

Thinking, straight or true?

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Abstract

This report summarises key findings and conclusions of a 13 year research programme conducted by Human Ecology Education between 2002 and 2015 into what has come to be called 'steering cognition'. The report documents key experimental findings and, where required, references previous papers in which detailed results were published. From the findings a best model that accounts for them is proposed: functional circuitry integrated around the imagination serves as an ecological executive system, involved in governing the self-regulation of conscious specific, effortful attentional biasing for the purpose of managing and responding to the epistemic demands of unpredictable, varied environments. Such a series, variable-state metacognitive system, referred to here as 'steering cognition', may account for some of the phenomena that have been interpreted as a parallel or dual processes. Evidence suggests steering cognition may also be a functional locus within which environmental priming has an attentional biasing effect. As such, steering cognition measurement may provide an empirically calibrated means of observing commensurate priming effects, of a wide variety of social and environmental cues, at both an individual and collective level.

Highlights

- Evidence is presented for a kind of heuristic 'steering cognition' which unifies dual-mind processing models
- The evidence supports a functional metacognitive executive system centred around the imagination
- A 13 year research programme involving 11,000 people has resulted in new understandings of the factors contributing learning, school ranking, pupil mental health and social cognition and personality formation
- The findings shed new light on existing research traditions, including dual-mind, automaticity, priming, self-regulation and cognitive linguistics
- Implications are posited for how we understand the relationship between errorful knowing and wise action.

1. Introduction: Does the brain think straight?

Since the 1970s a research agenda has emerged around brain processes that have been conjectured to create errors in human reasoning. Diverse research streams and their associated research models and traditions have described findings which loosely relate to the conditions and processes that lead to the brain making errors in cognitive judgement. This question is interesting because evolutionary selection pressures predict that errorful cognition would be an adaptive disadvantage. Mechanisms by which such cognition is, therefore, maintained through human evolutionary history are required.

A general term used to describe this kind of errorful thinking has been 'heuristic'. From the Greek, *eurisco* to discover, heuristic thinking has been posited to provide certain advantages of speed and approximation which, in the real world, may offer some benefit. A brief history of research, with reference to only the leading research figures, describing the character and properties of heuristic thinking is rehearsed below.

Automatic thinking. First described by Schneider and Shiffrin in 1977 who evidenced that the brain processes familiar and repetitive tasks/data faster and less consciously than novel data and tasks (Schneider, Shiffrin 1977; Schneider 2003). Evidenced that automaticity required effort and practice to attain before becoming a persistent cognitive pathway in processing familiar data.

Cognitive miserliness. First described by Fisk and Schneider who evidenced over a series of studies between 1981-3 that the brain will choose the lowest cost route to a solution rather than choosing a more effortful, higher cost route which may be more accurate (Fisk, Schneider 1984).

Cognitive biases. Described principally by Kahneman, Slovic and Tversky in the 1970s and 1980s, who evidenced that the brain will fail to detect logical fallacies presented to it, choosing instead solutions which are less complex and less effortful. This leads to errors of judgment and decision making (Kahneman, Tversky 1973; Kahneman et al. 1982). Kahneman applied these conclusions to the fields of economics, showing how trading decisions which were thought to be rational were often in fact irrational and errorful (Kahneman 2003, 2011) and is awarded Nobel prize for contribution to economics.

Heuristic substitutions. Kahneman and others went on to describe various forms of bias which seemed to involve thinkers substituting complex, abstract computations with personal, experiences of the same event. Concluded that a critical element of this quicker kind of thinking was the substitution of the abstract with the personal, imagined, first person scenario (Kahneman et al. 1982; Kahneman 2011).

Priming. First described by Bargh in the 1990s, who evidenced that the mind is nonconsciously influenced by the environmental cues around it (Bargh et al. 1996). Named 'priming' and shown to create conditions like attentional bias and blindness which could direct unconscious social decision making of the mind (Bargh et al. 2001; Bargh 2006; Bargh, Morsella 2008; Bargh et al. 2012).

Bounded rationality. Described principally by Gigerenza in 1990s who evidenced that in real-world systems, in which rationality was bounded by incomplete access to all the data available, the mind would make approximations and guesses to direct both thinking and acting (Gigerenzer, Todd 1999; Gigerenzer 2008; Gigerenzer et al. 2011). Argued that this gave evolutionary advantages of speed and the ability to cope with large volumes of novel data. Others referred to 'bounded rationality' as 'heuristic thinking' (Kahneman 2003).

Algorithmic / heuristic cognition. Described principally by Stanovich and West in the 1990s and De Neys and others in the 2000s who investigated the difference between the fast and slow forms of cognition, principally from the slow side (De Neys W. 2006; Neys, Glumicic 2008; Stanovich 2011). Researchers asserted a model of the slow, effortful, accurate cognition as algorithmic. By this they meant that when the brain has to come to accurate conclusions it uses a step by step algorithmic procedure in which it works its way through a series of steps to the right answer. They argued that this accounted for the difference in speed between this and 'heuristic thinking' which used more associative processing (Stanovich, West 2008; Stanovich 2011).

2. The dual-mind paradigm

By the 1990s these varied traditions of research organised their conclusions under a general theory of the mind called Dual-Mind Theory (Slooman 1996; Evans 2006; Evans, Frankish 2009; Evans, Jonathan St. B. T. 2010). Dual mind theorists assert that the brain has two systems for processing data. System 1 is a fast intuitive system which works by associative thinking and come up with approximations that may contain error. It is generally and very loosely described also as 'intuitive, unconscious and heuristic'. System 2 is a slow, effortful system which works by algorithmic processing and is used to reach conscious, accurate conclusions. The brain will choose system 1 before system 2 because it is less effortful. System 2 can override system 1 but only with conscious effort. Roughly speaking, system 2 approximates to what is measured by tests of fluid intelligence- algorithmic processing (Stanovich, West 2014).

In relation to the question 'Does the brain think straight?' the dual-mind answer is: it can but it often chooses not to.

Questions over the dual mind paradigm

Whilst becoming a widely accepted framework, the two system theory of the mind does have unresolved questions. These pertain to some theoretical problems with the model, methodology, as well as questions over the generality of interpretation of data. I will take these in turn.

The lack of a system 1-2 monitoring and switching mechanism. There is no clear understanding of how the brain switches between the two systems of processing. By what mechanism does the brain know whether to funnel data down the fast system 1 route or the slow system 2 route? Various proposals have been made (Ball et al. 2006; Neys 2010; Thompson, Morsanyi 2012). Theorists are often required to insert into the allegedly 'unconscious' heuristic system 1 a component of conscious metacognitive rationality to account for how system 1 can judge when to 'switch' routes to system 2. Stanovich has favoured a 'third rational' mind in addition to the heuristic system 1 and algorithmic system 2 (Stanovich et al. 2011; Stanovich, West 2014).

System 1 and system 2 are assumed to be equivalent routes to solving the same problems. However, Walker evidenced in repeated studies that the two are not equivalent systems; heuristic cognition is ecological and adjusts to environmental conditions, whilst algorithmic cognition is independent of the environment (Walker 2014 h.). These experiments provided evidence that heuristic and algorithmic cognition perform different functions. Heuristic cognition represents an executive function by which the brain regulates or biases other cognitive processing to meet the varied demands of the environment. Additionally, algorithmic cognition processes already incorporated data.

Dual mind research methods have tested cognitive processing only of limited structures of data. Typically investigators have used stimuli of the computational and linguistic kind (oral or written complex computations, tests and problems). As such, inferences and conclusions are limited to how the brain processes data of that kind. However, the brain processes an enormous range of varied epistemic structures of data, often very rapidly.

Some researchers have recognised the flaws in heuristics methodology (Stanovich, West 2014; Burgess et al. 2006). A test of heuristic cognition as an executive function, proposed to control the cognitive strategy used in novel, unguided situations would need to assess an individual via an epistemically unguided assessment. No test for heuristic cognition as a kind of executive function has been designed. Current cognitive and executive function assessments set up narrow epistemic tasks (a verbal problem to solve, a spatial match to find, a calculation to make), and guide candidates what the expected kind of answer is: find the match, calculate the sum etc... By doing so, they define the kind of thinking that is activated.

Later findings only loosely related to original core cognitive heuristics concepts may have become thrown into an already wide melange of ideas. It may be argued that, as the research tradition has widened, heterogeneous evidence that does not belong together has become too easily conflated under the term heuristics and biases. For example, Shiffrin's automatic processes related to repetitive processing; this would seem to be a different concept than that described by 'bounded rationality' conjectured as part of how we process novel, unfamiliar situations. As such, data interpreted as system 1, 'heuristic' processing, might not relate to that category of processing at all. Wikipedia lists 91 'cognitive biases', many of which are highly diverse and unrelated (https://en.wikipedia.org/wiki/List_of_cognitive_biases). This suggests the category may have become bloated and too loose to retain strong conceptual coherence .

One system would be better than two. A final problem with the dual mind model is that it is unparsimonious: a one system explanation of the evidence would be better than a two.

4. Research carried out by Walker and Walker 2002- 2015

Walker's Human Ecology research programme initiated in 2002, and joined in 2010 by Walker J., designed a research technology to collect a specific kind of non-algorithmic heuristic data.

General Method

For the sake of clarity, the Human Ecology research relates to a kind of cognitive heuristic phenomena called 'representation substitutions'. Kahneman and Tversky originally defined cognitive heuristics as the replacement of a complex, difficult question with an easier mental substitute (Kahneman et al. 1982). Many questions are too difficult for us to answer without considerable effort, they suggest. Kahneman posited that the question 'how much would you contribute to save an endangered species?' is complex involving consideration of kinds of species, spending priorities, environmental causality etc (Kahneman 2011). He suggests that system 1/process 1 mentally substitutes a simpler heuristic question as an imperfect but adequate means of getting an answer to the too-difficult question; in this case 'How much emotion do I feel when I think of dying dolphins?'

According to Kahneman, other heuristic substitutions might include: 'How happy are you with your life these days?', becomes 'What is my mood right now?' 'How popular will the president be in six months from now?' becomes 'How popular is the president right now?' How should financial advisers who prey on the elderly be punished' becomes 'How much anger do I feel when I think of financial predators?'

What is common to such heuristic substitutions is that they replace a more general, abstract, remote, theoretical scenario with a concrete, immediate, personally-experienced and affect-loaded scenario. In contrast to non-heuristic thought which is detached, rational and logical, *heuristic* thought centrally sustains mental participation in the story, an act of self-identification with the issue. It implicates a neural capacity to imagine ourselves as first-persons into a situation. It is this characteristic of heuristic cognition which we research and to which all of our findings relate.

Creating an imagined space.

To avoid inadvertently collecting algorithmic, non-heuristic, cognitive data along with non-algorithmic data, Walker first designed an assessment which involved no computational calculation, deduction or other algorithmic process. Walker exploited Kahneman and Tversky's correlation between heuristic cognition and the imagination (representation substitution). He created an online imagination exercise in which the candidate were instructed to imagine and then occupy a physical place in their mind. Candidates were instructed to imagine its setting, scale, dimensions, features, feel and occupants and activities.

In designing this exercise, Walker drew on Polanyi's proposal that a person's primary contact with the world is at the *tacit* or sub-conceptual level, rather than the explicit level, Walker conjectured that the imagination may serve as the cognitive function for tacit participative mentalizing (Polanyi 1958, 1966; Walker 1996, 1997, 1998). Embodied cognitivists have conjectured metaphor as the kind of language central to mental categorisation (Kopp, Crow 1998; Lakoff 1987; Lakoff, Turner 1989). Walker conjectured that such a neutral, metaphorical representation would represent a state of unprimed heuristic bias; that is to say, a state of heuristic representation to which no influence, other than the self, can be attributed. Informed by an older psychotherapist tradition (Lawley, Tompkins 2000; Siegelman 1990) and more recent findings from affective neuroscientific investigation (Panksepp 2003; Panksepp, Jaak, & Panksepp, Jules 2000; LeDoux 2000) Walker also conjectured that in imagining a mental space direct, affective mentalizing would be engaged.

The characteristics of the place, termed their 'space' during the exercise, were determined by the candidate primed only by clean language cues (Grove, Panzer 1989). The same set of verbal priming cues were used with candidates between 2002-2015 with only minor, modifications to language and number of cues. Children from the ages of 8 up to adults aged 60 undertook the same process. Candidates were informed and parental consent was received if a child prior to the assessment process. No candidate was required to write down, represent or share their imagined space with another. The space remained within the candidate's mind.

Post-assessment interviews with more than 500 consenting adult candidates indicated a very high degree of individual specificity and particularity to the spaces people imagined in their minds (Walker 2014b). Candidate-imagined spaces ranged from mountain caves, to sand beaches, from plains to castles, from wooded glens to high rise tower blocks, from hidden dells to beating party scenes, from arid deserts to river rapids, from busy homes to remote hideaways, from barb-wired territories to defended bunkers, from high-hedged houses to open ranches, floral gardens to rubbish dumps. Imagined spaces sometimes referenced explicitly recalled places from

the individual's own past. Often these merged with fictional imagined elements to form a composite real-unreal space. Other candidate spaces were entirely fictional.

Candidate interviews revealed a high level of detail and texture could be described, not only in relation to the physical appearance of the imagined space, but in relation to the activities and events seen taking place within it. Central to the process was the prime to see oneself within the imagined space. Candidates both viewed the space through their mind's eye, so to speak, but also saw themselves as an actor within the space in the third person. Candidate interviews revealed the extent to which the imaginer mentally participated within the space. Some adult self-report indicated a high degree of emotional valence associated with specific aspects of their imagined space (Walker 2014a). The goal of the priming exercise was to elicit an affective attachment to the symbolic landscapes imagined (Walker 2014b; Siegelman 1990; Lawley, Tompkins 2000).

Assessing first-person response to priming stimuli imagined within the space

Walker then assessed the first-person cognitive response of the candidate to a sequence of affective, social and cognitive mental priming stimuli imagined to take place within the imagined space. These were inserted into the assessment process as a sequence of 'imagined events' which the candidate responded to consider and incorporate into their space.

7 clusters of priming events were inserted to stimulate conjectured aspects of heuristic cognition. The priming clusters were: 1. how you define your space; 2. how you react to the impact of others upon your space; 3. how you manage change in your space; 4. what you choose to disclose of your space; 5. how you make sense of information in your space; 6. what distance of perspective do you take in your space; 7. how you exercise control in your space.

For example, a priming stimulus belonging to cluster 2. (How you react to the impact of others upon your space) was: *Someone else says your space is too big. Would you make it smaller?*

Between 1 and 4 priming stimulus statements, or items, were used for each priming cluster, depending on the particular experiment being conducted. Candidate response to each statement was measured by a selection on 6 point Likert scale. For example, to the priming stimulus *Someone else says your space is too big. Would you make it smaller?* Response options would be: *Not at all, no, probably not, maybe, yes, definitely.*

Selecting a response from the online set triggered the next statement to appear. In this way, the candidate's imagination was sequentially primed by up to 28 priming stimuli (Figure 1). Typical overall completion times for a 28 item priming assessment were between 8 and 15 minutes.

No response task required computational, abstract or procedural calculation. Using this method, Walker was able to ensure that responses were a measure of the candidate's associative processing, without the interference or contribution of algorithmic processing.

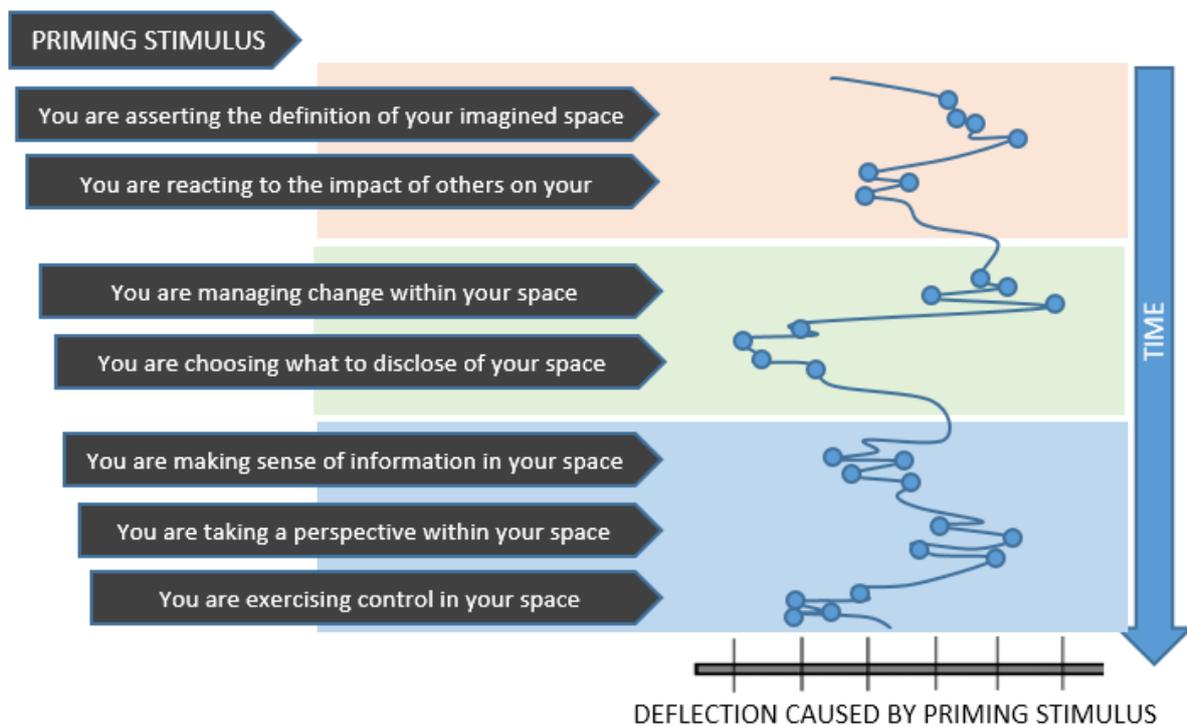


Figure 1. An example of a candidate bias deflections caused by 28 priming stimuli in 7 clusters.

Identifying a parsimonious factor structure

Walker's goal was to identify the most parsimonious explanation of the variance in imagined primed responses. He conducted the test with more than 11,000 candidates between the ages of 8 and 60 between 2002 and 2015. Using Principle Component Analysis, Walker was able to identify 7 latent largely independent 'heuristic substitution' factors (Figure 2) which he labelled S, L, X, P, M, O, T (Walker 2007, 2009, 2014c, 2014c). In the most recent and largest ever study, involving more than 8,000 secondary pupils in the UK, exploratory factor analysis confirmed a largely orthogonal factor analysis structure in which Eigen values revealed the CAS model 7 latent factors explained 50% of the overall variance (Figure 3). For the sake of parsimony, a 7 factor solution has been regarded as acceptable

In 2014 Walker referred to this 7 factor model as the Human Ecology model of CAS state – cognitive affective social state (Walker 2014c, 2007, 2009). In collaboration with Walker J., statement, or item, loadings onto each factor were analysed and improved by revisions during the period. In 2015, Walker J. described four of the factors in great detail (S, L, X and P) elucidating the relationships of the factors to affective-social self-regulation literature (Walker 2015a, 2015b, 2015e, 2015f, 2015c, 2015d, 2015g, Walker, Walker 2013).

-0.01	-0.01	-0.03	-0.01	-0.01	0.01	0.07	0.79	ratio_moderate_T
0.00	-0.01	0.03	0.22	0.04	-0.01	0.03	-0.02	ratio_moderate_M
0.02	-0.00	-0.25	-0.04	0.03	0.04	0.01	-0.03	ratio_moderate_O
-0.05	0.11	-0.01	-0.01	0.09	-0.02	0.88	-0.04	data_moderate_P
0.02	-0.00	-0.04	-0.03	0.01	0.79	0.06	-0.05	data_moderate_S
0.00	0.26	-0.04	-0.01	-0.01	0.01	0.05	0.06	data_moderate_X
0.04	0.01	0.01	0.02	0.75	-0.01	0.06	0.06	data_moderate_L
-0.02	0.10	0.08	-0.02	0.03	-0.06	-0.02	0.43	data_moderate_T
-0.10	0.04	0.05	0.98	-0.08	-0.03	-0.05	0.04	data_moderate_M
0.05	-0.09	0.99	0.04	0.06	0.03	-0.03	0.02	data_moderate_O
-0.31	-0.01	-0.00	0.01	-0.02	-0.01	0.01	0.03	my_ranks
0.99	-0.03	-0.04	-0.06	-0.00	-0.00	0.02	0.02	mid_yis
Factor1	Factor2	Factor3	Factor4	Factor5	Factor6	Factor7	Factor8	

Figure 2. Factor analysis of a population of more than 8,000 13-18 year old candidates carried out in 2015 indicated a high degree of factor independence, suggesting orthogonal structure to Walker’s data model.

Factor	Factor name	Factor biases			
T	Trust of own ideas, opinions	Questioning of own ideas etc....	↔	Trust of own ideas etc..	Affective factors
L	Trust of others’ ideas etc...	Questioning of other’s ideas etc....	↔	Trust of other’s ideas etc...	
X	Embracing change	Resisting change	↔	Embracing change	Social factors
P	Self-disclosure	Holding back ideas, opinions etc...	↔	Disclosing ideas, opinions etc...	Cognitive factors
M	Perspective	Detached perspective when thinking	↔	Personal perspective when thinking	
F	Processing	Connecting ideas when thinking	↔	Sequencing ideas when thinking	
T	Planning	Focusing on the process/ experience	↔	Focusing on the outcome	

Figure 3. Walker’s Human Ecology 7 factor model of CAS based on the latent factors that emerged from the factor analysis

Distinguishing instinctive and contextual biases

Candidates’ CAS scores were referred to as ‘instinctive’ biases. Walker and Walker conjectured that instinctive biases represented a ‘baseline’ or resting state of heuristic bias to which the individual would revert unless primed to respond to a distinct, specific, contextual cue (Figure 4).

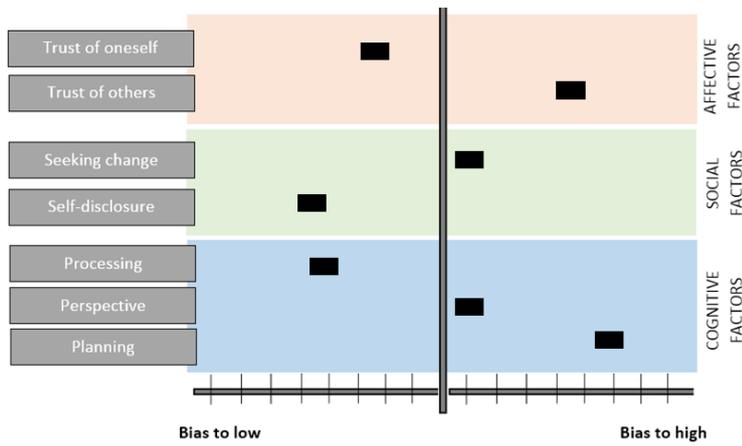


Figure 4. Candidate’s instinctive, bias score set against each factor represented a conjectured neutral, resting bias to which the candidate would revert unless responding to a specific, contextual priming cue.

Walker and Walker conjectured that, once the candidate had completed the baseline, by inserting an additional, specific, contextual priming cue into the imagination exercise, any measured deflection from the baseline scores that resulted could be attributed solely to the inserted priming effect. A calibrated effect of the primed event could be measured by a repeat of the same response statements, enabling the degree of deflection, adjustment or self-regulation of heuristic cognition in response to the contextual primed event, to be quantified. This pattern of deflection could then be reliably compared to any wider population similarly primed using the technology (Walker 2015g; Walker 2014 g.; Walker 2015g).

The contextual priming event might be a real event or a fictional but imaginable event. For school children a real event might be: being at school, or participating in a maths lesson, or participating in an english lesson. A fictional but imaginable event might be: taking a parent round the school, or facing an exam, or giving a presentation. Adult events might be: meeting a client, or chairing a board meeting, or leading a work team. Relative deflection of contextual CAS state from instinctive state was then measured (Figure 5).

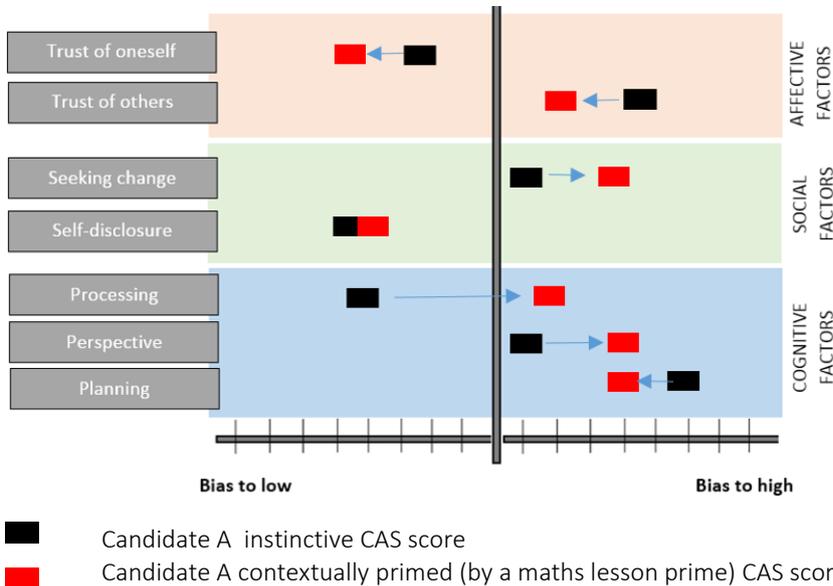


Figure 5. An example of deflections from instinctive to contextually primed CAS for an individual candidate.

5. Human Ecology Research 2002-2015 programme

Simon Walker, with post-2010 Jo Walker, conducted a programme of experiments between 2002-2015 in the UK to test the impacts of CAS instinctive-contextual bias regulation in both adults and children. The total number of adults involved in the programme was 960. The total number of adolescents and children was more than 11,000. The largest studies, involving CAS assessment with up to 8,000 UK secondary school students, compared ability to self-regulate CAS with academic outcomes, general intelligence. In all, more than 5,000,000 adjustments of CAS heuristic cognition were measured in relation to independent variables including algorithmic cognition, academic ability, mental health, age, gender, ethnicity, school type and school rank. In addition, several school populations, numbering between 1,800 and 2,000 pupils, were tracked for up to three years, through repeated annual or twice yearly assessment rounds. This provided longitudinal and chronological data. In so doing, Walker was able to identify the statistical relationship between CAS and a range of other both individual and institutional variables in large populations.

Programmes were developed to improve candidate steering cognition by using the feedback from the measured CAS data. Technologies developed included individual candidate reports, tracking graphs, advisory guidance, taught curricula and group training, coaching and education processes. In all, more than 2,500 children and 500 adults participated in such developmental programmes between 2002 and 2015. The impact many of these programmes was evaluated through participant response and other measures.

Walker and Walker’s findings to date:

Analyses were performed using PSPP and Lisrel 9.1 and R. Additional results tables are shown in the appendix. Results described in detail in previous papers are referenced.

5.1 Different curriculum subjects have different optimal CAS bias states.

Optimal CAS state models for core curriculum subjects maths, english and science were developed through multiple experiments. Multiple Pearson rank correlations were performed to identify whether heuristic bias regulation (as measured by optimal heuristic biased state) correlated with academic outcome, as measured by grade rank, or cognitive ability, as measured by CAT score. A best fit model of optimal CAS state biases that explained most variance was calculated (Figure 6).

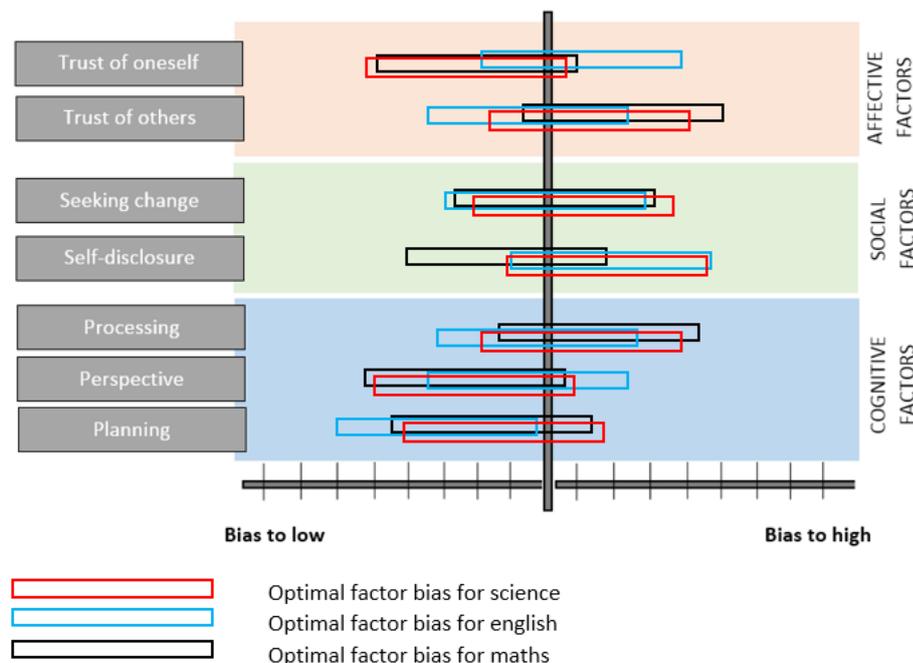


Figure 6. Optimal model for CAS state biases for each of the three subjects maths, english and science for secondary school students.

Results indicated that different subjects had different optimal CAS biases. For example, optimal bias in maths requires a lower trust of oneself than optimal bias in english. Similarly, optimal bias in science requires a higher degree of self-disclosure than in maths.

In one study (N= 97), a significant correlation of 0.3997 was measured between the ability of the pupil to adopt optimal CAS bias for maths, science and english and grade rank. A strong correlation (0.6451) between CAT score (a measure of *g*, general intelligence) and candidate academic grade for maths, science and english for was also measured.

ANOVA and multiple regression analyses were performed to test for the relationship between CAT, grade rank and optimal heuristic bias. One-way ANOVA was used to test for the relationship between optimal heuristic bias and grade rank. The relationship between optimal heuristic bias and grade rank differed significantly $F(1, 96) = 6.679, p = 0.0142$. A regression analysis was performed to confirm the relationship between optimal heuristic bias and grade rank, $F(1,96) = 6.689$, significance $F = 0.0141$. The slope is significantly non-zero, indicating that there is probably a relationship between optimal heuristic bias and grade rank.

The ability to adopt the optimal CAS state in a specific lesson, as identified by the model, explains 15% of the GCSE grades in maths, science and english that a pupil may achieve. In two independent study (N= 90 and 496) CAS score explained an additional 15% component of the variance of predicted pupil GCSE grades or other academic measures.

The ability to regulate CAS across varied subjects indicates that CAS is an epistemic cognitive biasing system which contributes to the accurate adjustment of ecological cognition to the *in situ* learning task (Walker 2014 g.).

5.2 CAS state adjustment explains an element of academic outcome not explained by CAT (a measure of general intelligence) (Walker 2014 g.).

Two separate studies evidence that CAS is a previously unexplained component of individual academic outcome. Correlation analysis of a large study (N= 8,000) showed the effects of CAS on academic outcomes could not be explained by existing measures of general intelligence (Pearson $r = 0.03$) suggesting that CAS is not a component of algorithmic cognition.

Our studies consistently found that pupils are able to adjust the CAS model 'Perspective' bias as they engaged in science and maths (detached, neutral perspective) and then switch when engaged to english (personal, involved perspective) correlated with higher academic outcomes (Walker 2014 g.). The flexibility to shift between first person viewer (my relation to this) toward greater abstracted data engagement (it's relation to others) may reflect the dynamic, at neural level, between existing relational mappings and the crystallisation of updated abstracted relational mappings. Other subject-specific switches included the ability to shift from high to low disclosing; from high to low trust of self; from high to low trust of others. As such, CAS self-regulation may be part of the brain's wider relational cognition approach.

5.3 CAS state may correlate with CAT but the relationship is asymmetrical: CAS explains a proportion of CAT but CAT does not explain CAS (Walker 2014 g.).

In one small study (N= 56), factor analysis showed that CAS explained a proportion of CAT score, whilst CAT score did not explain a proportion of CAS. It may suggest CAS has a causal influence on CAT potentially acting as a prior, serial data processing stage.

Factor analysis confirmed that CAS score loaded onto an independent explanatory factor of academic grade than CAT. CAT score loaded heavily onto factor 1 (11.26) but not onto factor 2 (0.35). Grade rank loaded heavily onto factor 2 (-1.97) and also onto factor 1 (0.91) with optimal heuristic bias loading onto both factor 2 (1.24) and onto factor 1 (-1.77). Factor analysis also confirmed that 70% of the variance between the two variables of grade rank and optimal heuristic bias could be accounted by one factor and 29% by a second factor. Optimal heuristic bias loaded heavily onto factor one (1.55). Grade rank also loaded onto factor one (1.15) indicating that optimal heuristic bias accounted for a significant proportion of grade rank. (Appendix 5.3 details).

5.4 CAS state was consistently and strongly influenced by school environment and can therefore be said to be subject to ecological priming effects (Walker 2014 h.).

Multiple independent studies (N = 11,000) across 20 primary and secondary schools, over 3 years, indicated that school consistently affected pupil population CAS scores, compared to instinctive scores (Figure 7). The results

evidence that school serves as an environmental priming effect, constraining and directing available CAS adjustment across whole populations. Unlike general intelligence which is a non-ecological cognitive function, CAS is an ecological form of cognition.

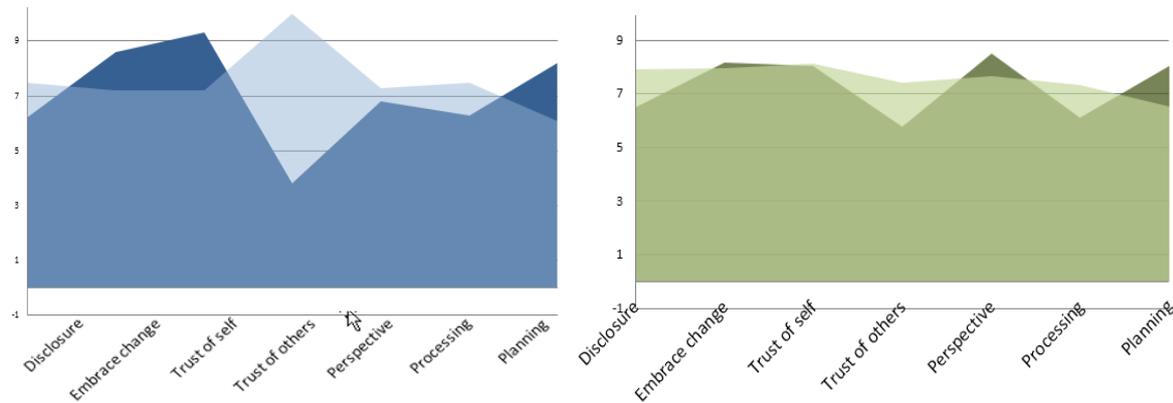


Figure 7. Showing the priming effect of two schools (blue school and green school), where the dark contour map shows the instinctive pupil CAS state biases in 14-15 year olds at the school, and the pale contour map shows the 'in school' priming effect on the same population

5.5 School environment can provide protective support to improve pupil self-regulation

A comparison between a student's instinctive dis-regulation and in-school dis-regulation score in one boarding school was made. A paired t-test was performed to determine if a boys' boarding house environment reduced dis-regulation of pupil affective-social state. Dis-regulation can be defined as a lack of self-regulation in the affective-social factors of CAS, measured by the standard deviation of a student's factor scores from a neutral, non-biased factor score (7.5).

The mean reduction in dis-regulation (M=0.18, SD =1.64, N= 51) was significantly greater than zero, t critical = 2.03, two-tail p = 0.021, providing evidence that the boarding house environment reduced dis-regulation and increased better self-regulation (Figure 8)

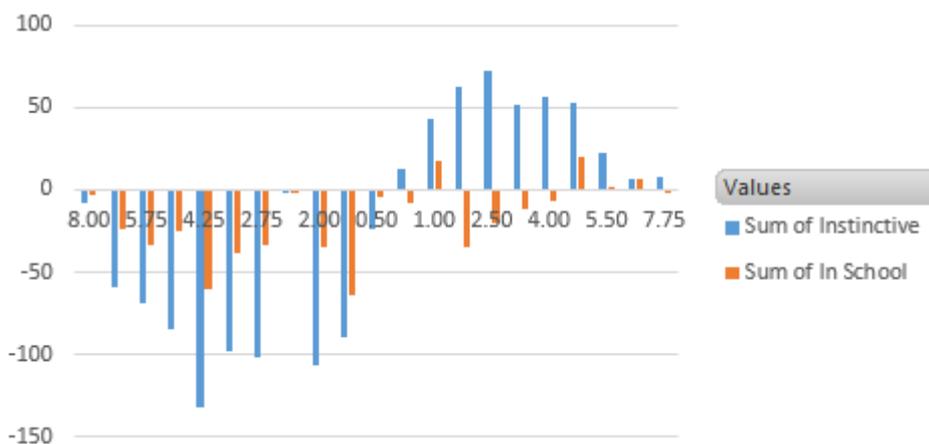


Figure 8. Showing the sums dis-regulation (divergence from the mean) of affective-social factor scores in a population when measured instinctively (blue) compared to in house (orange).

5.6 Some school experiences can have strongly dysregulating effects on pupil CAS score (Walker 2014 h.).

Multiple studies showed that some specific experiences common to schools may also have a dysregulating effect on pupil CAS self-regulation. In particular, experiences which expose pupils to public peer reaction (e.g. public ranked, competition results), trigger patterns of dysregulation. (Walker 2015a, 2015g, Walker 2014 h.)

Walker produced evidence of the role of CAS self-regulation under strain, through a manipulated example of such strain in a study of primary school children. In an experiment, 9 year old pupils (N= 98) were distressfully primed

by being asked to imagine seeing the results of a school race in which they came first, and then last, up on the noticeboard (Walker 2014d). The losing result was conjectured by the researcher to be a strainful experience, involving a child coping with feelings of anxiety, disappointment and embarrassment. They also imagined simply seeing their name displayed as participant with congratulations for taking part, rather than ranking.

Displaying the results of coming LAST had a polarising effect on pupil self-regulation; scores were pushed from a medial level to become either HIGH or LOW for each CAS factor. The effect was most acute for Trust of one’s own opinions, ideas and qualities and disclosure. This result is seen in Figure 9, where the graph of LAST scores shows two peaks at extreme dysregulation (where median is well regulated). By contrast, the graph of FIRST OR UNKNOWN scores shows a typical bell-shaped distribution, with the bulk of the children’s scores being in the medial range.

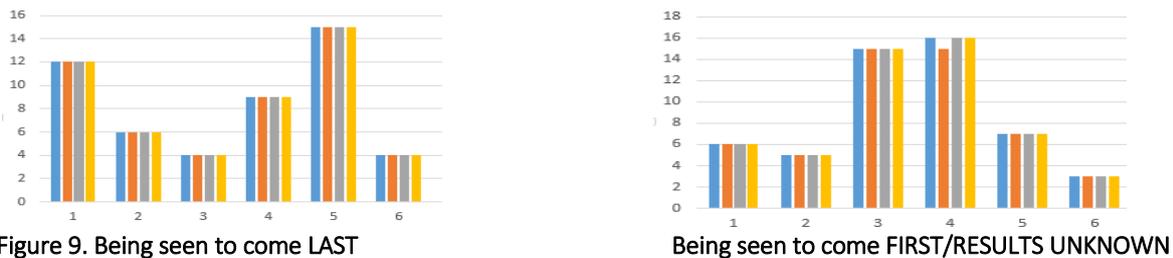


Figure 9. Being seen to come LAST

Being seen to come FIRST/RESULTS UNKNOWN

This result indicates that being seen to come LAST causes a large proportion of children to dis-regulate: in other words, to move toward an Affective-Social state that is more extreme and less well-regulated.

5.7 Less academically successful students can be primed to adopt a more optimal CAS state, though it appears this is effortful (Walker 2014a).

One study with year 10 pupils (N= 56) indicated that pupils be trained to exhibit better CAS states through targeted, precise individual CAS feedback and coaching (Walker 2014 g.). In a small pilot study (n= 13) of mixed-ability year 10 students in school H, 1:1 coaching was provided to support student development of CAS state bias regulation. Pre-intervention student CAS state biases in English, maths and science was measured using the CAS heuristic bias assessment. Over a 10 week period involving a 10 minute coaching conversation each week, advice was provided to individual students suggesting specific in-lesson behaviours that could improve their individual bias regulation, on the basis of their CAS state bias scores. After 10 weeks, post-intervention change in an individual’s subject-specific CAS score was re-measured (Figure 10). Changes in each student’s predicted GCSE grades in English, maths and science over that period were also measured.

Positive or negative changes in student CAS bias score compared to subject-specific optimal CAS were calculated and ranked. A Pearson’s r correlation (r= 0.291) was performed on the data to test for the effect size of changes in CAS to predicted GCSE grade; there is a moderate effect size (correlation) between changes in a student’s subject-specific CAS score and changes in predicted GCSE grade in that subject. A larger sample would be required to confirm the outcome of this small experiment.

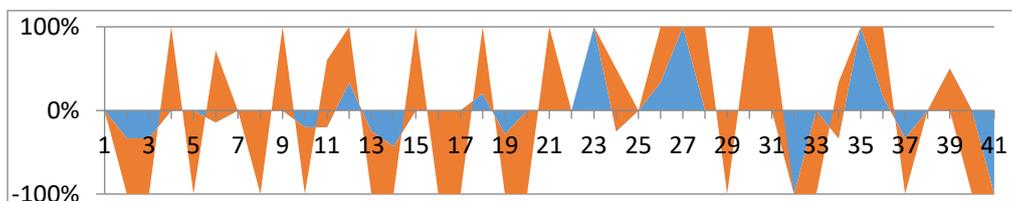


Figure 10. Change in CAS bias optimal score (BLUE) plotted against predicted GCSE grade changes in english, maths and science subjects (ORANGE), as a % of observed range of change for each in 14 year old pupils.

A second study, in 2015, with first year business studies undergraduates in the UK (N= 101) indicated that feedback on CAS score and coaching to improve CAS self-regulation could achieve statistically significant

improvements in both CAS and academic outcomes when compared to control groups. Training students to improve their CAS score may provide a previously untapped academic dividend (unpublished).

5.8 Pupils at higher ranking schools (as measured by better A Level grades) showed more tightly bunched CAS scores than lower ranking.

A large study (N> 8,000) of secondary, coeducational, state and independent day and boarding schools was undertaken during 2014-15. This involved populations of adolescent students in year 8,9,10,11, 12 and 13. 5 UK state schools, 5 UK independent day and 10 UK boarding schools were involved in the study.

Schools were ranked using 2012 A Level league tables on the basis of the average pupil grade score achieved. <http://www.telegraph.co.uk/education/leaguetales/9821874/A-level-league-tables-2012-compare-your-schools-performance.html?REGION=England>

Pearson r (from 0.22 up to 0.59 / factor) indicated that school rank correlated weakly to moderately with CAS variance. High ranking schools showed tighter in-group effects in social-affective biases than lower ranking schools, suggesting that social conformity, compliance and higher group goals contributed to the academic success of those schools. By contrast, in-group cognitive biases tended to be higher in high-ranking schools than low ranking, suggesting that high ranking schools fostered greater diversity in some aspects of cognitive thinking (Figure 11).

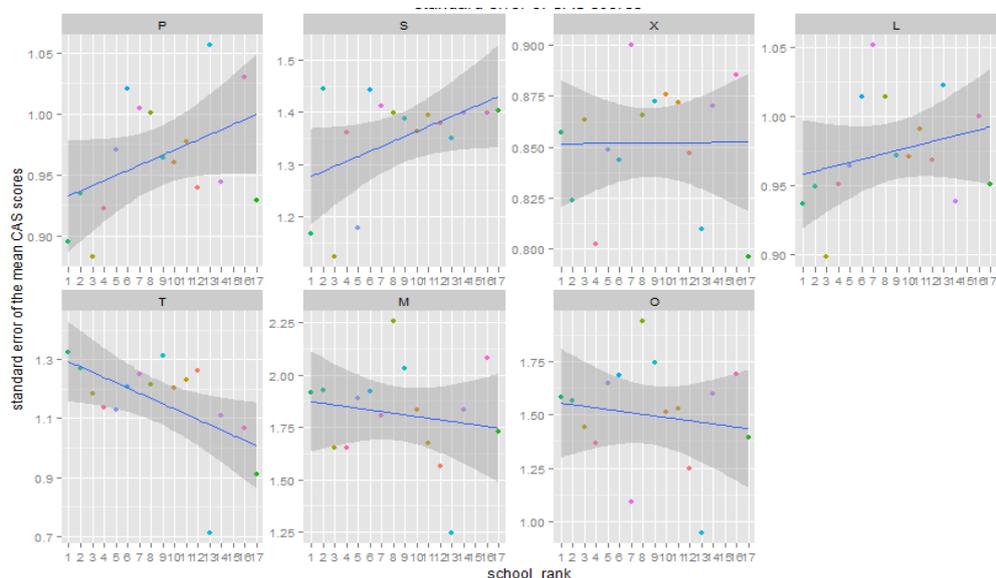


Figure 11. High ranking schools showed lower CAS variance for affective-social factors, but higher CAS variance for cognitive factors.

5.9 Surprisingly, pupils at lower ranking schools *effortfully adjusted* their CAS self-regulation more effectively when learning maths, science and english than higher ranking pupils did

A measure of in-lesson effortful control of CAS bias was developed. This model was designed to measure the amount of additional, contextual effortful control a pupil was exerting to adjust their CAS state from its instinctive state when engaged in lessons.

First, the model was developed for each of maths, science and english by:

$$\frac{(\text{Instinctive pupil bias} - \text{optimal maths lesson bias})}{(\text{In-lesson pupil bias} - \text{optimal maths lesson bias})} = \text{Effortful in-maths control of CAS bias (EC CAS maths)}$$

Second, the mean of the model scores was calculated by:

$$\text{Mean (EC CAS maths) + (EC CAS english) + (EC CAS science) = EC CAS lessons}$$

EC CAS lessons was then correlated with school rank to investigate the relationship between the effortful in-lesson control of students and school rank. Spearman rank was used to calculate correlation as data was ranked and monotonic. $R_o = 0.4$ evidencing that an additional 15% of school rank was explained by EC CAS lessons (see appendix for full rank results table).

However, the majority of the school rank variance explained by EC CAS lessons was counter-directional to A Level grade ranking (Figure 12). Pupils at lower ranking schools showed higher EC CAS lessons than pupils at higher ranking schools for most CAS factors. This result evidences that pupils at lower ranking schools exhibit greater effortful adjustment of CAS when engaging in their lessons than their equivalent peers at high ranking schools. The factors in which high ranked schools exceeded low ranking schools were the affective-social CAS factors rather than cognitive factors.

This result indicates that effortful self-regulation of CAS is an indicator of metacognitive labour and precision that is currently not represented or measured by formal, public secondary school academic school assessments.

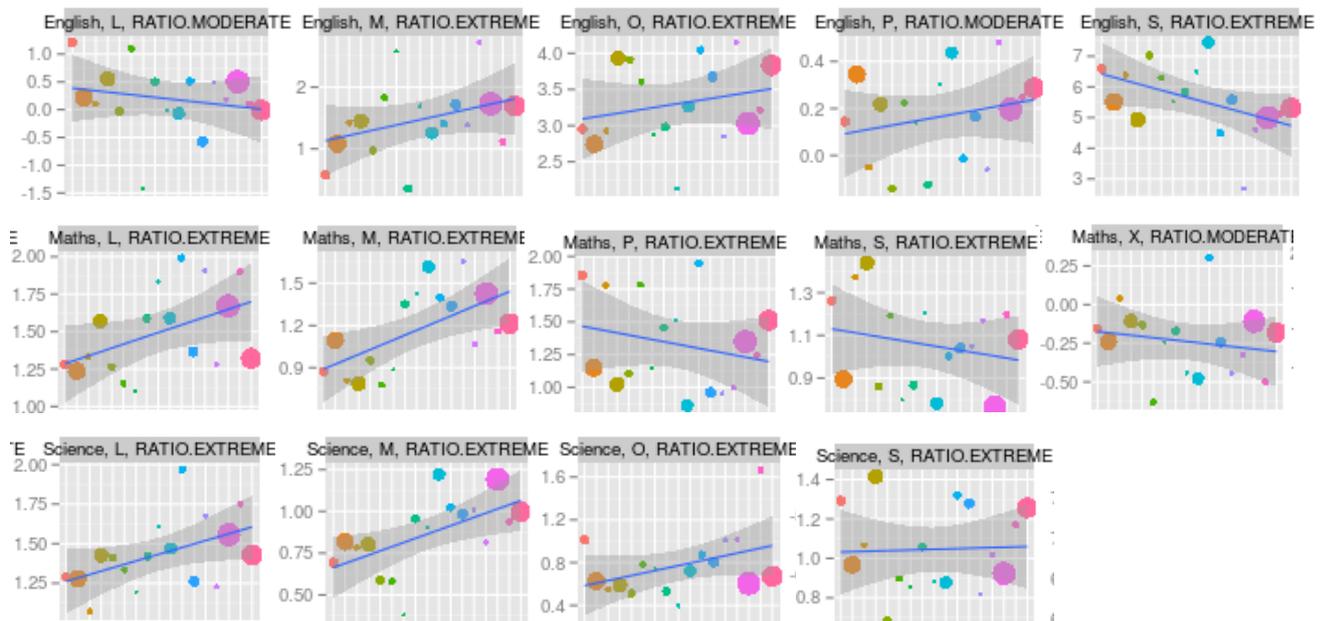


Figure 12. The majority of factors showed that low ranking schools (right on X axis) had higher, therefore, better EC CAS lessons than high ranking schools (left on X axis).

5.12 Speed of CAS adjustments associate with variance and CAT score suggesting that CAS self-regulation is effortful and slow, whilst CAS automaticity or dysregulation is effortless and fast (Walker 2014 g.).

Secondary pupils in a large study ($N > 8,000$) with low CAT (algorithmic cognition) showed greater automaticity in their CAS self-regulation and greater dysregulated bias. This was evidenced by variation in their adjustments to different priming cues, and increased speed of response to priming cues. The result suggests that both CAS automaticity and CAS disregulation are effortless and fast, whilst CAS self-regulation is effortful and slow.

When measured, pupils from higher ranking schools showed higher speed of response to priming cues than pupils at lower ranking schools (Figure 13). This result was statistically significant ($P = 0.04$), and explained 26% of the variance of school rank (Pearson's $r = 0.51$). One interpretation may be that pupils at high ranking schools are not rewarded for investing cognitive load into effortful CAS adjustment. Instead, pupils may deploy cognitive energy into algorithmic, computational tasks. Teacher-feedback from the highest ranked participant school indicated pupils were frustrated at the pace at which test items auto-scrolled forward.

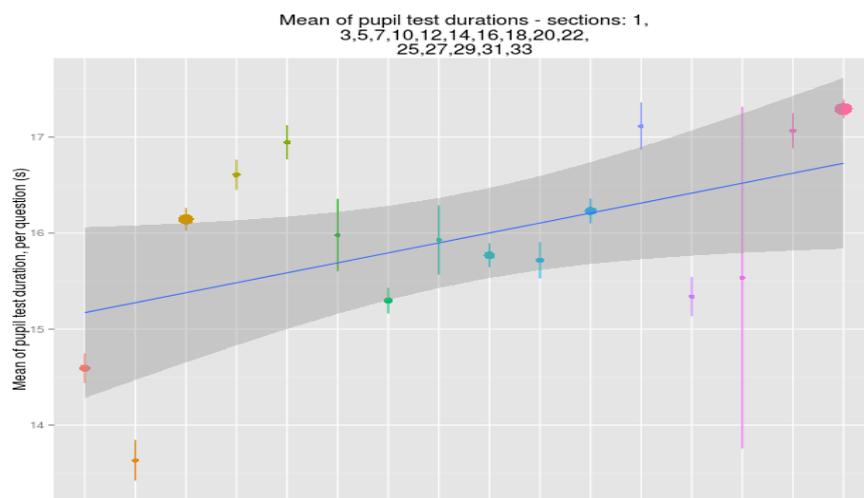


Figure 13. High ranking schools (X axis) showed shorter 'time of response to priming cue' (Y axis) than low.

High speed of response was also found to correspond with both low and high pupil CAS variance (Figure 14). High variance + high speed is interpreted as a dysregulated CAS state, which is thought to be effortless and inaccurate. High speed + low variance is interpreted to be an automatic cognitive state, which is thought to be effortless and quick.

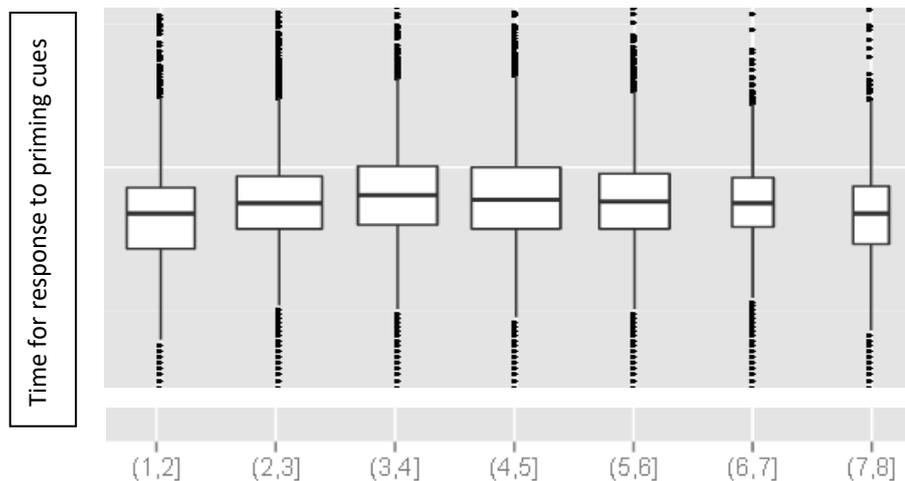


Figure 14. Time of completion showed a monotonic, non-linear relationship with CAS variance (X axis)

By inference, *over* self-regulation (a high degree of control and self-monitoring) is conjectured to involve effortful control that is costly, depleting and may be unsustainable (Walker 2015b).

5.13 Pupils with better self-regulation of AS factors of CAS (affective-social) show significantly less mental health / welfare concerns than those with poor regulation of AS.

Pupils in a large study (N= 2,918) were asked anonymously if they suffered from self-harm, bullying or coping with pressure at school. Statistically significant differences in AS dysregulation between the populations of those who did and did not suffer from each variable, evidenced that three categories of welfare risks are associated with poor AS self-regulation: experiencing bullying, not coping with pressure at school; self-harming.

A support-vector-machines (SVM) model was trained on the dataset. When used on the non-training data, the % accuracy of predicting only from pupil AS self-regulation score pupils who were considering self-harm, experiencing bullying or not coping with pressure. The model was cross-validated to test for both the % probability of both cases (bullied/not bullied etc.)

Bullying

The model achieved an 80% accuracy (83/78% both classes) in predicting children who were experiencing bullying. Experiencing bullying was associated with a significantly higher level of overall AS dysregulation and specifically with low self-disclosure. Pupils who have an AS bias toward low self-disclosure, as well as a high degree of dysregulated bias (a high deviation from the mean across their AS item scores) are more likely to have been or

experienced bullied. In contrast, pupils who have high self-disclosure and high self-regulation (low deviation from the mean in their item scores) are less likely to have been bullied.

Pressure

The model achieved a 83% (88/77% both classes) accuracy in predicting children who were not coping with pressure at school. Coping with pressure was statistically associated with overall AS dysregulation as well as, specifically, with self-disclosure and embracing change. Pupils who have an AS bias toward low self-disclosure, or a bias toward low embracing change, or a high degree of dysregulated bias (a high deviation from the mean across AS item scores) manage less well with the pressure experienced at school. In contrast, pupils who have high self-disclosure, high embracing change scores and high self-regulation (low deviation from the mean in item scores) cope better with school pressures. Pupils who show a combination of these factors (low embracing change, low disclosure and high dysregulation) are the most at risk population coping with school pressures.

Self-harm

The model achieved a 80% (82/78% both classes) accuracy in predicting children who were considering self-harming. Self-harm was associated significantly with overall AS dysregulation as well as with self-disclosure and embracing change. Pupils who have an AS bias toward low self-disclosure, or a bias toward high embracing change, or a high degree of dysregulated bias (a high deviation from the mean across their AS item scores) are significantly more likely to have self harmed or considered it. In contrast, pupils who have high self-disclosure, low embracing change scores and high self-regulation (low deviation from the mean in their item scores) are significantly less likely to have self-harmed or consider doing so. Pupils who show a combination of these factors (high embracing change, low disclosure and high dysregulation) were the most at risk population when it came to self-harm.

These results provide evidence that AS self-regulation scores are an indicator of hidden welfare risks in large pupil populations.

5.14 Those with poor self-regulation can be improved through support and show associated improvements in risks of self-harm.

13 pupils identified as having high risk on a welfare scale were supported by specific, targeted interventions over a period of 6 months by the school to lower their risk (for example, coaching, 1:1 mentoring). AS bias scores were also measured. At the end of the intervention, AS bias scores were remeasured, allowing a before intervention and after intervention measure to be obtained. Changes in pupil AS Tracking score were compared to changes in welfare risk score over the same period. Targeted dysregulated AS factors improved at a statistically significant level. Results were analysed using Pearson’s correlation (N= 13, df = 4) and indicated $r = 0.76$. P value < 0.0001 indicating that there was a significant correlation between changes in pupil AS Tracking scores and pupil welfare risk scores over the same period. Charts confirm the covariance of AS tracking and pupil risks over the period (Figure 15) (Human Ecology Education 2015).

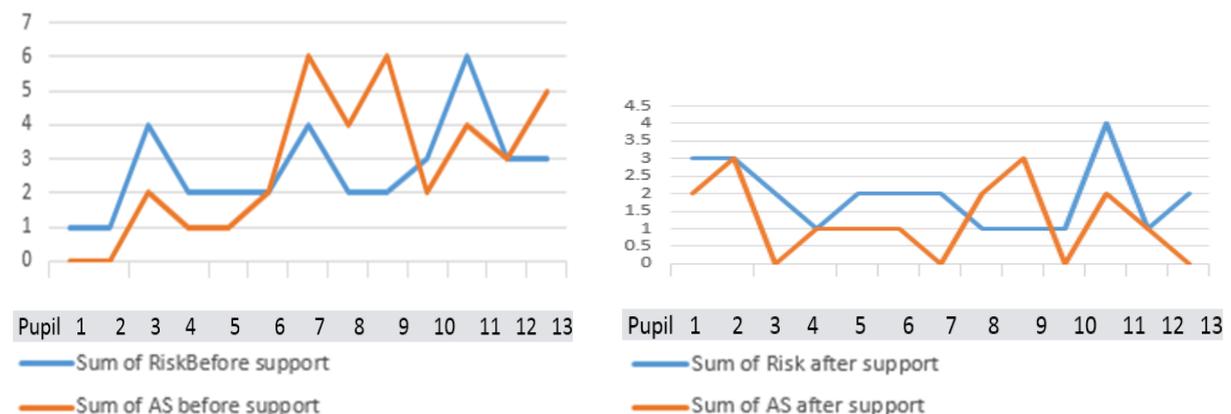


Figure 15 showing welfare risks (blue) and number of AS disregulated, polar, bias scores (orange) before (left) and after (right) support.

5.15 Previously unmeasured school type characteristics can be observed in empirically observable, distinct patterns of CAS self-regulation in their pupils.

Pupils in a large study (N> 8,000) from 17 schools of three types (independent boarding, independent day and state day) were measured for instinctive mean population CAS scores for affective-social factors P, S, X and L. Results showed no significant differences in instinctive mean population scores within margins for error (Figure 16 a.).

Populations were primed by 11 specific priming cues to investigate whether school type had an effect on CAS self-regulation. Examples of priming cues were *'taking parents round school'*, *'giving a presentation'*, *'facing a problem at school'*, *'visiting another school'*, *'being interviewed for a university place'*. Patterns of AS self-regulation in response to specific priming stimuli differed across the three types of school. For example, boarding pupils exhibited greater flexibility of adjustment of AS, as well as higher in-group, or tribal, biases. Day pupils exhibited greater individual autonomy and self-reliance through lower adjustment of AS and lower in-group biases (Human Ecology Education 6/19/2015).

Many other specific in-group effects were reported, indicating that the technology had a capacity to detect brief, previously uncalibrated cognitive causes which may contribute to socially recognised in-group features (Walker 2014d, 2014 h.).

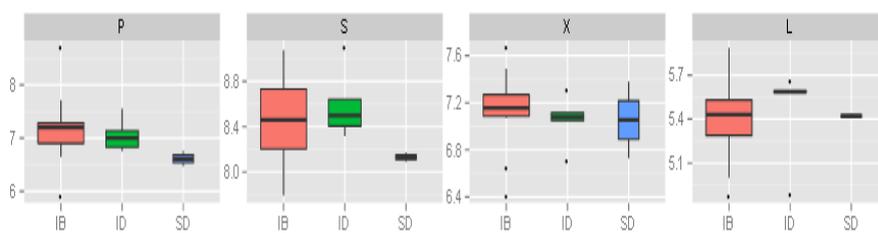


Figure 16 a. Instinctive CAS biases

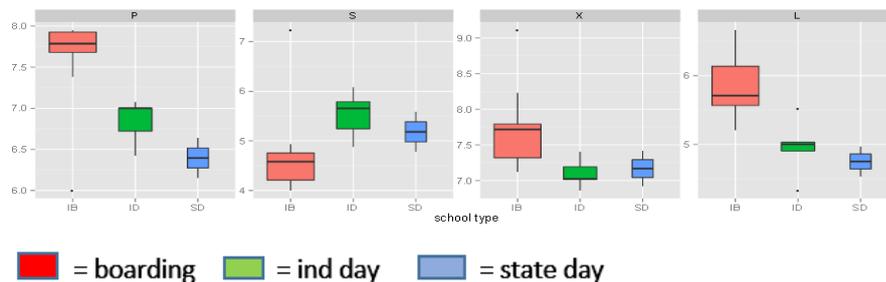


Figure 16 b. An example of contextually primed CAS biases, illustrating school-type specific contextual biases when primed by an imagined stimulus. Different imagined stimuli produced different priming effects.

5.16 During child development, ecological plasticity of CAS diminishes and becomes more crystallised

Walker has evidenced (with assessments of over 2,700 individuals between the ages of 8 - 18) that CAS biases become more figured and crystallised during child development (Figure 17).

In one longitudinal study over 12 months, Walker found that adults consolidated prior instinctive CAS biases despite repeated opportunities to shift them in the face of new opportunities and motivation. Walker also found a match between the adult's steering cognition bias and their perception of the biased state of other people around them; this supported a view that fixed cognitive steering bias involves a kind of attention blindness and other-representation bias identified by heuristics and biases studies (Walker 2002).

Walker evidenced in his doctoral thesis that such CAS bias configurations can be associated with distinct, defended personality patterns. They also correlate with different professional roles, suggesting that they become manifested as habitual, socially recognisable and functional traits in adults (Walker 2014a; Walker 2007, 2009). Such biases may account for patterns of social cognition and an individual's recognised habitual behaviours. Walker observed through therapeutic group work with more than 400 adults over 10 years that relinquishing such iterated patterns involves considerable effortful, attentional reworking which may trigger points of rapid, self-revolution and reconfiguration (Walker 2014b).

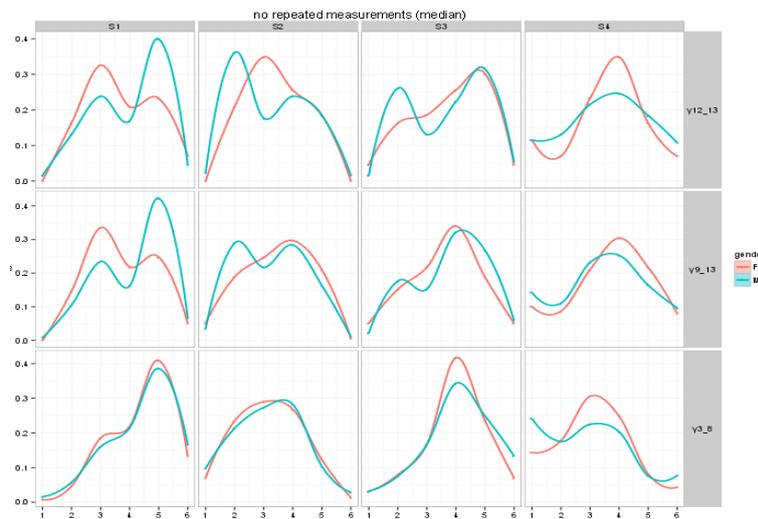


Figure 17. CAS item distribution scores for different age (10 yr olds bottom, 18 yr olds top) and gender (boys blue, girls pink) populations. Distributions show increasing crystallisations of bias patterns as age increased.

CAS population bias skews across populations are also age related. Younger children (8-9 year olds) show distinct population bias skews for each of the 7 factors, which diminish over development to adulthood (Figure 18). This suggests that, whilst individuals develop and crystallise their own specific CAS biases with age, the adult population exhibits a normal distribution of all possible crystallised CAS biases within it. By contrast, younger populations skew toward a narrower range of CAS biases, but that those biases are individually plastic.

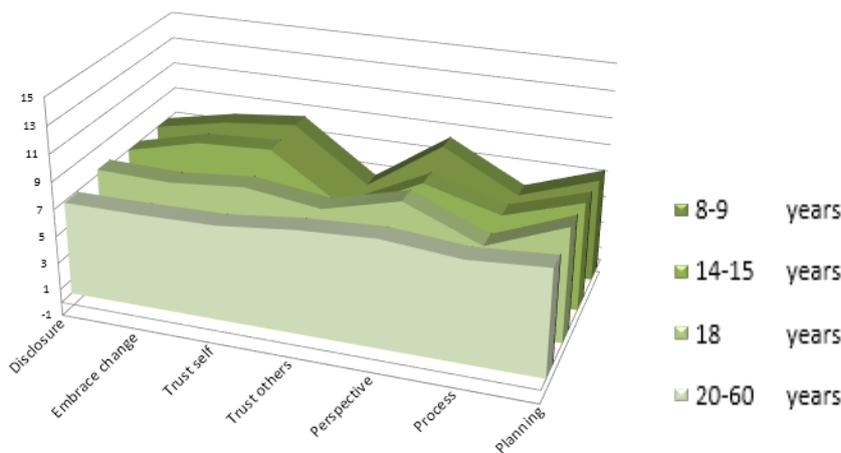


Figure 18. Population skews of CAS factor scores (Y axis) are distinct and age related and diminish with age

6. A model of steering cognition best explains the data

A model has emerged that best explains the data. The model, which I will develop in stages, can be summarised as this:

(6.1) Functional circuitry integrated around the imagination appears to serve as an ecological executive system, (6.2) involved in governing the self-regulation of conscious specific, effortful attentional biasing for the purpose of managing and responding to the epistemic demands of unpredictable, varied environments. (6.3) Such a serial, variable state metacognitive system, referred to here as ‘steering cognition’, may account for some of the phenomena that have been interpreted as a parallel or dual reasoning processor. (6.4) Steering cognition may also be a functional locus within which environmental priming has an attentional biasing effect.

6.1 *Functional circuitry integrated around the imagination appears to serve as an ecological executive system*

The 'simulation' role of imagination in heuristic cognition

Steering cognition centrally involves the simulatory function of the imagination, which serves as a plastic data manipulator and simulator in working memory. Novel representations of data are initiated within the working memory of the imagination prior to being filed, located, within long term memory. Self-and other representations simulate potential action and integrate with past experience, enabling goal-orientated action.

Supporting fMRI evidence

Wide research, using fMRI techniques, has identified and confirmed the role that the imagination plays in prospective and retrospective memory, self-representation and self-operation. From neuroimaging studies in rats and humans, Buckner suggested that the interaction of sub-regions within the hippocampus '*could provide the neural building blocks for simulating upcoming events during decision-making, planning, and when imagining novel scenarios*' (Buckner 2010). Schacter and Addis argue from abundant studies that the hippocampus is involved in both episodic memory retrieval but also prospective, future memory (Schacter, Daniel L., Addis, Donna Rose and Buckner, Randy L. 2007; Schacter 2012; Schacter et al. 2012; Addis, Schacter 2012). They assert that complex sub-regions within the hippocampus play various roles in the mental simulation of possible events and actions. Metastudies have also implicated a wider set of neural bases involved in functions relating to the prospective function of memory (Spreng et al. 2009), the simulation of self and other mental states (Decety, Sommerville 2003; Decety, Grèzes 2006) including Tempero Parietal Junction (TPJ), Precuneus (PC) and medial Pre Frontal Cortex (mPFC) (van Overwalle, Baetens 2009).

The imagination may provide the de-coupled mental environment in which experimental actions, choices and thoughts are simulated, played out, selected or inhibited. Decoupled simulation may be a critical process of heuristic imagination by which data of unfamiliar structure is mentally manipulated. Like a three-dimensions jigsaw piece might be manipulated and turned round in order to find the right orientation to fit it into the model, decoupled simulations within the imagination may play a role in the fitting of alien data into existing mental frames of reference. A model of *cognitive decoupling* has been proposed by several authors as a central mechanism by which the mind simulates possible scenarios in order to come to judgements (Evans, J. S. B. T., Stanovich 2013; Evans, Frankish 2009). One possibility is that such decoupled reflective simulation is best understood as part of heuristic cognition, performed within the imagination.

The data integration role of the imagination

The imagination may perform integration as well as manipulation of alien data in order to transform the internal narrative (Schacter 2012). Gaesser provides evidence that the regions of the brain that structure memory and imagination are involved in the construction of our affective, empathic responses to our environment (Gaesser 2012). Neuroimaging studies have evidenced that remote memory retrieval is also associated with the hippocampus (Ryan et al. 2010) and involves data of different kinds- spatial, visual, somatic, auditory, emotional.

Imagination is not limited to concrete, sensorial data manipulation but is involved in early-stage concept formation, as well as novel abstraction and concept-association (Leszczynski 2011; Halford et al. 2007; Colgin 2015). Data may be held in process by the machinery of the imagination, during working memory, and may enable activation of bindings to existing epistemic categories of long term memory (Halford et al. 2007).

Imagination and metacognition

The imagination integrates with other circuits in the executive function system, which provide a mechanism for self-regulation, effortful control, attentional bias, self-other thinking and metacognition.

In his series of experiments with secondary school students, Walker (2014 g.) provides evidence that regulating of steering cognition differentially between maths, english and science lessons explains around 15% of academic outcomes and school rank not explained by CAT score. What matters, he found, was the ability of the student to *regulate* their steering cognition toward an efficient solution for the learning task in hand. Efficient cognitive-affective heuristic strategies were adopted to cope with the varied epistemic forms of knowledge that were encountered in maths, science and english lessons. These included heuristic strategies of planning, sequencing, perspective-taking and learner-responsiveness in order for external data to be accurately retrieved and incorporated by the learner (Walker 2014 g.).

These results evidence that steering cognition contributes to the metacognitive execution of solutions to meet epistemic challenges. Researchers implicate metacognitive ability as a central component of the executive function construct (Halloran 2011; Miyake et al. 2000; Fernandez-Duque et al. 2000). Executive function is an umbrella under which many neural circuits implicated in *ad hoc* cognition are swept (Elliott 2003; Banich 2009). Miyake and Friedman's theory proposes that updating, inhibition, and shifting are central tasks of executive function, each of which relates to the capacity to adapt one's cognition to the task in hand. Updating is defined as the continuous monitoring and quick addition or deletion of contents within one's working memory. Inhibition is one's capacity to supersede responses that are prepotent in a given situation. Shifting is one's cognitive flexibility to switch between different tasks or mental states. Bull and Scerif have identified that inhibition and shifting are predictors of children's mathematical ability (Bull, Scerif 2001) and effective learning (St Clair-Thompson, Helen L, Gathercole 2006). Studies on mental state switching have shown that processing speed is slowed when learners are required to switch from one mental task to another. This suggests that mental states required for mental activities may exist in a state of neural inertia or require a costly switch to be thrown to be activated (Derakshan 2010; Mayr, Keele 2001; Monsell 2003).

Supporting fMRI evidence

An increasing number of studies have identified the link between decision-making and action with imagination. Decety et al. evidence that the imagination plays a central role in organising our behaviours (Decety, Grèzes 2006; Garry, Polaschek 2000). Schacter et al. evidence that the brain projects forward a method of self-operation prior to then enacting that projected sequence (Schacter, Daniel L., Addis, Donna Rose and Buckner, Randy L. 2007), serving as a guide or route map directing action (Schacter 2012; Stein 1994). Therapists Tompkins and Lawley describe a process of using the simulated imagination as an arena to re-model one's imagined self in the light of new data, as a means of obtaining control and self-agency (Lawley, Tompkins 2000; Siegelman 1990). In this regard, prospective memory may play an important role in imagining future selves (Decety, Grèzes 2006; Schacter 2012).

The executive function model of steering cognition provides an explanation of how humans navigate epistemically the varied and unpredictable 'real' world in which stimulus data is neither predictable nor homogeneous in structure..

6.2 Functional circuitry integrated around the imagination appears to serve as an ecological executive system, involved in governing the self-regulation of conscious specific, effortful attentional biasing for the purpose of managing and responding to the epistemic demands of unpredictable, varied environments.

Self-regulation

Affective-social self-regulation has been defined as the ability to flexibly activate, monitor, inhibit or adapt one's non-conscious, automatic affective-social strategies in response to direction from internal cues, environmental stimuli or feedback from others, in order to bring about an intended outcome (Rothbart et al. 2000a; Demetriou 2000; Eisenberg N. et al. 2006). As such, it is often effortful, volitional, conscious and purposeful (Eisenberg et al. 2000; Eisenberg et al. 2010; Hofer et al. 2010; Rothbart, Bates 2007; King et al. 2013, Bauer, Isabelle, M., Baumeister, Roy, F. 2011, 2011), and is sometimes described as effortful control. Put simply,

Self-regulation is the ability a pupil has to read the cues, both internal and external, and purposefully adjust their response in a particular situation, enabling the pupil to adapt in a flexible manner.

Supporting fMRI evidence

Neural circuits dedicated to resolving conflicts and managing error within the prefrontal cortex have been identified (Wang 2005). Lavin et al. review neuroimaging evidence that the Anterior Cingulate Cortex, ACC, is a part of the decision-making network that involves activity in prefrontal and parietal areas related to the observation of alternatives (Lavin et al. 2013) including responding to strain (Euston et al. 2012; Weissman et al. 2005; Bush et al. 2002). Ventromedial prefrontal cortex, vmPFC, vmPFC, has also been linked to consciousness of frustration (Blair, R J R 2010). Studies indicate that the ACC triggers activity to optimise fit to reduce strain and improve reward (Bush et al. 2002; Euston et al. 2012; Weissman et al. 2005). ACC is also thought to be central to stimulus inhibition (inhibiting response to non-salient stimuli) associated with attention deficit disorders (Fallgatter et al. 2004; Houghton, Tipper 1996) as well as management of conflict between incompatible response tendencies and error detection ((Polli et al. 2005; Weissman et al. 2005; Gehring et al. 1993). When the ACC was active, fewer errors were committed providing more evidence that the ACC is involved with effortful performance. Such strategies to reduce strain may take different forms, including organising and

executing enacted responses (averting gaze, moving toward/away from the stimulus) at its most basic, to complex intersubjective social actions, on the basis of mentalizing, which is designed to manipulate the kind of data requested and received).

It may be that strain experienced during the simulation of imagined events, decisions and activities in hippocampal regions, is detected by the ACC, which then plays an executor role in triggering appropriate responses to strain. Functional and structural relationships between the hippocampus and ACC have been identified. Studies in mice show that hippocampus plays a role in structural neuronal formation within ACC during the establishment of remote fear memories (Restivo et al. 2009). Some authors assert the cingulate cortex and hippocampus to be parts of an integrated limbic system of emotional memory detection and management in humans (LeDoux 2000; Etkin et al. 2006) and evidence has been shown that the ACC performs top-down control of limbic responses (Etkin et al. 2006).

The attention biasing function of steering cognition

In the study of children whose results from three hypothetical sports events were displayed in front of peers, the winning/losing results resulted in a switching of introspection-external processing (Walker 2014 h). When primed with either disappointing or elating results, children who had an instinctive steering cognition bias toward trusting others rather than themselves switched their attention from being internally biased to being externally biased. By contrast, children who had an instinctive steering cognition bias toward trusting themselves rather than others, switched their attention from being externally biased to being internally biased.

These results evidence that steering cognition regulation may involve introspection-external perception switching in response to environmental stimuli. Steering cognition involves the registering and recognising of ecological cues which are both social (embarrassment, status etc) and non-social. Biasing externally on the environment allows for actions such as noticing rapidly changing events, detecting subtle shifts in social cues, or executing responsive actions. Biasing internally allows for paying attention to the state of self-representation, incorporating new and unfamiliar ideas into an existing cognitive framework, managing internal affective state such that it does not overwhelm the perceptive system, or mentally rehearsing a set of actions prior to enacting them.

Supporting fMRI evidence

Studies implicate rostral prefrontal cortex (rPFC) as sub-serving a system that biases the relative influence of stimulus-oriented and stimulus-independent thought (Duncan et al. 2005; Paul W. Burgess, Jon S. Simons, Iroise 2005; Gilbert et al. 2005). Interestingly, such evidence of a gateway switch implies two systems of competing consciousness (one internally focused, one externally focused) which cannot both be attended to simultaneously. The evidenced association of mPFC and hippocampus in memory formation and retrieval and decision making (Preston, Eichenbaum 2013; Euston et al. 2012) suggest that it would be worthwhile to investigate the interaction of rostral PFC with hippocampal mental simulation processes.

Walker also evidenced other attention-biasing effects in steering cognition (Walker 2014 g.). He has postulated a relationship with theories of how the brain focuses attention upon its own thoughts as opposed to the thoughts of others; so called Theory of Mind (ToM). ToM circuits are conjectured to be the central basis for enquiry, listening and dialogue through conjectured processes of mental simulation (Decety, Sommerville 2003). Neuroimaging and lesion studies suggest that Temporoparietal junction (TPJ) Precuneus (PC) and medial Pre Frontal Cortex (mPFC) are neural networks involved in simulating self and other mental states (van Overwalle, Baetens 2009; Decety, Sommerville 2003; Decety, Grèzes 2006).

A central role for the imagination in self-regulatory executive function

A central role for the imagination as an integrator of metacognitive, self-regulatory executive functions has not been proposed before. However, close relationships in neural activation between hippocampus, ACC, TPJ, rmPFC and mPFC in mental simulation, strain management, self-other attention bias motivating, introspection-external perception switching suggest a possible coordinated heuristic executive system contributing to metacognition.

6.3 Such a serial, variable state metacognitive system, referred to here as 'steering cognition', may account for some of the phenomena that have been interpreted as a parallel or dual reasoning processor.

The steering cognition model explains some heuristic biases as a failure to effortfully regulate cognitive steering when faced with an epistemically unpredicted scenario

Steering cognition functions not as a parallel processing system to algorithmic cognition but as a series processing system. Algorithmic cognition is the procedural computation of data already located in the internal data set. Steering cognition integrates affect processing, algorithmic processing and embodied processing (sensory-motor control) (Figure 20 a. and b.).

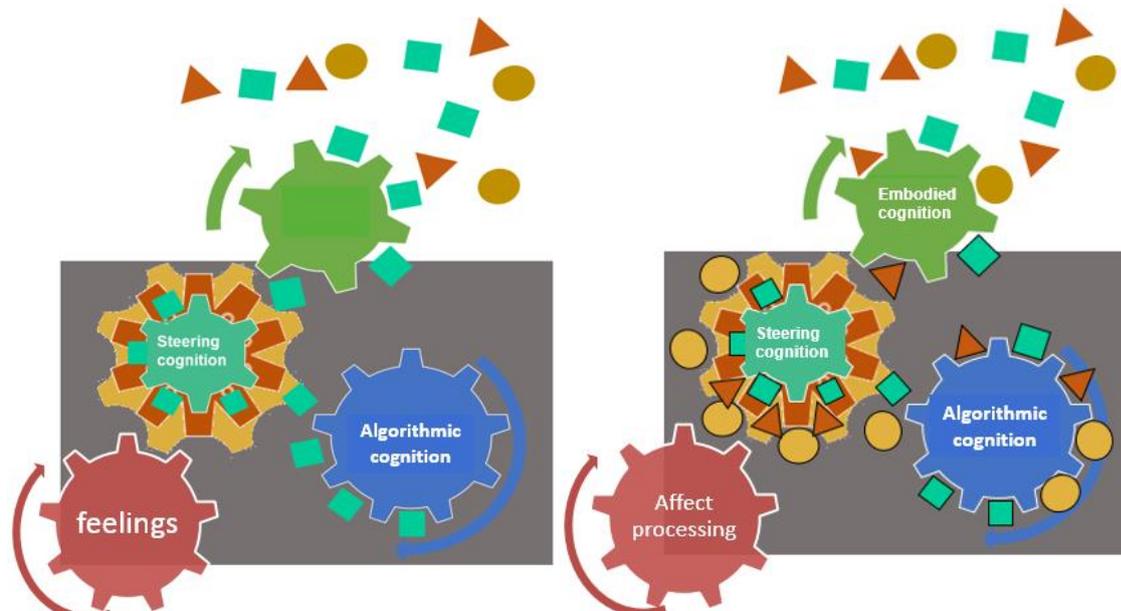


Figure 20 a. Errors may occur when steering cognition becomes attentionally blind to epistemically varied environmental data.

Figure 20 b. Cognitive accuracy is increased when steering cognition is metacognitively regulated to incorporate epistemically varied environmental data.

Cognitive steering data has indicated that heuristic bias can increase accuracy rather than reduce it. Steering cognition bias is the essential mechanism by which an individual steers their cognition to cope with an epistemically varied landscape. Steering cognition enables human cognition in a real world of epistemically varied, novel data.

A lack of adjustment of cognitive steering would account for some previously observed errors (Figure 20 a). The 'state' of a person's steering cognition can be said to give them heuristic momentum; an up and running set of attentional biases which, unless explicitly checked and adjusted, will drive cognition in a certain direction. Representation, affect and introspection illusion bias errors (White 1988; Pronin 2009; Kahneman et al. 1982) may be explained by such notions of cognitive steering bias error.

The well-evidenced ‘fast speed’ of heuristic cognition is interpreted by the steering cognition model as a state of unadjusted cognitive steering. Heuristic cognition has been widely evidenced as ‘fast’ (De Neys W. 2006; Schneider, Shiffrin 1977; Schneider 2003). When cognitive steering cogs are aligned in a pre-potent pattern then data is processed through them fast; this leads to cognitive errors when unexpected environmental cues have to be negotiated (Figure 20 a). This is supported by the finding that high steering cognition speed correlates with either extreme high or extreme low steering cognition variance, who exhibit low effortful control of both algorithmic and steering cognition.

Automaticity phenomena: In repetitive tasks, cognitive steering biases become fixed in a certain configuration, which means no effort needs to be maintained in adjusting it to search for, and process, varied and different kinds of data. As such, data is retrieved and passed down to algorithmic cognition very fast. This is an accurate process when the data task is repetitive and consistent (Schneider, Shiffrin 1977; Schneider 2003); however, it is inaccurate if the brain has to process a difficult or trap question (Lieberman 2007).

This has previously been interpreted as a second parallel processing system (system 1) which is always fast, automatic and makes errors (Slovan 1996; De Neys W. 2006; Evans, Jonathan St. B. T. 2010). In Walker’s model, cognitive steering is not necessarily fast or automatic. It can *become* fast and automatic if the settings of the cogs get aligned such that it only has to search and locate a single kind of data (Figure 20 a). In that circumstance, steering cognition becomes like an open channel through which data passes directly through, rather than being turned around, manipulated and simulated- a time consuming, effortful process.

What has been described as slow and effortful system 2 may involve steering cognition labouring away to cope with varied kinds of data (Figure 20 b). When instructed to do so, a person can consciously engage their steering cognition, accurately process the external data, locating it into the right place in the memory for algorithmic processing (Walker 2014 g.). An individual may still, after this slow, conscious and effortful process make computational errors if they have poor algorithmic cognition. The accuracy of algorithmic cognition itself is determined by other factors such as working memory and prior knowledge.

Thus, steering cognition is neither fast or slow; it is fast AND slow. It is a regulating processor which is differentially engaged depending on the degree of complexity of the epistemic landscape the learner is engaging in at the time. The key regulating factor is affect (Walker 2014 h.). What has been described by some as a metacognitive mechanism which controls switching between system 1 and 2 upon detection of affective states (Alter et al. 2007; Amsel et al. 2008; Ball et al. 2006; Thompson et al. 2011; Thompson, Morsanyi 2012; Thompson et al. 2013) is described instead as differing states of steering cognition (Figure 20 a. and b.).

By polarising biasing of their steering cognition, accuracy is sacrificed for data processing speed and momentum- conjectured to be an evolutionary response to threat. Low tolerance of strain biases steering cognition to an extreme state, reducing cognitive accuracy, and is fast and effortless. Inversely, increasing tolerance of affective strain regulates steering cognition toward a less biased state, but is demanding and effortful. Steering cognition therefore works inversely with working memory load and is affected by self-regulatory depletion (Baumeister et al. 1998; Baumeister, Vohs 2004; Walker 2014a, Walker 2015b, 2015g). Distress causes students to less closely regulate their steering cognition- it increases bias polarity, which may increase speed of processing, thus enabling rapid advantageous response to threat.

Steering cognition may be a mechanism by which initial evaluation of one’s relation to the data is evaluated, through self-representation. Halford et al. claim that seeing objects in relation to others is central to cognition (Halford et al. 2010; Halford et al. 2007). The neural-basis-of-memory researchers have developed a model of how data is encoded at a neuronal circuit level which may undermine the basis of system 1 and system 2 as dual, alternative pathways. A model of knowledge encoded through its directional relationship to existing categories is proposed. For example, cup is encoded in relation to saucer as a directional relation (cup sits upon saucer; saucer sits underneath cup). Cup and saucer is encoded as a set of directional relations not, as in traditional associative analogising, simply cup associates with saucer.

Halford et al. claim that relational encoding may be the mechanism by which both heuristic and algorithmic reasoning are united. For example mouse-dog-horse is a relational framework of directional size. This in turn becomes heuristic in that it allows the encoding of ‘elephant’ to be predicted and encoded correctly in relation to the schema. The researchers claim that these relational analogies take place within working memory, and are provisional and revisable as relational schemas are updated over time through experience (I am smaller than Sarah at T = 1, but I am taller than Sarah by T = 10). Relational knowledge, therefore, remains linked to context and does not become fully abstracted.

Steering cognition centrally enables a thinker to evaluate initial inter-relations between self-other objects, and other object-other object, through mental scene construction and imagined self-representation. Such a process

may facilitate the location of more precise relational mapping, through, procedural association within existing remote memory schemas. An analogy may be the zoom process on a Google map, whereby initial location of a region facilitates and leads on to a precise identification of a specific place within that region.

Steering cognition implies a model of conscious-nonconscious cognition. Extreme steering cognition bias is an unconscious, unreflected state (Ball et al. 2006). What is thought of as conscious cognition is a state of labour. The analogy of a clutch and gear system in a car is useful: unconscious state is the gears in neutral; consciousness emerges with the re-engagement of the gears with the revolutions of the engine and demands of the road. An unconscious state may become conscious through the active exercising of control to regulate the extremity of bias in order to process data more optimally (Amsel et al. 2008; Rawson, Middleton 2009). The cue to engage or disengage is determined by ecological and internal demands: bias in the road, internal affective distress (Alter et al. 2007; Thompson et al. 2011).

6.4 Steering cognition may also be a functional locus within which environmental priming has an attentional biasing effect.

The steering cognition model provides a cognitive circuitry within which some widely observed cognitive-affective-social phenomena of priming can be interpreted. Priming effects can be interpreted as environmental cognitive steering biasing effects. Priming effects work (often affectively or associatively) by conditioning the cognitive steering system to a specific bias state, which results in attentional blindness potentially in both observer and observed (Bargh et al. 1996; Doyen et al. 2012; Bargh 2006; Doyen et al. 2012).

Steering cognition provides a model of conscious-nonconscious cognition which may fit priming phenomena. Steering cognition automaticity is defined as a nonconscious, unreflected bias which lacks self-awareness and metacognitive reflection (Ball et al. 2006). The susceptibility of steering cognition biases to priming across large populations, such as school pupils, when primed with the same experimental priming stimuli has been reliably and repeatedly identified.

Steering cognition may provide a cognitive basis for in-group biases. In-group behaviours may be due, in part, to shared nonconscious steering cognition priming effects. This may provide a cognitive basis for some tribal phenomena.

Whilst priming effects are often considered as negative biases, environments including schools can have a positive regulatory effect upon a population's biases. School has been shown repeatedly to reduce the variance in instinctive AS dysregulation of its population of pupils.

Steering cognition in-group bias provides an explanation for a proportion of school rank differences. Up to 18% of school rank was explained by tighter in-group effects (lower steering cognition variance across the school population when measured in lessons).

The steering cognition data suggests that heuristic biasing and priming are two sides of the same coin: priming is the environmental stimulus whose effect is felt upon the heuristic (steering) cognitive circuitry. By analogy, priming is an effect of the environmental 'road' which, by its contours or signposts, may nonconsciously bias the steering cognition of drivers.

6.5 Steering cognition contributes to self-regulation

Poor steering cognition regulation associates with poor self-regulation.

The self-regulation of steering cognition has been shown to be a factor explaining lower pupil welfare and mental health. Pupils with *less steering cognition bias* are more likely to *read* the particular situation, encounter or context; they notice extrinsic and intrinsic cues which lead them to purposefully choose a particular affective-social response (Rothbart et al. 2000b; Eisenberg et al. 2000; Halberstadt et al. 2001; Tangney et al. 2004). These pupils can be said to exhibit greater self-regulation.

In contrast, pupils who develop a *polar steering cognition bias* are less likely to notice those extrinsic and intrinsic cues; they tend to iterate the same self-strategies again and again which further reinforces their bias. These pupil can be said to have poor self-regulation; poor self-regulation predisposes them to a number of incipient risks (Eisenberg et al. 2003; Sallquist et al. 2009; Simonds et al. 2007).

Walker J. has identified both fixed steering cognition bias, dysregulated bias and over-regulated bias as causes of self-regulatory problems (Walker 2015g, 2015a, 2015b). Research into the development of self-regulation in children and adolescents has grown exponentially over the last fifteen years. A swathe of evidence identifying self-regulation as a foundational developmental skill which underpins future affective, social and academic competence (Vohs et al. 2008); in contrast, poor self-regulation has been found to correlate with a wide range of internalising and externalising difficulties (Eisenberg et al. 2000; Blair 2002; Trentacosta, C.J., & Shaw, D.S. 2009; Tangney et al. 2004).

Steering cognition contributes to trait development

Patterns of a steering cognition appear to become fixed and crystallised over childhood. Steering cognition biases become more stable with age. During development, over adolescence and into adulthood, more discreet, crystallised and non-normal steering cognition patterns emerge.

Adults consolidate steering cognition biases despite repeated opportunities to shift them in the face of new stimuli. Adults also confirm their own steering cognition biases by representing the biases of others around them as a mirror to their own. Such bias configurations can be associated with distinct, defended personality patterns. They also correlate with different professional roles, suggesting that they become manifested as habitual, socially recognisable and functional traits in adults.

The steering cognition data offers a new perspective on the relationship between state and trait development in personality theory, which is the subject of another paper.

7. From this model, some further inferences about learning, reasoning, education and social cognition follow.

The best model to account for the data is that functional circuitry integrated around the imagination serves as an ecological executive system, involved in governing the self-regulation of conscious specific, effortful attentional biasing for the purpose of managing and responding to the epistemic demands of unpredictable, varied environments. Such a serial, variable state metacognitive system, referred to here as 'steering cognition', may account for some of the phenomena that have been interpreted as a parallel or dual process. It may also be a functional locus within which environmental priming has an attentional biasing effect.

As such, it may provide an empirically calibrated means of measuring commensurate priming effects of a wide variety of social and environmental cues at both an individual and collective level. This final section sets out some inferences that follow from the steering cognition model described.

Functional reasoning circuitry in the brain means that all human knowledge is relational. One can infer that knowledge which the reasoner claims to be absolute is unreliable.

The evidence for steering cognition challenges the belief that unbiased cognitive processing, through the subordination of affect and representation biases, is cognitively possible. Underlying the dual mind model is a philosophical assumption that true knowledge is only attainable when the relation of the reasoner is removed from the reasoned; thus, where affect and self-representation intrude, bias is judged to have occurred, and error crept in. Steering cognition evidences that computational, algorithmic knowing is also subject to relational processing, and occurs through the reasoner's self-representation toward the reasoned. Steering cognition claims that it is the appropriate adjustment, not the elimination, of heuristic biases that determines the veracity of data incorporated into the mind. Veracity shifts from an objective-subjective discourse to an relational-awareness discourse.

The learner is changed by learning. Cognitive biases either become more automatic or more effortfully regulated through learning. One can infer that automatic biases may play a role in the development and recognition of attentional skills and characteristics.

The mind cannot incorporate new data except by the route of its steering cognition. In passing through a person's steering cognition, data reinforces the specific attentional, affective bias to which their steering cognition is adjusted. As a result, that bias becomes a little more automatic, effortless and easy to adopt the next time. Without effortful control and metacognitive awareness, data will travel down the easier and quicker route to remote memory in the future, reinforcing pathways of existing attentional bias, and consequentially, of

attentional blindness. The learner will become reinforced in their biases. By conscious, effortful control and self-awareness a learner may, when faced with a new task, choose to adopt different and less automatic steering cognition biases. In so doing, the learner may both detect and incorporate into their remote memory a wider array of data. They may also become loosened from previous cognitive biases because they have opened up novel steering routes. Such iterated patterns may play a role in social recognition. They may contribute to the development of particular automatic attentional skills which may have value to specific professional roles.

Over time, biases become represented in recognisable configurations of cognitive steering and behaviour. These may become useful functions both for self-representation and social recognition, but in so doing may make self-development and growth harder.

Unadjusted biases in steering cognition become effortless, nonconscious and automatic over time. As such, our awareness of them will typically diminish. Because steering cognition biases integrate with affect and embodied response, such habituated bias states may be increasingly recognised by others as personal traits. The specificity, automaticity and nonconsciousness of steering cognition biases may be an important component of social recognition. As this occurs, a person's recognised traits become part of the social landscape detected by others. These others have a vested interest in maintaining that person's traits as stable data points in order to reduce their own environmental cognitive load and effortful cognitive steering. This self-reinforcing spiral is likely to reduce routes to personal change.

Shared group steering cognition biases contribute to in-group effects; these may create shared belonging, but also attentional blindness and out-group suspicion.

Shared experiences have been shown to create in-group steering cognition priming effects. Strong group experiences, centred around shared rituals, routines and identity appear to cause individuals to de-individuate and bias their steering cognition toward group goals and outcomes. Such cognitive biases will create shared belonging, comradery and values. However, they may also be the basis on which suspicion toward those not belonging to the group are cognitively and affectively reinforced in the brain. In-group attentional bias may also filter 'out-group' knowledge, limiting the opportunities for group members to revise their own ideas. Unhealthy groups may encourage attentional blindness, which may be able to be measured by shared patterns of group steering cognition bias.

Steering cognition may provide a functional circuitry explanation for group-think. In addition, disciplines which make claims to a position, whilst failing to acknowledge the inevitability of their in-group biases, are liable to be particularly problematic to a society seeking inter-group cohesion. Examples of such may include some religious groups whose source of authority is uncritically accepted as superior to human authority; some academic and scientific communities where there is an uncritical assumption of the unbiased eye of scientific process.

Current educational goals can be shown to produce clever people who may lack the steering cognition that may be needed for real-world judgement

Pupils at schools which most narrowly focus on achieving the educational goals of current examination assessment regimes tend to exhibit less effective cognitive steering self-regulation. Schools have recently been considered as academic race tracks on which drivers are publically assessed only for distance travelled (i.e. grades achieved). This approach may have negative consequences for both driver welfare and for learning-to-drive skills. Such skills will be arguably more important when learners leave the school race track and continue their working journey over the bumpy off-terrain of the professional landscape.

An alternative model for schools is that of a 'driving school', where the task is to train pupils in the skills of driving their vehicles across all kinds of terrain. Travelling to remote destinations (obtaining curriculum knowledge) remains an important and an assessable goal. However, the new ability to reliably measure the development of cognitive steering self-regulation means that previously unmeasured impacts of school can now be measured as well. If this were the case, schools would be valued as environments in which children learned to read the road (be aware of priming influences); to drive safely alongside other road users; and to understand how and when to use their brakes, gearing and steering in order to travel safely and efficiently to their destination.

Driving fast and far may be one measure of driving school success, but it is not the only measure that is now available to us.

Imagination has been mistakenly labelled as a childlike creative function, when it is in fact central to all learning

For decades, the imagination has been almost exclusively associated with creative and artistic functions in both the popular media and academia. One result of this is a belief that scientific, technological, financial and other disciplines do not rely upon the imaginative functions of the brain. This dualism may have influenced pupil subject choices, university degree choices and career choices. It may also, as a wider narrative, have polarised the kinds of populations that end up in different industries.

Steering cognition evidences that the imagination is not only a creative-artistic function of the brain. It may be central to all higher cognitive learning functions, which rely upon the unique plastic, data integrating capacity of the imagination. Such a revision, if reliable, of the place and role of the imagination would alter the current accepted model of the mind. It may also alter the popular understanding of the relationship between the arts and sciences. Science may be better understood as a discipline in which the imagination maintains effortful attention toward undiscovered data. Arts may be better understood as the creation of data to which the imagination effortlessly attends.

Equipping teenagers to better regulate their steering cognition can reduce mental health risks

UK teenagers are suffering a decline in general mental health. School resources to address this problem are limited and tend to be focused on individual pupil emergency response (counselling after the point of crisis). Steering cognition provides an additional, earlier-stage screening, action and tracking, response in which resources target the environment around the pupil as well as the pupil themselves. Such an ecological response can educate pupils and teachers alike to better self-regulation strategies, which in turn increase school capacity. At the same time, there is evidence that this is an effective mechanism for improving the mental health of pupils identified as showing early signs of risks.

Conclusion: Does the brain think straight or does the brain think true?

Hidden within the dual-mind tradition is an assumption about the nature of the world. The assumption is that the knowledge of the world *can* be errorfree - period. The cognitive heuristics tradition crystallises a paradox that has existed in Western metaphysical tradition since Aristotle; that of absolute knowledge and relativist uncertainty.

Some has argued that this dualism derives from Aristotle's 'law of noncontradiction'. *"It is impossible that one and the same predicative determination should at the same time be attributed and not attributed to the same object and in the same respect"* (Aristotle, Poetics, 1456b-1457a30).

For Aristotle, knowledge was based upon a correlation between the word and the world; the word accurately correlates with the nature of the world, and therefore a term ascribed to one object cannot be also ascribed to another without contradiction, and therefore, error.

The Western intellectual metaphysical tradition is built upon the goal of describing the world without contradiction, or without therefore, error. Such a goal requires the ability of the reasoner to be an entirely detached, neutral unbiased observer of the state of the world, otherwise perspective may create the possibility that I ascribe one label to an object seen from my angle, and you ascribe another label to the same object, seen from your angle.

Implicitly, and largely unknowingly, the modern heuristics research tradition has sought to provide the cognitive basis for this goal: a kind of cognition which is immune from the reasoner's subjective participation in the world and which is characterised by precise, procedural, algorithmic, repeatable steps to arrive at an unfalsifiable answer.

It has been an enterprise to define the careful, analytical, procedural mental processes which are required for the mind to dominate the subversive, unreliable and errorful effects of the untrained mind. The classification of two reasoning systems, one of which can account for our errors and the other which possibility of errorful-free, algorithmic calculation is a necessary categorisation to achieve this.

However, since Wittgenstein's later turn, philosophers of language have questioned the belief that such de-contextualised human cognition exists or is relevant to how we know what we know. Whilst strict post-structuralists such as Derrida and Foucault, abandoned the possibility of knowing at all, other such as Chomsky, Levi-Strauss, Gadamer, Polanyi, MacMurray, Steiner, Baudrillard, Buber and Ricoeur have found ways to describe

how knowledge only exists through the knower participation in the act of knowing. Knowledge itself may be the construction of shared perspectives by the knowers.

Cognitive linguists such as Lackoff, Johnson and Nunez, as well as embodied cognitivists such as Ballard, Clark, Maturana and Varella, have argued for the inherent ‘fleshy’ nature of all human perception. The embodied cognition proposal relates largely to sensori-motor perception, whilst the cognitive linguistics concerns higher-order emergent mind properties. In general, however, the research-focused cognitive psychology and neuroscience communities have continued to pursue the goal of describing a source of error-free, non-contextual human reasoning.

The question of whether the empirical evidence supports the possibility of error-free reasoning hinges on whether one can demonstrate there is a kind of reasoning which leaves the knower entirely untainted by the action of observation. If there is, then it may be possible for this reasoning route to establish a fact without inserting any perspectival bias.

However, if it were demonstrated that the cognitive mechanism of knowing and reasoning cannot be ever entirely suppress the perspectival processes because it requires them for cognitive steering, then epistemological confidence would need to be relocated. Instead of seeing the brain as a machine for ‘thinking straight’ (without error) one might need to see the brain as machine for ‘thinking true’. ‘Thinking true’ as opposed to ‘thinking straight’ is about the knower having the *right* perspective, not having no perspective or an inherently errorful perspective. The implication of such a discovery would mean we would need to see the brain as functioning to enable the knower to establish a proper relation *in* the world, rather than to obtain certain knowledge *of* the world. It would mean that the function of the mind is not principally to obtain data but perhaps, to use a piece of older language, to act wisely (Figure 21). It suggests that the basic division we should be researching may not be between errorful and errorfree reasoning, but between wise and unwise actions. The evidence from this 13 year programme on steering cognition serves as a contribution toward this possible revision.

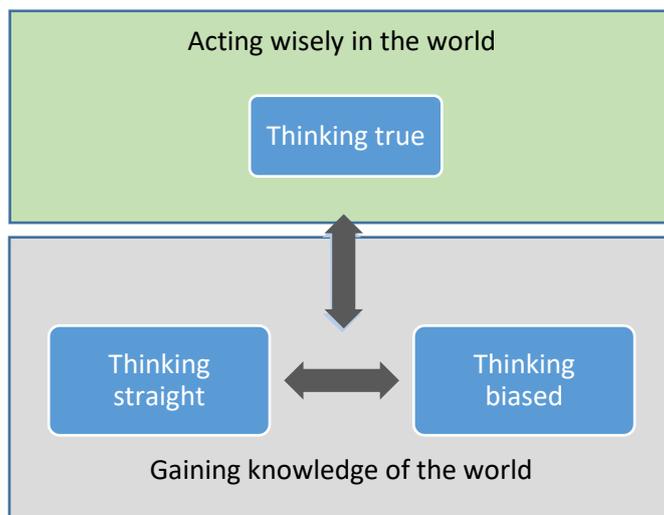


Figure 21.

Future research directions

Steering cognition investigation is in its infancy. Investigations have been largely carried out by a single team of researchers. They require independent teams using independently designed measures, data models and technologies, to confirm findings. Reported features of steering cognition to date have been repeatedly observed over multiple studies with independent, increasingly large and diverse population samples. These features can either be attributed to the data itself, or to an artefact in the data collection technology, which cannot yet be ruled out. However, working on the assumption that the features are real and not artefacts, the current steering cognition data opens up a new pathway for future research into human thinking and action.

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Appendix

5.3 Factor analysis optimal CAS bias, CAT score and grade rank

Variance between CAT score and grade rank

Factor	Total	% of total variance
1	130.0	96.9
2	4.05	3.02
<u>Rotated Factor Matrix</u>		
	<u>Factor 1</u>	
Loading of CAT score	11.26	
Loading of grade rank	-1.77	

Variance between optimal subject CAS bias and grade rank

Factor	Total	% of total variance
1	8.99	70.27
2	3.80	29.73
<u>Rotated Factor Matrix</u>		
	<u>Factor 1</u>	
Loading of optimal CAS bias	1.55	
Loading of grade rank	1.15	

Variance between CAT score, optimal subject CAS bias and grade rank

Factor	Total	Rotation % of total variance
1	130.8	88.23
2	5.52	9.32
3	3.43	
<u>Factor Matrix</u>		
	<u>Factor 1</u>	<u>Factor 2</u>
Loading of CAT score	11.26	0.35
Loading of grade rank	0.91	-1.97
Loading of optimal CAS bias	-1.77	1.24

5.9 Ratio model EM CAS Lessons

	subject	factor	Spearman's Ro
1	English	L	0.41
2	English	M	0.37
3	English	O	0.42
4	English	P	0.35
5	English	S	0.42
8	Maths	L	0.42
9	Maths	M	0.58
11	Maths	P	0.23
12	Maths	S	0.2
14	Maths	X	0.4
15	Science	L	0.42
16	Science	M	0.63
17	Science	O	0.37
	MEAN		0.40

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