Evolution of Empathizing and Systemizing: Empathizing as an aspect of social intelligence, systemizing as an evolutionarily later consequence of economic specialization

Bruce Charlton[1]

[1]School of Psychology, Newcastle University, NE1 7RU, UK

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Abstract

We argue that a theory of the evolution of Empathizing (E) and Systemizing (S) needs first to clarify that these are personality traits, as distinct from cognitive abilities. The theory should explain both the observed reciprocity of, and the sexual difference between, E and S in a context of the historical emergence of these traits and their balance in relation to local selection pressures. We suggest that the baseline state is that (since humans are social animals) ancestral human hunter gatherers are assumed to be relatively High Empathizers, lower in Systemizing: thus more interested in people than in things. Changes related to the development of agriculture and technology meant that it became economically useful for some men to become more interested in 'things' than in people, as a motivation for them to learn and practice skills that were vital to personal and (secondarily) social survival, reproduction and expansion. This selection pressure applied most strongly to men since in the sexual division of labour it was typically men's role to perform such tasks. We further hypothesize that High Systemizing men were rewarded for their socially vital work by increased resources and high status. Because marriages were arranged in traditional societies mainly by parental choice (and the role of parental choice was probably increased by agriculture), it is presumed that the most valued women, that is young and healthy women thereby having high reproductive potential, were differentially allocated to be wives of economically successful High Systemizers. Such unions of economically successful High Systemizing men with the most reproductively valuable women would be expected to lead to greater-than-average reproductive success, thereby amplifying the population representation of genes that cause high systematizing in the population. This hypothesis makes several testable predictions.

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BRUCE CHARLTON [1] PATRICK ROSENKRANZ

1. School of Psychology, Newcastle University, NE1 7RU, UK

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CORRESPONDENCE:
bruce.charlton@ncl.ac.uk

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INTRODUCTION: WHAT IS IT THAT NEEDS TO BE EXPLAINED?

The first purpose of this paper is conceptual clarification. In other words, we first aim to clarify what an evolutionary theory of Empathizing and Systemizing needs to explain: we need to be clear what has evolved, before we can suggest why and how it may have evolved.

Therefore we need to define the nature of both Empathizing (E) and Systemizing (S), and to emphasize that they are personality traits or 'dispositions' rather than cognitive abilities (see the section below for further explanation of this distinction). We consider E as the disposition to apply 'theory of mind' (or social intelligence) reasoning to experience; while Systemizing is a disposition to apply non-social, abstract and systematic reasoning to experience.

Therefore, E and S are distinctive modes of thinking – so that in an identical situation, an Empathizer would use one mode of thinking, while a Systemizer would use another – even if both had the same underlying cognitive abilities, their preferences or dispositions would be different.

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To put matters simply, E and S describe a fundamental *orientation* towards either *People* or *Things*. An orientation could be understood in terms of a spontaneous focus, or a preference. The reason for an orientation may be sought in terms of motivational systems of gratification and aversion: a concern with either people or things, will tend to give a particular person more pleasure (or less pain) than its opposite.

But the situation is not symmetrical for Empathizing and Systemizing, because Man is a social animal: thus a focus on people is to be expected, while a focus on things *in preference to people* is unexpected, and invites specific explanation.

In evolutionary terms, we therefore can take high E almost for granted, and the pressing need is to explain how it was possible that a preference to deal with things rather than people was able to arise, specifically in men more strongly than in women (Baron-Cohen, 2003). This need comes from our presumption that a preference for things over people would – on the face of it - be likely to cause a selective *dis-advantage* in terms of social relationships.

In particular, we would assume that (all else being equal) Systemizing would probably be a disadvantage from the perspective of sexual selection in its major form of female sexual choice – in a nutshell, it would seem probable that individual young women would prefer to choose high-Empathizers as sexual partners, rather than high-Systemizers. So, for high Systemizing to have evolved in at least some human populations; we need to explain how this presumed selective disadvantage may have been overcome: in particular how ancestral women of high reproductive potential could on average have ended-up reproducing with men who were relatively more interested in *things* than they were interested in *people*!

The second (and main) purpose of this paper is to describe specific hypotheses as to how and why E and S traits may have evolved in ancestral humans, what may have been their pay-offs in terms of reproductive success under specific conditions, and to clarify the reason for the reciprocity of these traits and the existence of sex differences in E and S (Baron-Cohen, 2003).

In brief; we regard Empathizing as the default human personality since, as the application of social intelligence, it reflects the great importance of social relationships to reproductive success. By contrast, we regard Systemizing as having emerged *later* in evolutionary history (and only in some, not all, human populations) as a result of novel selection pressures mainly due to changed economic conditions - especially the development of more-complex humans societies (such as those dependent on complex technologies or based on agriculture and trade) with a variety of socially-essential, specialized ‘jobs’: especially for men.

These evolutionary hypotheses are, at this point, necessarily speculative and intended to serve as a guide for future empirical research and testing, rather than providing definitive answers.

EMPATHIZING AND SYSTEMIZING CONCEPTUALIZED AS PERSONALITY TRAITS

Empathizing and Systemizing are personality traits – and the distinction between personality and cognitive ability, especially general intelligence or ‘g’, is something that needs to be made clear (Dutton and Charlton, 2016).

Intelligence and Personality are the two main ways that psychologists have developed for describing ‘individual differences’ between people and populations. The two types of differences can approximately be summarized as follows: intelligence is *ability*, while personality is *character*(or ‘disposition’); intelligence is *general* – with the level of intelligence affecting many specific abilities, while personality can be understood as a *pattern* of motivations, preferences, satisfactions etc.

In terms of an analogy with computers – intelligence is something like the processing speed, while personality is more analogous to the types of software installed. Or (and recognizing that a computer analogy for brain functioning is both selective and biased), intelligence is about the efficiency of the

brain, while personality is about what that particular brain is designed to do. Or, intelligence is about how well the brain works; while personality describes the circuitry, the hard-wiring – what *kind* of brain it is.

A further practical difference is that intelligence is measured by *tests* – for example IQ tests of various types; while personality is typically *evaluated by human beings* – either self-rated using self-describing personality scales, or else rated by other people.

But an important similarity is that both IQ and personality are (nearly always) *comparative* measurements. A person 'high' in intelligence, or high on a personality trait such as Empathizing, is high *relative to other people*. The terms 'High' and 'Low', when used both in intelligence and personality, therefore does *not* describe an objective measurement of a personal attribute in the way that (for example) high or low blood pressure or blood sugar measurements would. (This is why the psychological field is described as individual *differences*.)

Empathizing and Systemizing are properly conceptualized as personality traits, aspects of character, dispositions or preferences to behave in certain ways; and therefore not as cognitive abilities. E-S variations are thus not-necessarily correlated with cognitive abilities – and indeed in some studies there is no significant measurable correlation between E or S cognitive abilities. This is as expected, since personality studies were developed (especially by HJ Eysenck) to describe and compare individuals in a way that was not captured by IQ differences (Dutton & Charlton, 2016). For example, there is neither a strong nor consistent association between the 'reading the mind in the eyes' test (a test of a cognitive ability), and scores on a self-evaluation Empathizing scale (a measure of disposition or personality): so that an individual may score highly at reading the mind in the eyes but score low on an Empathizing scale, or vice versa (Lawrence, Shaw, Baker, Baron-Cohen, & David, 2004; Voracek & Dressler, 2006).

So, a disposition is a personality trait: understandable as a sustained tendency, an individual's characteristic of habitually deploying a mode of cognition. A disposition can also be seen as *an individual's preference for using an ability*. (In the sense that preferences can only select between a certain set of abilities; one cannot characteristically be disposed to act in any way that one is incapable of acting.) And preference to behave in certain ways is (presumably) based on a motivation, and motivation is associated with a psychological reward (or gratification) from doing something – or else a psychological punishment (or aversive consequence) of *not* doing something.

Ultimately, therefore, a disposition such as Empathizing reflects that certain types of behaviour lead to increased gratification (increased pleasure or diminution of suffering) – and behaviour that leads to increased gratification is preferred. Individuals differ in the types of behaviour that lead to gratification, and in the degree of gratification associated with a specific type of behaviour – so ultimately personality differences are underpinned by differences in what individuals find gratifying.

In sum, individual and group variations in Systemizing and Empathizing can be understood as variations in the type of behaviour that (on average) lead to gratification. Put simply: *Empathizers gain enhanced gratification from Empathizing behaviour, while Systemizers gain enhanced gratification from Systemizing behaviour*. For example, a typical High-Systemizer may have the *ability* to understand and empathize with other people, but he *prefers* to spend most of his time doing crosswords; while a typical High-Empathizer may be able to do crosswords to a high standard, but she would *prefer* to converse with a group of friends.

Naturally, the disposition to be Empathizing or Systemizing requires that there be the cognitive ability to do these behaviours; to empathize requires the ability to empathize and to systemize requires that different ability. And at extremes of disposition there may be a deficit in such abilities, so that the extreme Empathizer may be defective in systemizing ability and the extreme Systemizer may be defective in theory of mind ability.

However, deficiencies in either E or S ability are not necessary to the finding of variations in E-S, and it seems that there may be a wide range of E-S dispositions even when both abilities are fully intact. Therefore, these abilities must *first* have evolved in order that a disposition to find them rewarding and have a preference to use them may *secondarily* have evolved.

EVOLUTION OF THE SOCIAL BRAIN

The social brain hypothesis sees social selection pressures as the driving force behind human brain growth: higher cortical functions have evolved to deal with the adaptive problems of complex group living (Adolphs, 1999, 2009; Dunbar, 1995, 1998; Humphrey, 1976). The relative neocortex growth in humans and other primates is due to the demands on executive brain function required by living in complex social groups. Evidence in favour of this hypothesis shows that as group size increases across primate species, neo-cortex size also grows (Dunbar, 1995, 1998). The set of cognitive adaptations that enable successful group living, such as the abilities to perceive, recall and process information about others and act according to this information, is often termed social intelligence (Dunbar, 1998), Machiavellian intelligence (Byrne & Whiten, 1988) or social cognition (Brothers, 1990).

Group living poses a number of adaptive problems for the individual: attracting and maintaining a mate, monitoring and manipulating social interactions, outwitting rivals and forming alliances, inferring dispositions, motivations and intentions of others, etc. Selection apparently favoured those individuals who were the most successful at solving these adaptive problems of group living. In order successfully to survive and reproduce within a social setting, an individual requires the cognitive ability to react adaptively to social challenges and to affect others positively (Byrne & Whiten, 1988) .

Amongst the cognitive abilities enabling complex social interaction are face perception, emotional processing, theory of mind (TOM), self-reference and working memory (Grady & Keightley, 2002). These abilities are mediated by the interplay of activity of networks of interdependent brain regions which support the behaviours necessary for social interaction (Grady & Keightley, 2002). Amongst the neural architecture that contributes to social intelligence are the amygdala, ventromedial prefrontal cortex and the right somatosensory related cortex (Adolphs, 1999; Grady & Keightley, 2002).

An individual potentially benefits in terms of reproductive success by being able to predict the behaviour of others within the group, maintain beneficial social relationships and even manipulate social situations to advantage (Byrne & Whiten, 1988; Humphrey, 1976). A lack of the faculties required to function adaptively within the group can have negative reproductive consequences for the individual. The inability positively to affect others, at least to a degree, and adaptively to interact within a group can lead to negative emotional effects for the individual, social ostracism and ultimately, reproductive death (i.e. failure to raise any viable offspring). This can most clearly be seen in the devastating effects of lesions and or disorders to the social functioning of the individual (Ylvisaker, Feeney, & Szekeres, 1998). For instance, individuals with the autistic spectrum disorder have abnormal face perception (Klin et al., 1999) as well as strong deficits in the theory of mind mechanism (Grady & Keightley, 2002). Autistic individuals have difficulties in adaptive social behaviour, avoid normal social contact and are generally indifferent to social encounters (Baron-Cohen, 1997).

At the core of social intelligence lies the ability to “mind read” or theory of mind: this is the ability to infer the contents (beliefs, desires, intentions) of the mind of other individuals, predicting behaviour based on these inferences and empathizing with others states of mind (Baron-Cohen, 1999, 2000, 2006b; Baron-Cohen, Leslie, & Frith, 1985; Dennett, 1971; Premack & Woodruff, 1978). Mindreading is often seen as a predominantly cognitive ability, however emotions play a key role in inferring other agent’s content of mind and reacting adaptively.

EMOTIONS AND THE SOMATIC MARKER MECHANISM

Empathizing has evolved to *represent* the affective states of others and to react with an appropriate emotion. The importance of emotions in adaptive social behaviour is extensive; and they are pivotal in

successfully modelling social behaviour. Relevant here is the somatic marker mechanism suggested by Antonio Damasio (Damasio, 1994, 1996, 1999) and further elaborated by Charlton (Charlton, 2000, 2003; Charlton & McClelland, 1999).

Damasio (1994, 1995, 1999) makes a distinction between emotions and feelings: Emotions are changes in body state (and non-conscious brain state to a secondary extent) primed by either external or internal stimuli. Feelings are the conscious awareness of these changes in body state(Damasio, 1994, 1995). *Primary* emotions are those that are innate and triggered automatically in certain situations (Charlton, 2000, 2003; Damasio, 1995). For instance, a "fear" response can be triggered in the presence of a snake. The somatic response in this case would be an increase in heart rate, higher frequency of breathing, dilated pupils etc. This pattern of somatic changes constitutes the primary emotion of fear that can modify and initiate behaviour, such as a flight or fight response. These emotional changes in body states can be observed in most mammals; however, it is only some primates (the great apes probably, plus some monkeys; and perhaps a few other relatively large-brained social mammals such as dolphins, orcas and elephants) and of course humans that can be *aware of emotions* – that is, experience *feelings* (Charlton, 2000).

Secondary emotions are those emotions triggered by internal events such as remembering an encounter with a snake or planning a route to avoid a snake. Secondary emotions are induced by cognitive representations, i.e. internal events that have previously been associated with a primary emotion. These secondary emotional representations are dispositional in that they include evaluative information about the object/event priming the emotion in the first place. Thus, remembering an encounter with a snake can invoke the same changes in body state as the initial encounter. Secondary emotions can therefore be seen as being acquired through experience, and are built upon the foundations of primary emotions (Damasio, 1995). Secondary emotions therefore occur *in response to cognitive modelling or cognitive simulations* - such as memories or plans (Charlton, 2000).

Feeling an emotion involves secondary emotions, because feeling is the conscious awareness of a pattern of changes in body state in relation to the representation that primed these changes. Thus, representations are juxtaposed with relevant somatic states, i.e. emotions, to the extent that these representations are associated or marked with a particular emotion. This juxtaposition of representation and emotion is what constitutes the somatic marker mechanism (Charlton, 2000; Damasio, 1994).

According to Damasio (Damasio, 1994, 1996), the somatic marker mechanism is fundamental to distinctively human reasoning and decision making, especially within the social and personal realm. The neurobiological site which is critical for the somatic marker mechanism to function is the prefrontal cortex, more specifically the ventro-medial sector (Damasio, 1996). Individuals with damage to this section of the cortex have defective feelings, and face considerable difficulties making appropriate social decisions (especially in relation to context and planning), while still retaining normal intelligence and most intellectual capacities including the ability to experience primary emotions (Damasio, 1996).

Ultimately, a good decision for any organism is one that is advantageous for the reproductive success and survival of the organism, as well as the quality of survival (Damasio, 1994). Somatic markers assist and guide the decision making process by modelling outcomes of decisions through changes in somatic state. A possible bad outcome of a decision can manifest itself as an immediate negative feeling such as fears, misery or disgust. The representation of the negative outcome of a given response option is marked with the unpleasant feeling, allowing the organism to reject a possible decision from the outset. Thus, in Damasio's words "somatic markers are special instances of feelings, generated from secondary emotions. Those emotions and feelings have been connected, by learning, to predicted future outcomes of certain scenarios." (Damasio, 1994). The somatic marker mechanism functions as both a warning and incentive system for possible negative and positive outcomes.

When somatic markers operate consciously, they can assist in the modelling and planning of behaviour towards other organisms. By thinking about previous social encounters and being aware of the

emotional /somatic responses that are evoked through these deliberations, dispositions and intentions of others can be inferred (Charlton, 2000; Damasio, 1994).This means that somatic markers are pivotal in internally modelling social behaviour.

Representations of other people are linked in working memory with an appropriate feeling, thus associating own emotional reactions with the representation of others. For instance, the perception of a rival male can invoke the emotional reaction of fear. The perceptual representation of this individual is then marked with the somatic state of fear. At a later point in time, thinking about this individual, i.e. drawing upon the representation from long term memory can similarly produce the same emotional reaction. Inferences about the disposition of the other individual can be modelled upon the subject's own emotional reaction to the encounter (Charlton, 2000). In sum, 'theory of mind' is ultimately derived from awareness of the subject's emotional response to another person.

The somatic marker mechanism can be seen as being the underlying neurobiological mechanism of the theory of mind mechanism and the empathizing system. Where Baron-Cohen (2005) describes the development and function of these two systems, Damasio's somatic marker explain the underlying neurobiological mechanism by which both dispositions and inferences about another organisms' mental as well as affective states can be made.

Because human intelligence and consciousness have fundamentally evolved to deal with the social world, the spontaneous and immediate experience of the environment is infused by social information. Humans are primed to interpret ambiguous situation (like the fluttering of leaves) as being caused by agency (Barrett, 2000; Guthrie, 1995) and to reading social meaning into natural events (Bering, 2002). This tendency to anthropomorphise the significant environment and to imbue it with social agency may underlie the evolution of religious beliefs (Charlton, 2002a, 2002b; Guthrie, 1995; Rosenkranz & Charlton, 2013).

EMPATHIZING EVOLVED TO FOCUS ON PEOPLE, SYSTEMIZING EVOLVED TO FOCUS ON THINGS

Empathizing is based upon the above-described 'theory of mind' ability. Theory of mind refers to the ability, found in some social animals, to infer metal contents such as dispositions, motivations and intentions in another con-specific.

We conceptualize Empathizing as *the disposition to apply 'theory of mind' cognitive ability*– this can be applied to the social situations for which the ability (presumably) evolved, and also to understanding the world in general (and not just the social world). In other words, Empathizing is the spontaneous tendency of humans to focus on people, and also to regard 'things' as if they were people ('anthropmorphism').

Since humans are social animals, and in line with evolutionary concepts such as the Social Brain and 'Machiavellian Intelligence', we regard social intelligence as probably deriving from primate ancestry, and therefore closer to the ancient, natural and spontaneous form of human interest and motivation than is an interest in non-human-*things*. We therefore regard the highly Empathizing personality type as underpinned by an evolutionarily more-ancient personality type than is Systemizing.

In other words, Empathizing is more fundamental to humans than Systemizing, and is intrinsic to the species: Empathizing *came before* Systemizing. Further, it is possible that a preference for Systemizing did not evolve in all populations, and may be weak or absent in some human groups still extant. But in ancestral hunter gatherer situations – perhaps including pre-modern hominid ancestors – we would assume that all reproductively successful humans were not just able to infer theory of mind, but disposed to focus on other humans and their mental contents: almost everybody in these circumstances was probably a high Empathizer and so it seems likely that the Systemizing trait was low, and that there may have been few or zero high Systemizers.

Empathizing - in its evolutionary origins - is therefore personal in its application, being specifically

directed towards actual human relationships. To have an Empathizing disposition is to feel rewarded by attention to social matters, and to use this cognitive style (evolved to deal with humans) as a general model of understanding. Therefore be a high Empathizer is to *see the world through social spectacles* (Charlton, 2000): to have a tendency to focus attention on social relationships and to understand the world as analogous to social relationships.

Empathizing seems to be the natural and spontaneous way for humans to deal-with phenomena they regard as important: this is seen in the tendency to anthropomorphise large and important animals, significant places and landscape features, treasured possessions and so on; and to treat human *groups* (or modern institutions) as if they were unified, conscious and intentional organisms.

RE-DEFINING SYSTEMIZING AS A PREFERENCE FOR FOCUSING ON LINEAR SEQUENCES OF THINGS

Systemizing is (in its extreme) the disposition to attend to non-human matters – to things rather than people; underpinned by the tendency to find non-social interactions more rewarding, hence more motivating, than social matters.

The usual definition of the trait of Systemizing relates to a preference to analyse the world in terms of the *rules* which govern systems: such that the Systemizer is a person who sees the world as composed of systems, and is interested in categorization and understanding the rules, patterns or principles that underlie these systems (Baron-Cohen, 2010; Baron-Cohen, Ashwin, Ashwin, Tavassoli, & Chakrabarti, 2009). However, while this is clearly an accurate description of the interests of a high Systemizing personality *who also has high general intelligence*, we suggest that this is a potentially misleading description of the Systemizing trait since it refers to the understanding of *complex systems*; that is systems of processes that are governed by rules.

Yet it seems plausible that an interest in the abstract understanding of the processes of complex systems is underpinned (and evolutionarily preceded) by the simpler abstract task of *learning linear sequences*. So in terms of a personality trait, the interest in complex systems which is measured by Systemizing questionnaires may be considered a *more advanced* type of an elementary interest in simpler 'strings' of facts, names, numbers, tasks or procedures.

To create categorizations, to infer a pattern, and to extract the rules from a system are higher-level cognitive abilities; possible only to those of relatively high general intelligence (that is, high IQ). Abstraction of rules is, indeed, one of the main attributes of 'g' which is measured in standard IQ tests: for example in supplying the next member of a number series, or establishing group membership, or performing a visuo-spatial task like Raven's matrices (Deary, 2001; Gottfredson, 2005; Jensen, 1998). Those of low general intelligence are poor at these tasks (which is why they are used to measure IQ), and this implies that a focus on understanding the rules of systems is probably only a practical definition of Systemizing among those of higher intelligence; because people with a low IQ would not cognitively be able to infer and understand rules, even if their disposition was high-S.

Therefore, while inferring categories, patterns and rules certainly count as Systemizing behaviour, we would favour a more basic and less cognitively-advanced definition of systemizing: that the Systemizing trait is a disposition to be interested by things rather than people which is seen at its most basic in trying to learn *linear sequences of abstract facts or actions*.

The two main aspects of Systemizing, we suggest, relate to the *nature of content* which is *not-social* i.e. abstract; and to the content being understood in terms of linear sequences of facts. Therefore Systemizing relates to:

1. Abstract phenomena (things not people)
2. Of a specific identity (these particular things)

3. In a specific 'organization' (in this *order*, or *categorized* thus)

A modern example of the Systemizing preference, would be the kind of crazes and 'obsessions' which are characteristic of people on the autism spectrum or with Asperger's syndrome: learning lists of names and numbers from the telephone directory, or certain types of dates, or pictures make by highly-literal copying, or learning all the facts on a non-social themes such as automobile performance or the performance of a sports team, or literal recollection of sequences from favourite TV shows or passages from books, or hobbies involving collecting and arranging – such as stamps, cards or train-spotting.

These and other pastimes such as crossword or other puzzles, or some types of computer games, are often about assembling sequences of correct facts or procedures (united by theme or category) in a correct and specific order or pattern – yet these facts or procedures may not have any rule-based 'systemic' structure. Typically, one cannot learn these kinds of activity by learning and applying *rules*; rather, the activity consists in performing exact sequences of correct responses on specific material.

Interestingly, an explanation of Systemizing in terms of the disposition to focus upon 'close-up' consideration of abstract linear sequences, bears striking similarities with the concept of left cerebral hemisphere dominance as described in Iain McGilchrist's *The master and his emissary* concerning autistic traits and 'attention to detail' (Baron-Cohen et al., 2011; McGilchrist, 2009); although at the same time McGilchrist's evidence and argument renders implausible any direct equation of left hemisphere with male, right with female. The argument is complex and we flag it here as a matter deserving further and detailed consideration.

SYSTEMIZING AND PSYCHOLOGICAL NEOTENY

Indeed, this kind of behaviour focused on linear sequence of abstract knowledge is characteristic of children; for instance when they insist on a fairy story being told with exactly the same words and details. Many pre-adolescent boys, in particular, have periodic 'crazes' on various subjects (aircraft, trains, a type of book, a type of construction model, a particular sport) about which theme they voraciously learn everything they can manage.

These pre-adolescent boy's crazes are typically *not* focused on people nor on social relations, nor are they focused on rule-based understanding; rather they are fact-based, convergent activities involving listing, collecting, categorizing, memorizing – based on learning sequences and patterns but not often complex or dynamic 'systems'.

This similarity between pre-adolescent boys and high Systemizing men does not tell us *why* high trait-Systemizing may have evolved – does not tell us how high Systemizing may have improved differential reproductive success in our ancestors - but it may suggest *how* high Systemizing evolved: by *perpetuation of pre-adult behaviour into sexual maturity.* In other words high Systemizing trait in adults may be a *neotenous* phenomenon.

(Neoteny is one type of the more general class of 'heterochrony' in which evolutionary change is brought about by alterations in the timing of developmental events; Horder, 2001.)

And this may provide a clue to the proximate mechanism for the evolution of higher levels of trait Systemizing. Natural selection usually works by quantitative modification or amplification of some already-existing trait (as when a hand, or an arm, evolves into a wing in a bat, or a bird; or when a neck, or a nose, become lengthened in a giraffe, or an elephant). In humans, the evolution of the high levels of Systemizing seen in modern people suggests that there was some original trait which underwent evolutionary adaptive modification.

In other words; if neoteny – or something similar – was the proximate mechanism *via* which natural selection led to Systemizing, then we need to consider the trait which was present in immature humans that may have provided the basis for the evolution of adult Systemizing.

E-S RECIPROCITY AND SEX DIFFERENTIALS AS A CONSEQUENCE OF SELECTION PRESSURE FROM POST-AGRICULTURAL AGRICULTURAL ECONOMIC FACTORS

The main observations concerning E and S which an evolutionary hypothesis must explain are, we suggest, firstly the *reciprocity* between Empathizing and Systemizing – that when one is high the other is usually low; and secondly the characteristic sex differential with S higher on average in men and E higher in women.

In a sense, reciprocity is an intrinsic property of some personality traits: one cannot be both highly extravert and highly introverted, cannot be both highly neurotic and very stable. Similarly, one cannot be fascinated by social relationships such as to spend most of one's time and energy on that matter, and *at the same time* fascinated by learning about abstract facts and figures and systems so as to spent most of one's time and energy on *that* matter as well.

Most strong personality traits can, in principle, alternate in dominance over time and with circumstance – but they cannot dominate simultaneously. So it is an intrinsic property of E-S being descriptive of a *personality trait* that the predisposition towards one *extreme* of the trait is itself a predisposition away-from the other extreme.

However, in addition the E-S personality traits have been persistently observed as different, on average, between men and women. And most of the most highly empathic people are women, while most high systemisers are men. This observation invites an evolutionary explanation. We suggest that the ultimate (evolutionary) cause of sex differentials in E-S lies in the *sexual division of labour* among humans; men and women having different characteristic roles: women focused on child care and food gathering and preparation, men focused on whatever other tasks require doing: e.g. hunting, fighting, crafts (Lee & Daly, 1999; Lee & DeVore, 1968; Ridley, 1997).

Specifically, we regard Empathizing as a baseline state common to ancestral men and women, and Systemizing as having been selected-for at a later stage of human evolution, *primarily among men* due to the ancestral economic division of labour, and the economic benefits of having some men who are high Systemizers. We assume that there were significant material rewards for those men who were both able and willing to perform Systemizing tasks, and that these extra resources would have enhanced the survival of the offspring of successful Systemizers.

POST-AGRICULTURAL EVOLUTION OF THE SYSTEMIZING TRAIT

To recapitulate, the Empathizing trait refers to theory of mind abilities, which would be expected to be more evolutionarily ancient than the Systemizing trait, since they are found in non-human primates. Therefore a disposition towards Empathizing (theory of mind) are hypothesized to be a feature of pre-human primate and ancestral hunter-gatherer societies. We believe that Systemizing came later in human evolutionary history, and was an ability and disposition that (in a sense) *displaced* pre-existing Empathizing - on average and among men.

By contrast, while it may have been beneficial for men to be *somewhat* higher than women in Systemizing in hunter gatherer conditions; it is hard to see any need for, or evidence for, *high* levels of Systemizing trait in ancestral-type hunter gatherer societies, and it is hard to imagine a plausible benefit for a personality type which is characterized by the kind of high Systemizing which can be observed in modern Europeans – for instance those of the Asperger syndrome type. Ancestral hunter gatherers were (it is assumed) well-equipped by natural selection to deal with most of the non-personal/ 'thing'-related problems they would encounter, since they had lived in the same type of environment for up to hundreds of generations. The social brain perspective suggests that the most cognitively-complex tasks our ancestors confronted were related to understanding, predicting and manipulating human social interactions (Byrne & Whiten, 1988). And for these problems, humans were prepared by their theory of mind abilities, and the 'Empathizing' personality was motivated to apply theory of mind abilities in relating to the world.

Furthermore, ancestral hunter gatherers were *generalists*: apart from a sexual division of labour, essentially all women were involved in gathering and child care, only men were warriors and hunters. Any other activities needed to be fitted-around these requirements, but because the usual group size was small (probably around 15-35 including both the young and the old) there was only a little scope for specialization of function except in terms of sex and age (Charlton, 2000; Lee & Daly, 1999).

Systemizing abilities and interests therefore seems likely to be most beneficial in post-agricultural, more complex, less 'natural' human societies. Indeed, agricultural societies are usually characterized by some degree of economic specialization - especially among men (Woodburn, 1982). This is necessary because of the greater need for learned knowledge and technology – agriculture is itself a specialist expert activity requiring not just invention but significant preservation and inter-generational transmission of knowledge (which is why it was not invented as a stable and continuing social form until the past 10-15,000 years)

The evolution of Systemizing can therefore be seen in the context of life history (Rushton, 1985).Woodley (2011) sees ancestral hunter gatherer societies as characterized by a relatively *fast life history* – with high fertility, rapid maturation of offspring and early maturity – and this leading to an un-specialized type of human – with a narrow range or 'manifold' of abilities. This situation may be associated with strong sexual selection – men investing on average little in their offspring but competing for multiple promiscuous matings (with uncertain paternity); presumably men would tend toward early maturity, high vigour and physical prowess, but a short life and a mainly social intelligence (e.g. men being charming rather than Systemizing).

By contrast, as agriculture emerged, and population density increased; it is probable that life history was slowed due to greater competition between humans (Woodley, 2011) In such a situation, men especially would seek a *niche* in which they could excel, and this would be associated with slower and later maturation – and a wider range (or manifold) of abilities between individuals - which meant that some people were better at one thing while other people were expert at different things. The trend would be towards lower fertility but higher level of parental investment per offspring – and the father contributing economic investment to their offspring (about which they would need have had a high degree of certainty of paternity for this behaviour to be adaptive; Wilson and Daly (1992), Charlton and McClelland (1999).

HOW THE ADVENT OF AGRICULTURE AND TECHNOLOGICAL COMPLEXITY MAY HAVE FAVOURED HIGHER SYSTEMIZING TRAIT IN MEN

In ancestral 'simple' hunter gatherer societies there were probably a few tasks which focused on dealing with 'things' and where a personality preference for such tasks might be adaptive: problems such as navigating across a desert, manufacturing a spear thrower or stone axe, or preparing poison for a bow and arrow. Typically such jobs require (in pre-literate societies) learning and precisely remembering an *exact sequence of steps*. But such tasks are far more numerous, and more important, in agricultural societies where there is more technology, and where farming and the preparation and storage of food must be learned and repeated exactly year after year (Woodburn, 1982).

Such societies also typically develop specialists in religious ritual (priests) and in various crafts – and craft expertise in particular becomes absolutely essential to the survival of societies (Ingold, 2000; Ridley, 1997). Yet such crafts must be devised, remembered, and transmitted between generations. Our assumption is that it was this kind of selection pressure in agricultural societies which led to the evolution of high levels of Systemizing seen in some members of modern populations.

Systemizing was therefore a kind of *expert* disposition; indeed Systemizing was exactly the trait that would *enable* expertise to develop; because expertise was (we infer) mostly a matter of learning and memorizing accurately precise sequential facts and procedures. Thus the development of expertise is only partly about ability to perform a type of task – equally (or more) important is the personality which is motivated to do such tasks.

In other words, we suggest that *before* the development of agriculture, humans were originally towards the Empathizing end of the trait and that sexual differentiation was probably very limited; and that the characteristic observed modern pattern of E-S is primarily a product of economic selection pressures *after* the development of agriculture. We suggest, therefore, that the primary evolutionary cause of the range and reciprocity of E-S and also the higher average levels of S in men, was the sexual division of labour in a context of agricultural economic systems.

Adding together all these factors, our suggestion is that after the advent of agriculture, and amplified as human societies became more complex, more differentiated by specialization, and more technologically advanced; those men who were higher in the Systemizing trait enjoyed greater economic success with benefits in terms of wealth. This meant that high S men would have more resources to invest in their children, enabling them to rear more children to adulthood.

This matter of resources seems, indeed, to have been the major reproductive constraint in pre-modern societies. Until the industrial revolution, fertility was high in almost all social groups, but a high proportion of children died in childhood (e.g. from starvation and infectious diseases) – indeed among the poorest people, almost all children would be likely to die without reproducing. Those parents whose children had the lowest child mortality were therefore those with the highest reproductive success (Volk & Atkinson, 2013). The main factor that enabled some families to rear above-replacement numbers of children was wealth (Clark, 2007).

Therefore if high-S men did indeed (as we suggest) offer a higher probability of economic success, then under pre-modern conditions this would be highly likely to translate into greater reproductive success.

SEXUAL SELECTION

Personality clearly affects sexual attractiveness, and may therefore be subject to sexual selection. On the one hand, common sense, personal observation and theoretical considerations suggest that, on average, women do *not* find the highly Systemizing personality (with its preference for things rather than people) to be (of itself) sexually attractive in men. So, in a society, where young women chose their own mates and husbands, it seems hard to imagine that Systemizing would be amplified by sexual selection – rather, it would seem that sexual selection might tend to *prevent*an increase in systemizing trait among men.

On the other hand, individual female sexual preferences are not necessarily an important factor in determining sexual or marriage partners in the ancient and traditional human societies. This is because parental choice of a woman's sexual and marriage partners was the almost universal norm among pre-modern human societies, and indeed parental dominance of their daughters' reproductive decisions seems to have increased in frequency and strength with the transition from hunter gatherers to agriculture (Apostolou, 2014).

So, most historical human societies did not allow much scope for individual female choice of sexual or marriage partners and young women were essentially *allocated* to husbands – mainly by their parents (Wilson & Daly, 1992; Apostolou, 2014). In such societies, sexual selection, works not between a potential husband and wife, but primarily between a potential husband and his potential parents-in-law. What was important was not so much a man being sexually-attractive to a young women (as may be the case in modern societies), but primarily an attractive prospective husband and father as judged by the young women's middle-aged parents. This opens up considerable scope for positive sexual selection of high-Systemizing trait, if high-S is associated with the kind of attributes which parents-in-law are likely to value – that is, traits that seem like to increase the probability of rearing numerous grandchildren to adulthood.

Individual sexual choice seems, in particular, to be very limited in most stable agricultural societies and there seems to have been an increase in parental control over marriage between hunter gatherers and

agriculturalists, if modern examples of these societies are taken as a guide (Apostolou, 2014) – and it is our assumption that it was precisely these stable agricultural societies in which the Systemizing trait is likely to have arisen and been amplified in men.

A further factor is that one of the most powerful factors affecting female sexual preference is male*status*. Insofar as a high Systemizing trait *leads to* higher status in a man, then it may be *indirectly* sexually attractive – unattractive in itself, but associated with a higher status that *is* attractive(Buss, 1995; Symons, 1980).

If the Systemizing trait is probably (on average) either neutral or unattractive to individual young women, this suggests that when women are allowed to choose freely, sexual selection probably works to reduce or eliminate the Systemizing trait. This would imply that under modern conditions of independent female choice of sexual and marriage partners, Systemizing would be under a negative selection pressure; and that this aspect of male personality may well be experiencing a 'selective sweep' in which the representation of the trait in the gene pool will currently be changing from one equilibrium towards another (Miller, 2010).

Another aspect is that a highly Systemizing disposition would presumably (like all personality traits) be substantially inherited by female children as well as male children – even when there are sex differentials (Miller, 2000). So that high-S women would become more common, as well as high-S men – simply as a by-product of the economic selection pressure on men. Then, since Systemizing reflects a person's interests, and shared interest may be a factor in mate choice; it would be expected that more highly Systemizing women would tend to regard highly Systemizing men as relatively more attractive than would high-E women – especially if the woman was expecting to spend a lot of time with her husband. (This would be a form of *assortative mating*, whereby sexual partners are chosen on the basis of similarity; Miller, 2009.)

Assuming that high-S was rewarded by greater economic success and therefore the pay-off of being able to raise more children to viable adulthood – this would result in a population increasing in average Systemizing with each generation. And assortative mating between high Systemizers could plausibly be a mechanism by which *ultra-high* Systemizing might become a feature of populations – especially in men (Baron-Cohen, 2006a). Therefore this may be a plausible mechanism for the emergence of Asperger syndrome at a high frequency and severity – as a by-product of generations of relatively high-S women choosing high-S men as partners.

PREDICTIONS

The theory leads to a number of testable predictions:

Systemizing may be undergoing (in developed societies) on the one hand assortative mating which amplifies the number of very high Systemizers (Baron-Cohen, 2006a). However, in the opposite direction, the weakening of parental influence on mating decisions and the greater operation of sexual selection in the form of individual female sexual choice would probably generate a *selective sweep* that would be reducing the *average* level of S generation-by-generation.

The male female difference in E and S may have been quantitatively less in hunter gather societies than in agricultural or modern societies – and this smaller differential may be measurable in the modern social groups which have most recently been living as hunter gatherers; and who therefore have not yet experienced many generations of the selection effects of complex societies.

The theoretical model also suggests possible methods of measuring Systemizing and Empathizing by developing instruments that quantify people's spontaneous preferences as expressed in choices between focusing on either on *people* or else *things*.

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