ADAPTIVE INTELLIGENCE: SOURCES AND FOUNDATIONS FOR INTEGRATIVE THINKING

IF THE GOAL OF OUR EDUCATIONAL SYSTEM is to train problem solvers for the world – and not just specialized thinkers and speakers of tongues, jargons and dialects – then the very nature of human intelligence has to be re-appraised, because the problems of the world, great or small, *have no respect for disciplines.* This is true not only of problems that have distinct social and human components – which clearly require the interpersonally adaptive deployment of multiple patterns of thinking – but also of problems that are patently technical in nature.

Discipline-based education, nonetheless, continues to shape our current view of intelligence, which has led to a chasm between the problems we need to solve and the kinds of thinkers we are training to tackle those problems. This chasm threatens to make **Peter Drucker**'s admonishment that 'The education system will become the biggest burden on the back of a knowledge society' into a reality within, in my view, no more than a decade.

To address this gap, I will introduce the concept of Adaptive Intelligence – a form of intelligence that transcends disciplinary boundaries and represents the expertise of a

solver of real-world problems. It is my hope that its components can serve as a blueprint for the development of a new approach to education.

Far from the mechanical application of learned rules, Adaptive Intelligence is 'adaptive' in the sense that it is responsive to problem and context and encourages an individual to master and deploy one or more of the following modes of thinking, which have proven to be highly effective for the solution of problems in domains ranging from Physics to History, from Engineering to Sociology.

1. Analytic/Synthetic Thinking. Analytical thinking refers to thinking that divides up ('lysis') wholes into parts that behave in identical fashion ('ana'). For instance, some economic theories divide up a market ('whole') into a large number of buyers and sellers (traders – 'the parts') who behave individually in similar or identical fashion ('price-takers', 'rational', etc.) Likewise, classical dynamics carves up wholes ('suspension system of a car') into parts ('linked masses, dashpots and springs'). *Analysis* refers to the process by which a whole is divided up into a set of parts such that parts bearing the same names ('springs', 'traders') behave identically to one another; and *analytical thinking* refers to the pattern of thought produced by a process of analysis.

By contrast, *synthesis* refers to the *combination* of two or more parts to form a whole. For instance, one can attempt to *synthesize* a simulation of the response of a market to a new product from the set of predicted responses of a large number of individual would-be users of that product; or one can *synthesize* a new car design from a set of known power technologies, design modules, parts and components. Synthetic thinking is thinking that proceeds according to a process of synthesis – of placing together parts into a whole – whether or not that whole is itself new. If the 'whole' to be synthesized is 'new', then synthesis is a model for *design thinking*, which can then be understood as a subset of synthetic thinking more broadly.

2. Convergent/Divergent Thinking. Convergent thinking is thinking that aims to produce a unique final result or output that is optimal or in some way *better* than its alternatives. Attempting to prove a theorem in a real analysis textbook is convergent thinking, because the fact that a proof exists is known; otherwise it would not be an exercise, but rather an open question. Structuring a paragraph in support of a header statement is *convergent* because the paragraph is supposed to produce an argument *for* that statement, thus making it more credible or persuasive.

By contrast, *divergent thinking* often leads us *away* from a single and unique end point, and often has a plurality of possible final states. Randomly listing a set of strategic options for the launch of a new product, and *sketching* the possible experiences of a user of a service are both forms of divergent thinking.

3. Constructive/Deconstructive Thinking. *Constructive thinking* proceeds *from* a foundation *towards* an end goal. Proving that a market with a particular disposition of buyers and sellers who have desires and beliefs of a particular form is *constructive*, as is the thinking involved in designing an algorithm for computing the square root of *2* in *Mathematica* from a known set of sub-routines: one constructs by building something out of something else. The difference between constructive thinking and synthetic thinking is that the parts from which constructive thinking proceeds are given and fixed.

Deconstructive thinking, by contrast, challenges the foundations on which a structure – such as an argument, a phenomenon or a dialogue – 'rest'. One can 'deconstruct' the rhetoric of **Angela Merkel** by examining the propositions that *would have to be true* in order for her arguments to have the persuasive force suggested by the vehemence with which they are articulated; or one can deconstruct the policy of the **U.S. Federal Reserve Bank** by examining the set of propositions about human behaviour that would have to be true in order for these policies to be advanced in the hope of producing Pareto-superior results for the economy as a whole.

Deconstructive thinking can be understood as a (more precisely articulated) component of *critical thinking*, which has morphed beyond recognition in recent times, to the point where any thinking at all may be claimed to be 'critical'; and as a more general form of *analytical* thinking – one that 'breaks wholes apart' without the need for a specific set of parts that are identical.

4. Logically-Deep/Informationally-Broad Thinking. This distinction captures habits and patterns of thought in many different disciplines. 'Logically deep' thinking proceeds to draw multiple, logically-connected implications from a finite set of independent parts – propositions, axioms, principles. Computing optimal economic incentive or taxation policies based on a known optimization apparatus and a known set of constraints, or calculating the efficient price at which a financial derivative shall be bought or sold, are examples of logically deep thinking. Obviously, some forms of analytic, constructive or synthetic thinking may be logically deep and *informationally narrow*, but not all forms of such thinking need to fit this profile.

By contrast, constructing a rich scenario for the launch of a new product in an emerging market – which incorporates everything from new kinds of users to new regulations – is an example of *informationally-broad* thinking, of thinking that admits as starting point a large number of 'data points' which do not have to be ascertained to be logically compatible or logically independent *before* they are admitted into thinking.

5. Declarative/Modal Thinking. *Declarative* (aka descriptive) thinking aims to articulate *what is the case* or what is *true*. It is a form of *saying*, undertaken with precision and care to avoid misrepresentation. Describing someone's emotional response to the reception of terrible news is an example of declarative thinking, thinking that is regulated by the norms of validity ('saying what is true and not saying what is not true') and completeness ('saying all that is true').

By contrast, *modal* thinking is thinking that articulates *possibilities* – of the logical or physical kind. Thinking up various approaches to disposing of the Earth's garbage is *modal* insofar as it aims to conceptualize possibilities in ways that are not immediately constrained by considerations of costs and benefits or implementation logistics. The lesser the set of constraints on thinking aimed at generating options for thought and action, the more 'modal' the nature of the thinking becomes. Loosening the laws of grammar and logic 'unshackles' modal thinking further (as in poetry or rhetoric) at the expense of risking that the resulting products of thinking become unintelligible (i.e., a sentence becomes unintelligible if grammar is given up.)

6. Inductive/Deductive Thinking. *Inductive* thinking aims to establish the validity of a universal statement ('all swans are white') from the validity of a set of particular statements ('all of the swans we have seen to date have been white'), to seek the minimal set of universal statements that are compatible with a set of particular statements ('what is the most 'empirically supported' explanation for the mortgage backed securities crisis of 2007-08?') or to produce a set of particular statements that are most likely to 'follow' from some other set of particular statements ('given the co-dependence of inflation with the following 21 variables over the past 76 years, what is most likely to happen to the annualized rate of inflation 1,2,3 years out?')

By contrast, *deductive thinking* is generally understood to be aimed at deriving particular statements ('this person behaves as if he were rational') from universal statements ('humans behave in ways best explained by Rational Choice Theory' [major premise] coupled with 'this person is human' [minor premise]). Deductive thinking proceeds by applying a set of 'operators' (the law of the excluded middle, the identity principle) to statements or sets of statements in order to produce 'new' statements that are self-evidently consistent with the statements already accepted. Proving the existence and uniqueness of an equilibrium in a model of a market of rational traders whose preferences and beliefs obey certain conditions is an example of deductive thinking that highlights this thinking as a (highly constrained) form of *synthetic* and *constructive* thinking.

7. Deducinductive/Abductive Thinking. Whereas combinations of deductive thinking (deriving the validity of particular statements from the validity of universal statements) and inductive thinking (deriving the validity of universal statements from the validity of particular statements), *abductive* forms of thinking seek to derive *the best explanation* of one or more particular statements. 'There are bear tracks in the snow outside of my tent' seems to be best explained by the fact of a bear being in the neighbourhood and making the tracks – rather than by someone with a bear-claw-shaped shoe trying to make a joke at my expense – *except* if I know that there are no bears in the neighbourhood at this time of the year and that there is indeed someone who is likely to attempt to fool me into thinking there are. *Abductive* thinking cuts through the requirements of both deductive thinking (the existence of a set of universal statements that are 'beyond practical doubt') and inductive thinking (the existence of a large data set on which I can compute probabilities in the form of statistical frequencies of the conjunction of various statements of fact) and aims to provide a 'best local approximation' to a mechanism or law that generates the facts in question.

Explaining the '**Enron** crisis' by reference to mismatches between the incentives of executives and those of shareholders is 'abductive' in this sense. It is not the 'best-supported inductive explanation' because there has not been an exhaustive search for all possible mechanisms that could explain the phenomena; and it is not 'deductive' because we do not have a secure, logically compatible set of propositions from which we can proceed to derive the facts in the same way we derive theorems about the real numbers from the axioms of the real number system. Thus, the 'best-ness' of the best explanation produced by *abductive* thinking is always inherently *fallible*.

8. Mono-Representational/Multi-Representational Thinking. As disciplines and areas of expertise have evolved particular language forms for their subject matter (point masses, collateralized debt obligations, credit default swaps, forces, flows: the list goes on, interminably), they have proliferated *multiple representations* of domains of experience, which can be understood as stylized models of 'the way things are' from the standpoint of that discipline's practitioners.

Some disciplines are mono-representational (Classical Mechanics, Neoclassical Economics) in that they rely on a single basic representation of relevant objects ('masses and forces', 'agents, payoffs and strategies') and events ('flows', 'strategic moves') for the purpose of solving problems that are considered to be 'within' the domain. Other disciplines (Sociology, Psychology, Semiotics, Anthropology) admit of multiple different representations of the same domain. Insofar as Adaptive Thinking must transcend the boundaries of any discipline or formal set of codes and pragmatically alter and deploy them for solving 'real' problems, the distinction between mono-representational and multi-rep-

resentational thinking is highly relevant. In order to give this distinction 'teeth', however, we need to distinguish between different types of representations – or models – used across the different disciplines and 'problem scenarios', as follows:

Relational Models. A relational model is an imaging tool that is used to represent – in a manageable scale and format – the disposition (usually in space, but sometimes in space-time) of the 'mapped' or modeled entities. Prototypical examples are a geographical map, which represents locations in a two-dimensional plane, a topographical map (three dimensional plane) or an anatomical chart (two-or three-dimensional).

Structural Models. Structural models are relational models that contain additional information about the properties of the objects being modeled, such as their size, strength and texture. These include architectural scale drawings, engineering mock-ups and blow-up models of molecular orbitals.

Dynamical Models. Dynamical models represent the space-time evolution of entities such as electrons, atoms, molecules, cells, humans, organizations, markets and societies – and beyond. They can be distinguished in three classes:

Causal and Law-Like Models. These use cause-and-effect relationships and laws (such as conservation of mass and momentum and the minimization of free energy) to derive the dynamical evolution of an entity via the set of laws or cause-and-effect relationships governing the interaction between its parts. Using such models, one derives laws of motion for muscles and joints using basic causal mechanisms relating chemical to electrical to mechanical potentials and the behaviour of markets from the statistical mechanics of brains linked by means of information transmission and reception media.

Teleological Models. These represent the dynamical evolution of entities by reference to the goals and objectives of their constituent parts. Models of (real) markets as (ersatz) markets wherein self-interested and rational agents (buyers and sellers) come together to trade, or of ideas, identities and narratives that seek to increase their own cultural footprint by ensnaring minds are ready examples; 'conspiracy theory' accounts of market failure are naive forms of teleological models.

Functional Models. Functional models represent the dynamics of entities in terms of *functions* that these entities as a whole serve. Views of markets as functioning to maximize the joint welfare of producers and consumers or of a cell as fulfilling a function within a tissue that lies within an organ system are examples of functional models.

9. Monological/Dialogical Thinking. Monological thinking proceeds in 'monologue-like' fashion, isolated from the thinking of others – for which reason it may be called 'egocentric'; while dialogical thinking is constantly 'in dialogue' with the thinking of another person – and can be thought of as 'alter-centric'. The distinction is as much one of the form and pattern of thinking as it is one of the purpose and function of thinking. Thinking through the costs and benefits of introducing a new product in a competitive market without reference to what competitors think, or to what they think you think, is monological. It implicitly posits a division of the domain of thinking into 'self' and 'world'.

Dialogical thinking admits the introduction of other thinkers as 'thinking partners': the alter-centrically thinking strategist will think about what competitors will think, and, if he credits them with being dialogical thinkers as well, he will realize that they will think about what he thinks, and will therefore also think about what they think he thinks ... and so forth.

10. Simulative/Emulative Thinking. Thinking (or, feeling) *like* someone is a different form of thinking – I will call it *emulative* – than is thinking about how someone thinks or behaves – I will call this *simulative*. In the former case, one may seek to immerse oneself in the life of the other, to 'walk in her shoes'. In the latter, one attempts to build models ('logically deep', 'deductive', etc.) and to 'test' these models against observations of the (presumed) outputs of the other person's thinking – such as her words or actions. The distinction is relevant to the difference between the kind of understanding developed and used in Literature and Theatre Arts (emulative) and the Social Sciences (simulative); and to the difference between producing a screenplay for a social cataclysm (emulative) and producing a model of a social cataclysm (simulative).

Putting The Elements to Work: The Functions and Aims of Thinking

The patterns of thinking described above represent a toolkit, not a catalogue; an alphabet rather than a script. Because thinking has multiple contexts, understanding *the purposes to which it can be deployed* will add precision to your Adaptive Intelligence toolkit. Following are five broad functions and aims of thinking to which the toolkit can be applied.

Advocacy and Inquiry. One can think *advocatively* – for the purpose of justifying or persuading. Think of arguing a court case, or an 'investment pitch' to a potential partner. Or, one can think *inquisitively* for the purpose of uncovering information – think of a cross examination or an investor's due diligence following the pitch. In the first case, thinking is directional and usually convergent: it is aimed at achieving or creating a particular state of mind ('persuasion'). In the second case, thinking is non-direc-

tional, often divergent and may be random. It is aimed at opening new potential venues for further thinking.

Understanding and Explanation. One may understand without being able to explain – as when one understands another's feeling or when one can 'just do' a complicated calculation, without explaining how one 'got it' – and vice-versa – as when one can explain why someone could be feeling as they are, without being able to oneself feel the same. This is why I consider these functions of thinking distinct from one another. Successful performance has been used to distinguish between understanding and 'mere' explanation ('if you think you understand a behaviour or a phenomenon, then produce it, don't just explain it') but that distinction sometimes belittles the importance of explanation in the transfer of skill: explaining how the Black Scholes Formula for pricing a European call option maps onto real data is an important part of getting someone to competently use the formula; explaining how to make an efficient surgical incision into an infant's armpit may be an important part of teaching one to make a minimal effective incision. On the other hand, the proven ability to use the formula in the right way at the right time for the right reason, or the ability to surgically open up an infant's armpit are crucial signs of real competence in derivatives pricing or pediatric surgery, which cannot be substituted by the mere ability to explain.

Reliability and Validity. Thinking can be deployed to the end of producing more reliable or more valid judgments, propositions or actions, and these two purposes should also be considered as distinct. I can build a model that best fits the data at my disposal, thus maximizing validity or 'goodness of fit'; or I can build a model that is maximally exportable to other situations – and this will maximize its generalizability, or reliability. In the first case, my concern will be with the particular – with all of the differences that make a difference to this case. In the latter case, my concern is with only those differences that make the most difference in the most cases. It is simple to see how these different concerns colour the thinking of, say, a finance theorist concerned with the universal applicability of a model or formula (reliability) and the financier who has a large stake 'in play' in a specific situation in which any small detail could matter.

Performance and Description. Thinking can be aimed at *stating* states of affairs – as in writing an account of an experimental result in a scientific journal; or it can be aimed at *producing* a state of affairs – as in the bringing about of a state of inner calm by repeating a mantra. More simply: 'Here is a house' is descriptive; 'I now pronounce you man and wife' is performative – it 'performs' a marriage when said in the right context by the right person. Thinking, also, can have a performative function that is separate from its descriptive function, but embedded in it: writing a detailed account of a scientific result functions descriptively as an articulation of that result and performatively to signal to readers of the paper the credibility and intellectual honesty of the writer.

Symbolic Creation and Symbolic Manipulation. Thinking may be deployed for the creation of new categories, metaphors and associations ('the audacity of hope', 'the world is too much with us') or it may be deployed for the rule-based manipulation of existing categories of thought (words, models, pictures, sentences), as is the case with the derivation of a new call option pricing formula from modified forms of probability density functions of returns on assets; or the derivation of a new solution to **Maxwell**'s equations based on a new orthogonal set of basis functions that satisfy the wave equation.

In closing

The toolkit introduced herein is designed to function as a set of building blocks for representing situations (models), understanding arguments made by people trained in various disciplines and satisfying various norms of rationality, reasonableness and coherence. It will also be useful for building alternative possible worlds and interacting with people who have radically different patterns of thinking to solve the world's messiest problems.

In summary, these (20) forms of thinking (*10 x 2 distinctions*) may be deployed for the achievement of the (10) purposes (*5 x 2 distinctions*), which suggests a *20 x 10* 'look-up table' of forms *x* purposes of thinking meant to be effective in different contexts, which are trained by different disciplines and cultivated by different professions. 'Trained by different disciplines' sounds promising, but in fact is just the opposite: it means that no person is professionally trained to think in more than one or two different ways that are guided by more than one or two different purposes, which leaves – at most – four of the 200 cells of the look-up table 'covered' by any one educational process.

Nevertheless, we are now in possession of an initial library of patterns and purposes of thinking that can be used by educators to develop and nurture better problem solvers for the world. Collectively, it is a blueprint for *thinking integratively* – across the different modes and domains of knowledge production and problem solving – and fostering and training adaptive minds that can transcend the mental habits of current disciplines and deploy different modes and patterns of thinking to solve real problems, in real places, in real time. R

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