above compare/contrast with lemurs, and how, and what factors affect how techniques diffuse within social groups. Delves into communication theory for several pages, as a foundation for later discussions of how other primates use technology to communicate.

- Sample chapter observation: Discussion of how techniques of biological adaptations to environment (such as eating meat), and social behaviors (e.g. sexual specialization of roles), as well as physical adaptions to movement (e.g. the stabilizing effects of having a tail while living in the trees) accrete to create specific neurobiological adaptations (much of it unconscious) that are optimized for enhanced cognition related to these adaptive behaviors.

- Modern relevance: Apply this lens to modern human activity, where adaptions don't evolve in a geological or evolutionary scale, but in Internet time. E.g.: if eating meat increases calories and supports energy intensive cognitive traits, what happens when we dramatically change the human diet in the span of just the last century? If cognition of an animal is a function of its physical movements, what happens when you drastically change the daily patterns of movements in the human ecological niche, in just the last century? While these two examples, informed by comparison with the tarsier, are easy to observe and point out in the recent human past, it is much more difficult to observe effects that result from new technological adaptations, because the pace of change is so fast. It's also harder to understand whether new human techniques and technologies result in positive outcomes for the individuals who engage in them, in part because the pace of change is so great.

Chapter 5 New World Monkeys

43 mya

Introduces superfamily of New World monkeys (NWM). Review of characteristics, ecology, senses. Deep dive on the evolution of trichromatic color vision (similar to humans), which is found in certain NWM species, and retinal fovea. Discuss how 'techniques' such as color vision spread through genetic inheritance based on reproductive success, as a function of how that color vision creates competitive advantage in environmental niche. Introduce concept of tool use in capuchin monkeys, which brings up learning, and imitation; introduce mirror neurons as a concept. Point out that while traditionally, comparative psychologists may use the term "technology" to describe capuchin tool use, by making the distinction between "techniques" (processes by which an individual pursues valued outcomes), and technology (diffusion of techniques, including intergenerationally), we gain additional insights that help us better understand the evolution of technology. Just as Eskimos have many different terms for the different types of snow, we need to begin to break down the general word of "technology" into more specific language for underlying dynamics. Note that even though capuchins in captivity and the wild show advanced techniques like tool use, the diffusion of these techniques through social groups is somewhat inhibited, despite the fact that their social environments are conducive to it. Contributing factor may be lack of mirror neurons (the first strong evidence of mirror neurons is in OWM), and other adaptations. We also see that technology is shaped by cognitive factors such as attention, memory and conceptualization. Review NWM social structure, delve into sexual reproduction strategies and their effects on social structures, including allorearing (group/shared parenting) of offspring. Conclude with review of NWM cognition, which introduces concept of novelty/innovation, cerebral lateralization, and Theory of Mind.

- Sample chapter observation: Review the multiple ways that trichromatic color vision evolved in New World monkeys (polymorphic in females of many species and uniformly present in howler monkeys), and the effects of that primary sense augmentation on both the species behavior and on its environment.
- Modern relevance: Use the evolution of color vision as precedent that can inform modern day technology-enabled sense augmentations, from bio-hacking rare earth magnets into fingertips to sense electric fields, to the visual enhancements of augmented reality in Nintendo Go, Google Maps, and the latest cutting-edge augmented reality features of fighter jet helmets.

Chapter 6 Old World Monkeys

29 mya

Introduces superfamily of Old World monkeys (OWM). Review of characteristics, ecology, senses. Using OWM visual orientation as a jumping off point, deep dive into visual circuitry of brain, and co-evolution of physical hardwired adaptations (introduce epigamic displays), social behaviors, and unconscious behaviors such as gaze-following. Review of common causes of death, including predators (and defenses). Touch on reduced sense of smell, and genetic basis for reduced human smell. Dig into techniques such as mating patterns, dispersal of one sex at the time of maturity; introduce sexual bimaturity and energetics. Tie to modern day changes in population density. Delve into parental investment, as mechanism for influencing cognition in OWM and humans. Use OWM sexual activity, and social ranking/dominance as opportunity to introduce modern psychology motivation frameworks, including intrinsic and extrinsic motivations. Tee up that our motivations for engaging with technology are not well understood. Returning to OWM, delve into stress/cortisol systems. OWM social structure serves as opportunity to introduce social intelligence and related frameworks. Conclude with review of OWM cognition, which touches on limitations of EQ, learning, and cultural intelligence.

- Sample chapter observation: Note that among Old World monkeys there is a 'technique' of increased level of parental investment and an extended immaturity of the young, and that these are positively linked to a rise of enhanced cognition.
- Modern relevance: Consider how modern human children from wealthy industrialized nations have, on one hand, a much larger base of resources that can be applied to their rearing, but on the other the evidence that they are starting to mature earlier than previous generations. Discuss the rapidly changing social milieu of parental investment. E.g. China's one-child policy concentrated parental attention on only one offspring, whereas China's urbanization trend frequently requires rural parents to migrate to the cities, leaving villages with numerous "left-behind" children, who are forced to raise themselves for months at a time. Compare/contrast with children in other countries, and how this affects technology adoption, and in some cases, vice versa.

Chapter 7 Gibbons

20 mya.

Introduces gibbon family. Review of characteristics, ecology, senses of apes in general. Use lack of tail and erect posture during locomotion as a chance to discuss adaptations and exaptions (the use of an older adaptation for a new purpose). Spend time on 'techniques' that include evolving vocal, visual and smell communications, and gibbons' unique genetics. Conclude with a discussion of gibbon cognition, that underscores limitations of EQ, how ecological niche shapes cognition, introduce cerebral cortical cytoarchitecture, and Brodmann's areas. Summarize that transition from monkey to ape wasn't just about bigger brains, but other more nuanced changes in brain, along with adaptations that set stage for later key evolutionary breakthroughs.

- Sample chapter observation: Examine gibbon's relatively rare animal behavior of "monogam-ish" lifestyle, and how that technique influences the social structure, environmental behaviors, and the diffusion of monogamy techniques through genetic success.
- Modern relevance: Consider humans' also relatively rare tendency towards monogamy, and how changing techniques and technologies (e.g. freezing of eggs for having children beyond the normal age of fertility, and in vitro fertilization and sperm donors for producing offspring without a partner or in a same sex relationship), can influence rapidly evolving second- and third- order dynamics in social structures and other modern human behaviors. Humans can now harness techniques to move beyond the constraints of

biological reproduction, in many ways. How might that affect behaviors and the thinking that underpins those behaviors?

Chapter 8 Orangutans

15 mya.

Introduces orangutans, and great apes in general. Use past global climate change and other factors to explain ape migration in and out of Africa and Eurasia in the Miocene. Review of orangs' characteristics, ecology, senses. Note techniques of unusually high energy efficiency, slow life history, solitary social structure, and males' pronounced, staged, sexual bimaturity. Review of orangutans' cognitive ability digs into "great ape intelligence", including their performance in learning "language" in experimental studies, though with only modest increases in EQ. Explained through relative cerebral morphology (relatively larger prefrontal cortex) & neuronal distributions, and perhaps greater modularity of neural networks. Introduce Bischof-Kohler hypothesis and increased self-control, plus concepts of meta-cognition, noting parallels in modern world. Note increased imitation in orangutans, which is a building block in the platform of learning and technique diffusions. Touch on orangutans' Theory of Mind status. Deep dive on hierarchical thinking and the neurological basis. Conclude by digging into the reasons orangs are capable of using tools in captivity, but the diffusion of these techniques is much more limited in the wild, and how that has implications for modern day human information diffusion.

- Sample chapter observation: Discuss how "great ape intelligence" can be understood in part by a rise in nested hierarchical thinking, and corresponding neural adaptions.
- Modern relevance: Illustrate the disconnect between the various conscious demands of modern life, that are frequently nested in only the most informal and fluid sense, and how those competing conscious demands are hindered by the additional competition of powerful unconscious influences and demands, driven largely by neural and physiological adaptations shaped by the past.

Chapter 9 Gorillas

9 mya

Introduces gorillas. Notes close genetic affinity to humans. Spends several pages on history of discovery of gorilla in western science, to illustrate how recently, on a historical time-scale, western scientists have learned of our close living relatives. Review of characteristics, ecology, locomotion, social structure and life history. Noting gorillas' unique life history, introduces r/K selection theory. Review of common causes of death, including predators (and defenses). Review techniques such as communications, including facial and gestural communications. Conclude with review of gorilla intelligence, noting sparse tool use in the wild, and deep dive on cognitive requirements of gorillas' techniques for food acquisition/niche. Demonstrate relative jump in cerebellar size in gorillas and other apes, and introduce and delve into cortico-cerebellar loops. Introduce concept of embodied cognition. Touch briefly on Theory of Mind.

- Sample chapter observation: Highlight the large amount of time gorillas (particularly mountain gorillas) invest each day in food acquisition (8-10 hours a day), and how cognition is key to that acquisition.
- Present relevance: Examine how increased food production, packaging, and transportation techniques, as well as other corresponding technologies (e.g. refrigeration and microwave) have greatly reduced modern human food acquisition investment, even within just the last generation. Ask the question – how do humans tend to use the time saved from new "time-savings technology", whether it be food, other domestic chores, or work-related? Note the correlation between reduced time in normal American domestic activities (like cooking), and the increase in consumption in media. How does this

dynamic play out across other societies in the world? Ask the question – what will we do with the additional excess time we have with new technologies such as self-driving cars, and as technology gradually replaces other human cognitive demands?

Chapter 10 Chimpanzees and bonobos

6 mya

Introduces chimpanzees and bonobos. Discusses close genetic relatedness to humans. Spends several pages on history of discovery of chimpanzees, to illustrate how recently western science has learned of our closest living relatives. Review of physical characteristics, w/ compare/contrast between the 2 *Pan* species, and detail on evolution of hands, feet, sex organs. Review of common causes of death, including predators (and defenses). Deep dive onto primate gonads/mating structures, including review of modern humans. Review locomotion (increased bipedalism), life histories, and increased non-reproductive sexual activities, especially in bonobos. Social structure – deep dive into techniques of fission/fusion structure, and cognitive implications, especially those that inform modern day humans. Note techniques of chimpanzee hunting, territoriality, and the social intelligence implications. Introduce concept of activity budget of daily activities. Deep dive on role of sleep in maintaining cognitive ability. Touch on cognitive implications of chimpanzee techniques of foraging and "resting". Very deep dive into techniques and role of "play" in cognitive development, introducing modern literature of human development and educational models (e.g. Huizinga, Piaget, Vygotksy). Deep dive on tool use. Touch on communications, with enhanced 'audience effects' and communications flexibility, hinting at biological basis in cerebral hemispheric specialization (e.g. Wernicke's area). Discussion of chimpanzee "culture". Very deep dive into chimpanzee cognition, with introduction of salience maps, pre-motor theory, top-down and bottom-up processing, attention networks, prospective cognition, innovation, and Theory of Mind, and the implications for increased ability to acquire and pass on techniques within social groups.

- Sample chapter observation: Thorough review of how chimpanzees navigate their complex social dominance hierarchies.
- Present relevance: Ask the question of "why do humans consume modern media the way they do?" Note the relative lack of research and evidence on this basic question, despite the astronomic amount of human and financial capital spent in these modern human behaviors. Review human media consumption through the hypothesis that humans frequently consume media unconsciously to service their hardwired need to navigate social hierarchies. Note the preliminary evidence that exists to support this hypothesis, including the fact that while navigating social hierarchies may be the drive, the behavior of consuming and interacting with media may in fact be counter-productive, as the information an individual gets from their typical media consumption provides them with a flawed view of their social networks, and this consumption then greatly reduces their individual satisfaction as well as their ability to interact effectively with others. I.E. consuming media as we do may be maladaptive, as it may hinder our social success and wellness.

Chapter 11 Summary of what we've learned from our primate ancestry

Short summary chapter that introduces one of the major insights of this book: that many of the key forces that shaped the evolution of human thought and cognition over the last 80 million years of our ancestry, in many parts of the world have changed dramatically in the last 150 years, much of it in just the last 20 years. Factors such as changes in diet, environment, social structure, mating, locomotion, disease, lifespan, threats are all associated with key evolutions of the past. Change one of these environmental factors, and you can expect individuals to adapt, and that adaptation, over generations, can lead to major changes in a species. But in the last 200

years, and especially just the last 20, we've dramatically changed all of these factors, and many more. What do past changes tell us about what might happen now?

Primates, relative to other animal species, have significant technique innovations, across cognition, physical adaptations, and in many cases, sophisticated social structures. But relative to human species, the primates demonstrate limited innovation, and severely inhibited diffusion of new techniques into the larger social groups, due in part because of aspects of their social structure, and their relatively less neuroplasticity due to their life history schedules and brain growth. As a result, primate behavioral adaptation is relatively slow, especially when compared to the arc of human evolution.

Chapter 12 So What?

Discusses implications of the material covered in the book. What are the cumulative effects of technology on humans, and what does the early evolution of the primate brain have to tell us about those modern effects?

This book suggests that many of the factors driving our engagement with technology are intrinsic to us, not technology. These unconscious biases are encoded into our massively modular, and highly layered cognition, largely as a result of evolutionary adaptations. In the next volume, we'll talk about how we encode these biases and other cognitive traits in culture and the technology hardware and software around us, but here we look at the "wetware" of the primate brain. In the past, these adaptations were suited to the environments where past populations lived, and they became hardwired through inheritance into the way we think today. Many of them are still remarkably adaptive in our current environment. However, many of them also don't work as originally intended in this new environment, or do work in the short term, but cumulatively work against our long-term success, in this modern environment. The brain is not the amazingly perfect, sophisticated and finely-honed evolutionary miracle that we think it is. In the modern context of fast changing powerful technologies and rapidly emerging artificial intelligences, however, the modern human brain is less than highly optimized; some might say it contains some serious outdated functions, which, if used incorrectly, can turn out to be dangerous internal flaws. This leads to a re-assessment of the current technological environment: it is not technological driven, autonomous, progressive and rationally planned.

It is driven instead by humans, and humans' adoptions of technology is driven largely by unconscious and irrational processes that are a function of anachronistic cognitive processes. This unconscious influence, scaled up to collective action, results in uncoordinated and unplanned emergent results. These human-technology feedback loops, can be termed "Technology", as opposed to the more fundamental term "technology" as used throughout this book. While "Technology" moves certain human values forward, it is also eroding certain other human values.

The "fat, broke, busy, stressed out and unhappy" conditions that are increasingly common in developed countries (admittedly somewhat hyperbolic, though, sadly, not too much) are not caused by technology, per se, but by the lifestyle factors, that result from these unconscious biases. We have inherited primal urges for sweets, energy conservations tactics which lead to more sedentary activity, as well as social behaviors and endocrinology and other key drives that are at best exaptions of primal impulses. These factors lead people to engage in technology which both entertains them during their downtime, but also create emotional stresses that cascade on the lifestyle nutrition and physical activity. At the same time, economics of this technology adoption across a broad population – in the form of new purchases or ad-revenue generated by our demands for new hardware, software, content and services, are a key driver of our economies. As

a result, there are widespread financial incentives for people to create technology that will be consumed by a large number of people, creating a positive feedback loop servicing these evolutionary-derived needs.

Just by becoming aware of these dynamics, by understanding their evolutionary provenance, we can begin to harness these adaptions in more positive ways, and learn to work around and coopt the potential weaknesses, and help us to lead better lives, build better technologies, and formulate better social and regulatory environments.

While we set out to provide a common history of the evolution of our brain which might provide an inter-disciplinary theoretical framework, we find the framework provides a foundation from which one can ask a number of concrete questions which may drive further research.

For example:

- Our memory processes - optimized to support the collection of food from a large number of plants and animal sources, distributed geographically across a given physical territory, and temporally across seasonal cycles: how do they function in a modern world, that is highly visual, not geographical, and whose change is constant and not seasonal? What are the strengths, weaknesses, predictable consequences of using memory optimized for the past in today's world? If one was to redesign this system from the ground-up, how would it be done differently, for a digital world? This follow-on question has real world implications on artificial intelligence, human intelligence augmentation, and human-machine teaming.
- How do mental processes and an autonomous nervous system that developed to deal with unmediated real-world visual, auditory, social and other cues, adapt to a hyper-mediated world subjected to significant manipulation and that has a popular bias towards extreme sympathetic nervous system stimulation? This has real world applications in a broad spectrum of fields from psychology and medicine to media creation and personalized curation.

Chapter 13 Conclusion

Discusses the major themes of the book, the next steps in this research area, and the personal implications to the authors of this work. Key point: when viewed through the very long lens of primate evolution, and a careful consideration of what drove that evolution, the modern era contains a remarkably condensed set of major changes to the human species. By themselves, any one of these changes could and did alter primate evolution. Now we are changing all of them, wittingly or not, in what amounts to a blink of the eye, when viewed through the arc of history, and evolution. While there is no roadmap to lead us through this unique and self-made period of animal biology, a review of how this played out in relatively slow motion in the past provides context to realize how unique this time really is.

Summary narrative: Today's popular media and academic literature have become occupied with the potential of today's technologies to distract us, and there is evidence that our children might have lower ability to control and direct their attention than previous generations. Our time is now commonly referred to as being "an attention economy".

But this is not a new problem. William James in his 1890 foundational classic, The Principles of Psychology, said: "And the faculty of voluntarily bringing back a wandering attention, over and over again, is the very root of judgment, character, and will. ... An education which should improve this faculty would be the education par excellence."

Developing skills like focus, attention and grit will serve anyone extremely well now, as it has done for hundreds of years. What is new is that technology has multiplied, by many folds, the effectiveness of us getting what we seek, what we attend to, for better or for worse. That has made it seemingly harder to concentrate on any one thing. As the demands for our attention climb, ironically, technology in its various forms is freeing up your time and attention, by decreasing the amount of attention it takes to shop, cook, drive, socialize or work.

Technology is not bad, or good, but nor is it neutral.

But reducing our world down to "an attention economy", we miss the discussion of where our attention wants to go and why. It is a disservice to this problem area, and ineffective to treat wandering attention as personal laxness or undisciplined response to 'unethical' technologies, without first understanding the root cause. Far better to understand, rationally and consciously, what, how and why the brain works the way it does, by understanding its evolution. Like a parent with a child afraid of monsters in their room, we can open the closet, and look under the bed. We can understand that much of what the brain is trying to do is to protect us, and unconsciously process information in a way that makes it easier for us to function. However, these responses originally developed in a time when danger was abundant, and resources were scarce. These optimization instincts don't always work in our favor in a modern environment in which danger is scarce, and resources are abundant.

Are these insights sufficient? No. They provide the beginnings of a theoretical framework, informed by one set of evidence gleaned by proxy, of how our brain developed from 80 mya-~7 mya. At a minimum, we need to move the clock forward, and continue to examine the evidence of how the human brain evolved its distinguishing characteristics from 7 mya to the present. Understand the "Stone Age emotions" (to the extent it can be understood from available evidence). That is the focus of Volume 2 in this series. Also, this theoretical framework raises a number of questions that could be evaluated on modern humans in field/lab tests in the near future. We can use the definition of techniques as a starting point: what valued ends are people pursuing when they engage in a specific practice? I.e. - what reasons do people give, consciously for why they interact with technology? How does that reconcile with their unconscious goals? And how effective is that technology at giving them what they seek? What does their physiological and other evidence tell us about how well they get what they seek from technology? And what about the unintended consequences of those interactions? E.g. – if a middle-age professional says they watch Game of Thrones at the end of a long day to relax and unwind, how well do their biological markers like heart rate variability, cortisol levels and other data respond to this explicit intent? And what happens when you provide that biofeedback to the TV watcher – can they adjust their actions to align with their conscious and explicit goals?

Personal observation on this unique time we are living in, and the lessons learned from working on the book.