Navigating the world by heuristic bias

Cognitive-affective heuristic biasing contributes to successful navigation of epistemically varied tasks in secondary school

Simon P Walker, D Prof.

Honorary Fellow, Bristol Graduate School of Education, UK

Abstract

Heuristic bias has been largely assumed to introduce error into human thinking.This study provides evidence that heuristic bias contributes to both cognitive accuracy and cognitive steering. Using a novel cognitive-affective-social state assessment technology different curriculum subjects were shown to require specific heuristic biases for high academic outcome. Students who exhibited the ability to regulate their heuristic bias to the optimal state for each of the specific curriculum subject were higher performing than those who did not. This ability correlated with a measure of general intelligence but also explained an element of academic outcome not explained by general intelligence. Evidence that students can improve their affective heuristic bias in response to local environmental stimulus was also shown. A conjecture that heuristic biasing is the basis for, rather than the enemy of, accurate epistemic navigation of the world is proposed.

Keywords
Dual mind theory, heuristic, cognitive-affective bias, epistemic self-regulation, academic outcome

1.1 Introduction

Fiske and Taylor's (Fiske, Taylor 1985) notion of cognitive miserliness is the key cornerstone to heuristic bias theories of cognitive decision making. The weight of research evidence first pioneered by Kahneman and Tversky (Kahneman 2011; Kahneman et al. 1982; Kahneman, Tversky 1973) comprehensively undermined the basis for the so-called naïve mind model of cognition (Barone et al. 1997) establishing that the brain will deploy the minimum resources toward cognitive perception, using heuristic judgements to make decisions more speedily and at lower cost.

Inherent in this proposal is the assumption that, whilst reducing cognitive load (a potential evolutionary advantage (Stanovich 2011; Kahneman 2011)), heuristic cognition builds in faults and biases to perception and judgement (De Neys W. 2010). This division between fast, but dirty, heuristic cognition and the slow, but effortful, accurate rational cognition is the central basis for all dual models of the mind (Evans, J. S. B. T., Stanovich 2013; Evans, Jonathan St B T, Frankish 2009). Built into this 'framing' is the expectation that the precious but limited resources of the rational mind (referred to variously as system 2/ process 2) are only sometimes deployed to intervene, reign in and cross check the low-cost intuitive cognitive operations of system 1/process 1.

Kahneman's research mainly focused upon the consequences of judgement faults associated with heuristic bias applied, to the field of economics in particular. Stanovich (Stanovich 2009) has pointed out that a massive subsequent body of publications have applied bias research especially to fields such as economics (Thaler, Sunstein 2008) and legal judgment (Sunstein 2006), in which bias effects command enormous interest due to the sheer financial consequences of decision making error.

It should be said, however, that not all authors have consented to the orthodoxy that heuristic bias is errorful. In particular Gerd Gigerenzer has mounted a sustained project to demonstrate that there may be numerous evolutionary advantages to heuristic perception (Gigerenzer 2008; Gigerenzer et al. 2011; Gigerenzer, Todd 1999; Goldstein, Gigerenzer 2002). The kernel of Gigerenzer's argument is that more data need not necessary lead to improved cognitive judgement.

However, beyond the field of judgement and decision making, there are several fields in which, not simply heuristic cognition, but heuristically *biased* cognition could be said to be functionally central to psychological operation. For example, an element of heuristic bias might be predicted to be beneficial to succeed in certain curriculum subjects at school, such as the Arts and English, where argument from one's own perspective is central to the subjective epistemology of the discipline. Research into child developmental aspects of dual-processing are in their infancy (Stanovich et al. 2011; Barrouillet 2011) but may provide untapped avenues for exploration (Evans 2011). It is not clear, yet, that cognitive miserliness does not, in fact, advantage students participating in highly my side-based subjects.

Another example might be personality formation. Theodore Sarbin's theory of narrative psychology makes the formation of narrative coherence central to the formation of identity (Sarbin 1986). Whilst the field of economic decision making may see myside bias and narrative representation as a flaw, narrative psychologists see it as central and indispensable to self-representation.

A third example might be therapeutic processes. Tompkins and Lawley describe a process of re-modelling internalised symbolic self-metaphors as a means of obtaining control and self-agency (Lawley, Tompkins 2000; Siegelman 1990). Such approaches rely upon biased heuristics as a prospective means of reconceiving of a possible future self. Bias is itself a tool within the imagination to alter the state of one's being toward a future goal (Schacter 2012).

My argument is that bias heuristics are not necessarily themselves simply a source of error requiring restraint by a corrective second mental processor. A focus on economics in the literature may have created its own framing effect in which researchers have focused on the assumption that heuristic cognitive strategies are at odds with capacities such as rationality and intelligence. One reason why this may not be the only avenue of profitable cognitive bias exploration comes from a new kind of assessment used to evidence cognitive-affective bias.

1.1 Beyond the evidence from cognitive trapping

The bulk of current evidence supporting heuristic bias effects has come from what might be called ‘cognitive trap’ experiments. Candidates are asked to make judgements, or predictions, based upon usually verbal, sometimes numerical and, occasionally, spatial scenarios. Like cognitive sink holes in the road, cognitive traffic falls into these traps when the mind fails to invest sufficient resources to overcome the instinctive, intuition to plough straight ahead into the sink hole. Priming-effect studies vary the approach to the extent that they intentionally prime an affect state effect and then ‘trap’ the consequent judgement bias.

Cognitive trapping evidences judgement-error arising from cognitive miserliness. The governor identified as controlling the recruitment of additional costly resources, to avoid cognitive sink holes, is affect. The affect heuristic was developed to account for evidence that mood has an impact on a person’s willingness to recruit effortful system 2 (Kahneman 2011; Keller et al. 2006; Sherman, Kim 2002; Winkielman, Zajonc & Norbert Schwarz, Robert B. 1997). Motivation rather than cognitive ability was the significant factor in higher cognitive ability candidates recruit system 2/process 2 rather than relying on system 1/process1 (Stanovich Keith E. West Richard F. 2014).

However, little research has been done about the positive role of affect in cognition beyond serving as a governor switch between system1/process 1 and system 2/process 2. This lack of research in surprising since *affect* is central to the distinction between a heuristic and a non-heuristic cognitive judgment. Kahneman and Tversky’s definition of cognitive heuristics can be stated 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 posits 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.

We now know a little more about the neural centres implicated in the act of imagining ourselves and our possible actions in our minds than when the idea of heuristic substitution was first proposed. 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). Others evidence that the imagination plays a central role in organising our behaviours (Decety, Grèzes 2006; Garry, Polaschek 2000).

Strikingly for heuristics, imagination is particularly implicated in future-orientated guidance. Schacter et al. evidence that the brain projects forward a method of self-operation prior to then enacting that projected sequence (Schacter, Addis, Buckner 2007). This supports a model of cognition that requires the ability to anticipate and organise mental operations in order to fulfil a sequence of mental activities effectively (Stein, 1994). The brain’s capacity to imagine serves as a guide or route map directing action (Schacter 2012). Evidence such as this suggests that the mind does not rest in a neutral state but rather is making ‘forward investment’ provided by the continuous activity of the imagination, projecting forward future self-operation.

It is, therefore, not surprising that theories of heuristic bias centrally implicate the imagined first-person self within mind/process 1. The imagination reveals the *forward investment* the mind makes toward a specific situation, an investment that builds in biases of perception and representation.

There are three implications that follow from this. The first implication is that, principally, recruitment of what is known as system 2/process 2 may be an act of *inhibition or braking* as much as intervention. The type of thought associated with system2/process 2 involves inhibiting such holistic response, deploying instead what Stanovich calls cognitively decoupled mental simulations, which have a high algorithmic or logical quotient. Inhibiting heuristic investment involves not simply mentally steering around a cognitive sink hole, but putting a sudden brake on an up-and-running cognitive, affective, behavioural operation the momentum of which may continue to take thought forward in that direction unless considerable cognitive effort is expended.

Considered this way, cognitive traps such as the Kahneman and Tversky's well-known Linda test, may fundamentally test for the capacity to first, trigger and second, exert such considerable holistic neural inhibition in favour of then pursuing a detached, introspective logical thinking route. It has been assumed that system 2/process 2 is itself effortful; however, the evidence for the role of the imagination in forward investment may locate the effort not in the deployment of rational processes but in the restraint of heuristic ones. This provides an alternative hypothesis as to why affect, motivation and mood has such a controlling influence over the deployment of system 2/process 2; it costs so much to stop heuristic momentum.

A second implication that follows is that the Linda test and other cognitive traps are reliable but will only detect a small proportion on the total bias invested by heuristic imagination. As I have argued, the Linda test is a cognitive sink hole test; it will catch the majority of people under whom it suddenly opens up when they have heuristic momentum. Other than that, though, such traps do not tell us very much about the accuracy, efficiency and efficacy of the routes the heuristic imagining mind is taking in general when not falling into sink holes.

A third possible implication is that heuristic bias may in fact be *central* to our epistemic steering system. Evidence of error from cognitive trapping does not preclude the possibility that, in general, bias may be the means by which we steer cognitive resource toward anticipated challenges. For example, such steering may involve focusing of effort, maintaining of attention, as well as priming of epistemically relevant data systems. As noted, a few authors (Reyna, Brainerd 2011; Ricco; Gigerenzer et al. 2011; Goldstein, Gigerenzer 2002) have focused on the potential positive effects of heuristic bias.

In summary, my argument is that heuristic thought is an expression of imaginative investment. Such investment provides heuristic, epistemic bias which may be central to anticipatory cognition required to succeed in data perception and processing. One consequence of this line of thinking, therefore, is that it may be possible to search for not only instances of cognitive traffic falling into sink holes, but techniques to measure the accuracy of cognitive, affective and social steering when provided with a variety of different epistemic settings. We might call this epistemic, self-regulatory steering.

This provides a testable hypothesis: ability to appropriately shift heuristic thought in the face of multiple different epistemic challenges, by heuristic epistemic self-regulatory steering, should correlate with measured success in the outcomes of those challenges.

However, the testable hypothesis requires a reliable test of heuristic bias. Because this is a central element in my proposal I will devote an extended section to the description of the construction of a testing process.

2.1 Method: Development of an assessment of heuristic bias

The sink hole analogy illustrates that an entirely different species of assessment would be needed to track heuristic epistemic self-regulatory steering; rather than observing heuristic error via trapping, a means of mapping heuristic bias by tracking its operation is required. This requires a fundamentally open assessment. Interestingly, Stanovich has appealed for the development of such an assessment. He criticises current tests used to test epistemic self-regulation because, by design, they pre-set the parameters and explicit goals which candidates then recruit their algorithmic resources to follow (Stanovich 2009; Stanovich Keith E. West Richard F. 2014). A true assessment of epistemic self-regulation, he argues, must involve an open assessment in which the regulation of the mind in identifying and selecting its own epistemic courses is measured.

I evolved a test over ten years and a number of iterations, to track heuristic bias by exploiting the so-called projective phenomena first articulated by Frank (1939) upon which breeds of projective tests have been previously developed for use in psychological diagnostics (Saklofske et al. 2013). Whilst from a different discipline, projection bears many of the characteristics of heuristic thought; it recruits affective, social and cognitive first person response toward one's imagined participation in an event or situation. A projective assessment question might be 'Look at this picture card. Imagine you step into the picture. What are you aware of feeling as you enter the scene?' or another 'What story comes into your head as you look at this image?' or 'What would it be like to meet the character on this page?'

Projective tests such as the Thematic Apperception Test, Object Relations Test and perhaps most well-known, Rorshach Inkblot Test, are used to detect bias in a candidate's self and other perception (Saklofske et al. 2013). Whilst such tests were mainly developed for clinical contexts, the principle of detecting bias by using an open neutral stimulus cued response process is transferrable to the normal psychological range.

2.2 Psychometric properties of the heuristic bias assessment

Projective tests suffer from poor psychometric characteristics, including poor reliability and observer report inconsistency. The psychometric qualities of this heuristic bias assessment were incrementally improved by removing third party scoring (replaced with self-scoring) and by introducing the standardised, structured response format via a six point Likert scale. I provide evidence in the Appendix that the seven factors measured in the assessment are largely independent, divergent factors with identified degrees of overlap. Eigenvalues and scree plots support the existence of seven latent factors within the data accounting for the majority of assessment variance. Cronbach's alpha (0.73) indicates that the assessment of instinctive and contextual heuristic bias is acceptably reliable.

2.3 Structure of heuristic bias assessment

The heuristic bias assessment is composed of three parts: an initial task, an instinctive heuristic bias response task and a contextual heuristic bias response task.

2.3.1 Part one: Initial task

The initial task of the heuristic bias assessment involves an online computer-based imagination activity. Through a set of audible, recorded instructions, the candidate is asked to imagine a mental image of the characteristics of an unprescribed open space. Rules developed by Grove and Panzer (Grove, Panzer ©1989) governing the use of instructional clean language when leading candidates in mental imagery ensure the candidate's imagination provides a prescription of the open space. This ensures that the effects of Stanovich's pre-set mental parameters are minimised. Explicit goals in the mental task are not specified ensuring framing effects are also minimised.

2.3.2 Part two: Instinctive heuristic bias response task

Following the initial imagination of the mental space, the candidate is asked to react to a series of 28 events, incidents or required tasks imagined to take place within their mental space. None of the events require technical skill or involve cognitive difficulty. Each task response is self-scored on a six point Likert scale.

The 28 items were developed to measure seven factors proposed by Walker in a model of Personal Ecology (Walker, Simon, P. 2007, 2009). Personal Ecology is a multi-factor, bi-polar model in which factor bias is conceptualised as a means by which an individual negotiates interaction with the surrounding environment. As such, it was identified as a potential model of some cognitive, affective and social factors conjectured to contribute to heuristic bias. Walker (Walker, Simon, P. 2009) claims that three of the seven factors (factors 5,6 and 7) contribute to cognitive learner bias, two factors contribute to learner affective bias (factors 1,2,) and two factors to learner social bias (factors 3,4).

Factor	Factor name	Factor biases			
1.	**Trust of own ideas, opinions**	*Questionning of own ideas etc….*	⟷	*Trust of own ideas etc..*	***Affective factors***
2.	**Trust of others' ideas etc...**	*Questionning of other's ideas etc….*	⟷	*Trust of other's ideas etc…*	
3.	**Embracing change**	*Resisting change*	⟷	*Embracing change*	***Social factors***
4.	**Self-disclosure**	*Holding back ideas, opinions etc…*	⟷	*Disclosing ideas, opinions etc…*	
5.	**Perspective**	*Detached perspective when thinking*	⟷	*Personal perspective when thinking*	***Cognitive factors***
6.	**Processing**	*Connecting ideas when thinking*	⟷	*Sequencing ideas when thinking*	
7.	**Planning**	*Focusing on the process/ experience*	⟷	*Focusing on the outcome*	

Figure 1. Illustrating the biased polarities for each of the seven factors.

Each factor is a bipolar construct in which the poles represent a heuristic biased state. For example, factor 1 is a scale between the two poles of *trusting of own ideas, qualities and opinions* and *questionning of own ideas, qualities and opinions*. A factor score toward trust indicates a heuristic bias to trust one's own ideas, opinions and qualities rather than question them; the extremity of the factor score represents the degree of heuristic bias manifest. Jo Walker asserts that an extreme factor score indicates both an extreme heuristic bias as well as a bias that is likely to be less modulatable.

Instinctive factor scores are computed from raw item scores via a transformational algorithm and standardised on a 1-15 scale.

2.3.3 Part three: Contextual heuristic bias response task

Having established a candidate's *instinctive* heuristic biases for the seven factors, candidates are then asked, via audible instructions, to imagine a specified *context or situation* taking place within their imagined space. The instructions follow as similar a routine, pattern and verbal format as the instinctive response task. An example of a specified context might be a maths lesson in which case, the candidate will imagine their concrete maths class taking place within their imagined space. Prescriptions as to whether the candidate should focus more on the teacher, material, maths task, or peers are not given in order to avoid the introduction of alien framing effects; the candidate's focus of attention is taken to be a representation of their own heuristic bias framing effect.

Candidates then react for a second time, to the series of 28 events, incidents or required tasks which are now described as occurring within the context of the maths lesson imagined to be taking place within their mental space. By the introduction of a specific context into the imagined space, a comparative measure of heuristic bias of cognitive, affective and social factors against is obtained. The second set of scores represent contextual heuristic bias.

After a short break, candidates return to the assessment and repeat the above instructions a third time. This time, a different subject lesson is introduced, for example science or English. Once again, the bias response task is repeated and the 28 items scored providing a third set of scores representing heuristic bias in this second subject lesson. Finally, candidates repeat the process one further time, focusing on the third remaining subject of science, maths or English, and a final measure of the 28 items scores is obtained for that third context.

By this mechanism four sets of heuristic bias scores are obtained for each of the seven factors: an instinctive heuristic bias score and three contextual heuristic bias scores, thus tracking the regulation of the candidate's heuristic bias as she moves between contextual learning activities.

Part one: Initial Task	Part two : Instinctive heuristic bias response task sample items:	Part three: Contextual heuristic bias response task sample items:
Imagine you are standing outside- choose an area of the space you want to call your own.	3. How easy would it be for someone to walk across your boundary into your space?	3. How easy would it be for your maths class to walk straight across your boundary into YOUR SPACE?
	9. Imagine you could keep part of your space private. How much of your space would you keep private?	9. Imagine that you could keep a part of your space private in your maths class. Do you feel more comfortable keeping your thoughts and feelings in your private space?
	11. Do you like things to change in your space?	11. Do you like change in YOUR SPACE when your maths class is in it
	16. Someone has given you a challenge to solve in your space. You can CHOOSE a challenge about facts and objects, or about people and stories. Which do you choose?	16. In your maths class, your teacher has given you a challenge to solve in your SPACE. |You can CHOOSE a challenge about facts and objects, or about people and stories. Which do you want to choose?
	21. If a visitor came to your space would you plan what they are going to do?	
	26. You need to make something in your space. Do you try new and different ways to do it?	
8 further cues	21 further items	23 further items

Figure 2. Sample items of parts one, two and three of the assessment

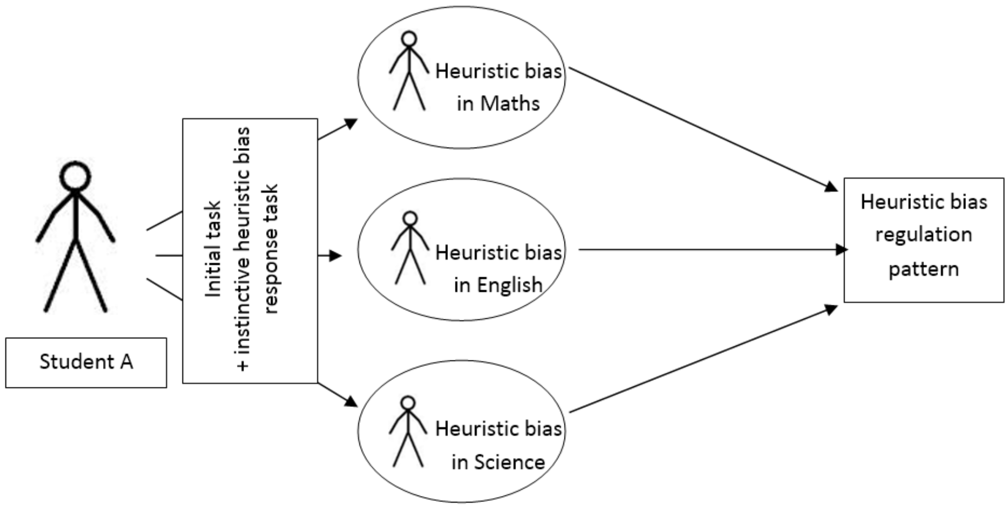

Figure 3. Schema of heuristic bias regulation assessment of maths, english and science class biases

2.4 Testing the relationship of heuristic bias against cognitive measures

Having described the construction of a heuristic bias assessment, we can return to hypothesis we are seeking to test. My argument is that heuristic cognition is an expression of cognitive, affective, social investment. Such investment provides epistemic bias which may be central to anticipatory cognition required to succeed in data perception and processing. The testable hypothesis is that an ability to appropriately shift heuristic bias in the face of multiple different epistemic challenges, by epistemic self-regulatory steering, should correlate with measured success in the outcomes of those challenges.

Secondary schools were considered to be suitable target populations to test this hypothesis for a number of reasons. The secondary school curriculum provides students with inherently epistemically varied settings as they move from curriculum subject to subject. For example, maths is epistemically different from english or science or history. Secondly, such classroom settings control for many elements such as location, teaching presence, environment and curriculum etc. Thirdly, large and stable populations of students experiences these settings, providing excellent study samples. Fourthly, schools measure academic outcomes using standardized measures. This allows correlation of measures of student heuristic bias in different epistemic settings (curriculum subject lessons), against measures of academic success in those subjects.

Fifthly, (some) schools take cognitive ability test measures of students, allowing comparison between academic outcomes and cognitive ability. Considerable evidence has identified multiple factors which contribute to variance between academic outcomes and cognitive ability (Deary et al. 2007). A strong result in support of the positive role of heuristic bias in successful cognition would be that heuristic bias explains a proportion of variance between academic outcomes and cognitive ability test score.

Studies during 2012-13 involved populations of adolescent students in year 10 (n= 496) approaching GCSEs in four different UK schools the heuristic bias assessment to test this hypothesis.

3.1 Results

No significant relationship was found between student 'instinctive' heuristic bias for any of the seven factors, or any combination of the seven factors, and school in year 10 students F (1, 496) =4.87, significance F = 0.396.

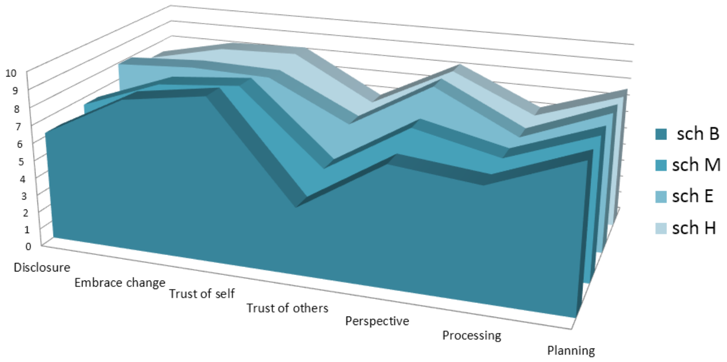

Figure 4. Illustrating that mean year 10 cohort instinctive heuristic bias scores were not related to 'school' when four schools (B, M, E and H) were considered.

This result indicated that *instinctive* heuristic bias was not related to differences in school. Walker (XXX) has evidenced that instinctive heuristic bias is strongly related to age. This result, of four UK populations of year 10 fifteen year old students, confirms that geography and schooling do not significantly alter age-related instinctive heuristic bias. This result does not undermine the hypothesis is that *regulation* of heuristic bias rather than heuristic bias *per se* which is predicted to correlate with cognitive ability.

3.2 Affective Factors 1 and 2 show positive and negative heuristic bias

'Contextual' heuristic bias scores in each of maths, science and english assessments for factors 1 and 2 were correlated against student cognitive ability test scores. Multiple regression analyses were performed to test for the relationship between cognitive ability score and heuristic bias in maths, science and english assessments for factors 1 and factor 2. Factor correlations were measured first, individually by factor, and then in combination of high/low bias for both factors 1 and 2.

The data indicates there was a significant relationship between cognitive ability and a combinative, paired bias of the affective factors 1 and 2 F (1, 96) =4.87, significance F = 0.0296. The slope is significantly non-zero, indicating that there is probably a relationship between a combination of factor 1 bias and factor 2 bias. High cognitive ability score correlates with a combination of heuristic bias toward questionning rather than trusting oneself (factor 1) coupled with a heuristic bias toward trusting rather than questionning others (factor 2) as shown in Figure 5. Low cognitive ability score correlates with a combination of heuristic bias toward trusting rather than questionning oneself coupled with a bias toward trusting rather than questionning others:

Factor	Significant relationship to low cognitive ability		
1.	*Questionning of own ideas etc*	→	*Trust of own ideas etc*
2.	*Questionning of other's ideas etc*	→	*Trust of other's ideas etc*

Factor	Significant relationship to high cognitive ability		
3.	*Questionning of own ideas etc*	←	*Trust of own ideas etc*
4.	*Questionning of other's ideas etc*	→	*Trust of other's ideas etc*

Factor	No significant relationship to cognitive ability		
5.	*Questionning of own ideas etc*	→	*Trust of own ideas etc*
6.	*Questionning of other's ideas etc*	←	*Trust of other's ideas etc*

Factor	No significant relationship to cognitive ability		
7.	*Questionning of own ideas etc*	←	*Trust of own ideas etc*
8.	*Questionning of other's ideas etc*	←	*Trust of other's ideas etc*

Figure 5. Results showed that specific combinations of factor 1/factor 2 contextual heuristic biases correlated with high/low cognitive ability

In another study, a one-way ANOVA was used to test for factor 1/ factor 2 combination biasing in relation to academic set. The relationship between factor 1 and factor 2 heuristic biasing differed significantly across the seven academic sets, F (6, 485) = 2.566, p = .0186. Low maths/science set correlates with a heuristic bias characterised by high trust of self and low trust of others.

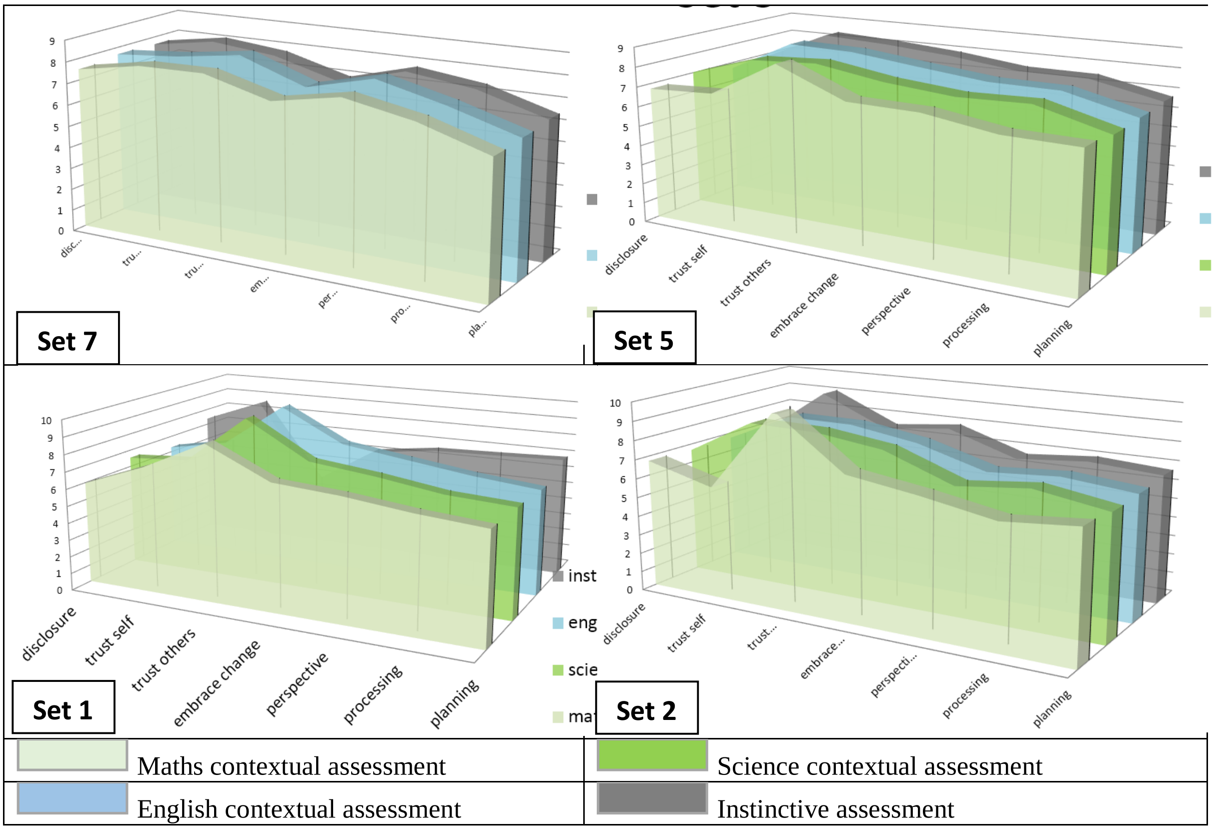

Figure 6. Graphs of mean 'set' heuristic bias scores for Sets 1, 2, 5 and 7.

3.2.1 Discussion

This result suggests that cognitive ability, whilst not relating to instinctive affective heuristic bias, relates to the regulation of affective heuristic bias in different contextual simulations. A capacity to adjust one's instinctive affective heuristic bias toward a 'low trust of oneself' as well as a high trust of others, when engaged in contextual curriculum class simulations, relates to both higher academic performance and to cognitive ability. By contrast, low cognitive ability is be related to a tendency to bias upwards heuristic 'trust of self' at the same time as biasing upwards heuristic 'trust of others' when engaging in those same curriculum subject simulations.

Heuristic biasing of 'trust of self' (factor 1) and 'trust of others' (factor 2) may be having a framing/coherency effect. A high 'trust of self' biased heuristic may lead the mind to seek data which is strongly coherent with pre-existing ideas. This myside bias may reduce the effort made to update internal understanding with new, apparently incoherent data. When combined with 'high trust of others' bias, the learner may expect others to provide help, reducing the motivation to wrestle with difficult ideas herself, yet not be willing to incorporate new challenging ideas, resulting in a disorganised responsiveness bias.

By contrast, a heuristic bias toward a 'questionning of self', coupled with a bias toward 'high trust of others', may reduce framing/coherency effects. The mind may be primed to engage in effortful struggle to listen to and learn from others, peers and teachers. It may also maintain a high alert state to detect novel data and seek to incorporate it, driven by a heuristic bias of assuming others know better than they. We might call this an effective responsiveness bias.

This result suggests that contextual regulation of heuristic affect bias can contribute to a measurable advantage or disadvantage in relation to academic outcomes. Within the analogy of cognitive steering, the result suggests that the mind can invest resources to sustain a state of effective responsive heuristic bias, which may reduce the likelihood of falling into cognitive traps, thus improving academic performance. By contrast, miserliness investment can reduce the create a state of heuristic biased unresponsiveness, which may increase the likelihood of being caught by traps, reducing academic performance in the classroom as a result of higher failure rates.

3.3 Heuristic bias is a modulatable state not fixed trait

The hypothesis suggests that heuristic bias is a modulatable cognitive state that may potentially be altered by a person in response to the demands of the situation. As such, the hypothesis would predict that low or high performing students could, under some conditions, exhibit unexpected heuristic biased state. If one found such counter-examples, it would demonstrate that heuristic bias was not a static trait-based function of cognitive ability, such as general intelligence but rather a cognitive-affective state which can be created by an investment of resource.

238 predicted student predicted grades across maths, science and English were obtained from one of the four schools, H. A one-way ANOVA was used to test for the relationship of the 'responsiveness factors' (factor 1, trust of self and factor 2, trust of others) against predicted grade.

The relationship between 'trust of others' and 'trust of self' differed significantly between students predicted D and E/F/G grades, F (1, 238) = 13.51, p = 0.0003 indicating that D grade students exhibited a more effective 'responsiveness' state than E/F/G grade predicted students. This result was not surprising as it fits the prior result that effective responsive affective state correlates with higher academic performance. The relationship between 'trust of others' and 'trust of self' differed significantly between students predicted D and C grades when data was transformed to equalise sample sizes, F (1, 368) = 10.18, p = 0.0015 indicating that D grade students exhibited a more effective responsive state than C grade predicted students. This result was counter-expectation, in which higher performing students (C grade) exhibited a disorganised responsive bias, associated with lower performing students and vice-versa. Finally, the relationship of 'trust of others' and 'trust of self' between C and E/F/G grade students was tested. There was no significant difference in affective responsiveness bias between C and E/F/G grade predicted students F (1, 233) = 2.71, p = 0.1004 when data was transformed to equalise sample sizes,

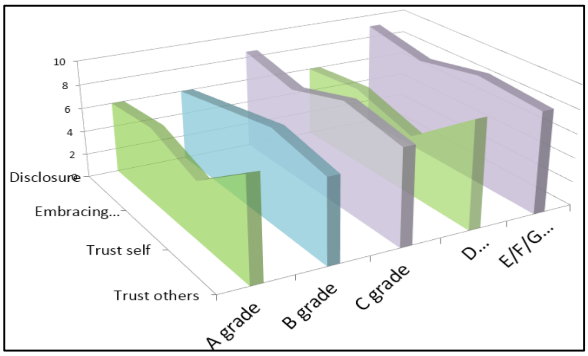

Figure 7. Students predicted E/F/G on grade scale exhibited the anticipated disorganised responsiveness heuristic bias (high trust of self, high trust of others) whilst students predicted D grades exhibited effective responsiveness heuristic bias (low trust of self, high trust of others), also seen in A grade students.

3.3.1 Discussion

The data suggests that D predicted grade students exhibit unexpectedly effective heuristic responsiveness bias, a bias level only evidenced by A grade predicted students. By contrast both C and E/F/G students show a consistently high incidence of students exhibiting a heuristic bias toward low responsiveness. The result supports the hypothesis that heuristic bias toward effective responsiveness (combination of factor 1 and factor 2 state) is not a fixed trait but a modulatable affective state. grade C is the pass/fail threshold for GCSE. It is a motivational goal for students to reach. This data suggests that students who are one grade short of a C grade and who have the highest incentive to learn and achieve are able to invest resources in attaining an aspirational effective responsive heuristic bias state. The D grade prediction has a heuristic state 'activator effect'. Behaviourally, this is manifests in students being more willing to question, review and revise their ideas.

Abundant evidence exists showing that summative assessments, such as predicted grades, create ceilings and floors for learners (Hattie 2009). This results provides a heuristic bias explanation for this phenomenon, indicating that low/high affective responsiveness heuristic bias state is not fixed but may be subject to extrinsic and intrinsic temporal regulation such as predicted grade. This result sits within the literature on the role self-regulation plays in the development of wide ranging of self, social and cognitive competences (Buckner et al. 2009; Vohs, Baumeister 2011). The evidence that self-regulatory strength is depleted after affective epistemic challenges are faced (Baumeister et al. 1998; Muraven, Baumeister 2000) provides a perspective on why the C grade slump may occur after the D grade hump.

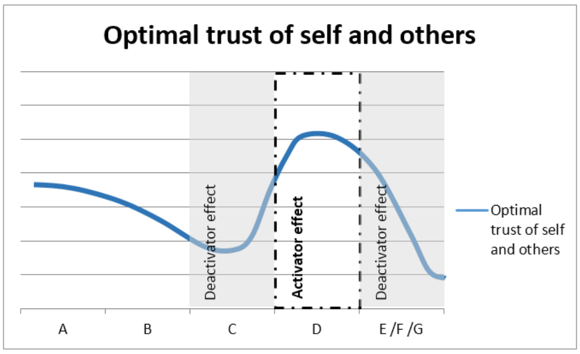

Figure 8. D predicted grades show an 'activator effect' on student heuristic bias for trust of self/trust of others- the affect responsiveness factors. By contrast, grade c and e/f/g predictions show a 'deactivator effect' on student trust of self/trust of others

3.4 Heuristic bias regulation or 'epistemic steering' explains variance between g and academic outcomes

The testable hypothesis (ability to appropriately shift heuristic cognition in the face of multiple different epistemic challenges, by epistemic self-regulatory steering, should correlate with measured success in the outcomes of those challenges) was subjected to a final test.

Cognitive ability test scores (CAT scores), academic grades and heuristic bias modulation scores for 96 yr 10 students in two of the four schools, H and M, were compared. Students were randomized and CAT scores were tested to check for normal distribution, which was confirmed.

3.4.1 Method

An inter-lesson optimal heuristic biased state model was developed for maths, science and english lesson simulated engagements. This model of subject-specific optimal heuristic bias established by a previous study with year 13 students. Subject-specific optimal heuristic biased state in four of the seven factors was identified in this earlier study (Figure 9).

	OPTIMAL BIAS AFFECTIVE FACTORS		**OPTIMAL BIAS COGNITIVE FACTORS**	
	Factor 1 (trust self)	**Factor 2 (trust others)**	**Factor 5 (perspective)**	**Factor 4 (planning)**
Maths	Questionning of self	Trusting of others	Detached perspective	Bias to outcome
Science	Questionning of self	Trusting of others	Detached perspective	Bias to process
English	Trusting of self	Questionning of others	Personal perspective	No bias

Figure 9. Optimal heuristic biases identified by a prior study of biased states in english, maths and science

In addition, optimal biased state interactions *between* the four factors were observed, resulting in the development of a combinative model shown in the appendix for both affective factors (1 and 2) and cognitive factors (5,6 and 7), shown in the appendix. In the previous study, multiple regression analyses confirmed the relationship of academic success and the proposed optimal heuristic biased state model, F (1, 56) = 8.145, p = 0.0061. The slope was significantly non-zero, indicating that there was probably a relationship between the optimal heuristic biased state model for maths, english and science and academic success.

Using this model, a model-fit score, transformed to scale of 1-20, was established for students, representing the optimality of their regulation of their biased state for these four factors, in maths, science and english classes. A high fit score indicated that a student's regulation of bias fitted the optimal bias model; a low fit score indicated that regulation of bias did not fit the bias model.

Finally, students were given a predicted grade ranking for their total predicted grades in Maths, Science and English 3 being the lowest potential grade rank, and 15 being the highest grade rank score.

3.4.2 Results

Analyses were performed using PSPP and Lisrel 9.1. Full results are shown in the appendix.

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.

3.4.3 Correlation analysis

A strong correlation (0.6451) between CAT score and grade rank was measured. A correlation of 0.6654 was measured when the optimal heuristic bias score was added to the CAT score indicating that CAT score + optimal heuristic bias gives a slightly stronger indicator of GCSE grade than CAT score alone.

A significant correlation of 0.3997 was then measured between the optimal heuristic bias and grade rank confirming that optimal heuristic bias correlates with grade rank. This compared to a slightly lower but still significant correlation of 0.3610 between optimal heuristic biased state and CAT score.

3.4.4 ANOVA and regression analysis

ANOVA and multiple regression analyses were performed to test for the relationship between CAT, grade rank and optimal heuristic bias.

One–way ANOVA identified that the relationship between CAT score and optimal heuristic bias differed significantly $F\ (1, 96) = 13102$, $p = 0.0297$. A regression analysis was performed to confirm the relationship of CAT score and optimal heuristic bias $F\ (1,96) = 4.87$, significance $F = 0.02968$. The slope is significantly non-zero, indicating that there is probably a relationship between optimal heuristic bias and CAT score.

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.

3.4.5 Factor Analysis

Exploratory factor analysis was used to identify loading onto identified factors. Factor analysis was performed using PCA and rotated Varimax solutions to identify the relative variance loaded to the factors of CAT score and optimal heuristic bias in grade rank predictions.

Factor analysis finally confirmed that 98% of the variance between the three variables of CAT score, grade rank and optimal heuristic bias could be accounted by two factors. Factor 1 accounted for 88% of overall variance, factor 2 for 9% of variance. This result indicated that the 9% of variance contributed to overall variance by factor 2 is not attributable to CAT, but is attributable to optimal heuristic bias. Both grade rank and optimal heuristic bias contribute to factor 2 indicating that factor 2 a component of academic outcome which is not explained by cognitive ability.

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 in school H.

4.1 Overall discussion

These results indicate that both cognitive ability and optimal heuristic bias, as measured cognitive-affective state regulation, contribute significantly to GCSE grade prediction in year 10 students in the two study schools.

Correlation data from this study suggests optimal heuristic bias correlates 0.39 with grade prediction. This suggests that it accounts for about 20% of the variance in within-school GCSE grade prediction in this study. The proportion of GCSE grade variance that cannot be assigned to CAT but can be assigned to optimal heuristic bias is 9%. In addition, optimal heuristic bias contributes to the 88% that can be assigned to CAT. These results suggest that whilst optimal heuristic bias contributes to CAT score, CAT score does appear to not contribute significantly to the distinctive factor of optimal heuristic bias

4.2 Heuristic bias and the algorithmic mind

Dual mind models conceive of two minds, systems or processes. This result supports a model of two discretely identifiable components of cognition which, taken together, account for more of the variance of academic outcome than either one alone. One of those components might be referred to as algorithmic or general intelligence and explains the large majority of academic outcomes. The other is referred to as heuristic biasing and explains a minority of academic outcomes. However, the relationship between the two is different from the widely accepted view in two respects.

Firstly, the role of heuristic biasing is not found to be simply cognitively negative and errorful; rather, the ability of a person to optimally regulate their heuristic bias improves academic outcomes. Equally, the lack of ability to do so, deteriorates academic outcomes. In this study, 9% of academic outcome is attributable the regulation of cognitive-affective state, which is independent of a trait representing g, cognitive ability. This enables us to assert that cognitive-affective state serves as a mediator of heuristic bias; it is a modulatable function that appears to have ecological sensitivity, evidenced by the contextual modulation observed between different epistemic environments (maths, english and science).

Secondly, the function of heuristic bias regulation contributes to g, or cognitive ability, whilst g contributes little to heuristic bias regulation. The relationship between the two functions is asymmetric in terms of contribution. One explanation may be that heuristic biasing represents a temporally primary data processing function, the outcomes of which are passed on, or passed down, to the secondary cognitive function of g. G is influenced by the performance of heuristic bias, whilst g does not appear to pass back up influence to the performance of heuristic bias regulation.

In this conjecture, heuristic bias regulation may act as a filter or a conduit through which data is passed through to deeper neural functions which then processes and retain meaning. The accuracy or inaccuracy of that filtering conduit determines a proportion of what a person ultimately retains and then, subsequently, retrieve when put through a cognitive ability test. By way of analogy, the ability of a business to benefit intelligently from analysing and interpreting its business data is dependent upon the quality of the data that is gathered from the business environment in the first place. As the industry phrase puts it ‘Rubbish in, rubbish out’. If heuristic biasing plays this filtering conduit role, then cognitive analysis will never be able to get past the limits of its bias and will always be enhanced by the accuracy of its bias.

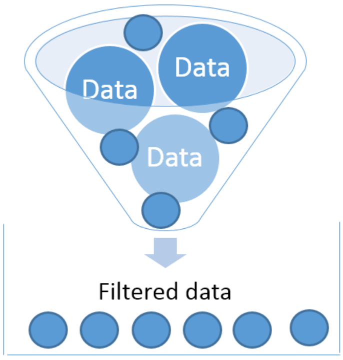

Figure 10. A model of the relationship between heuristic biasing as a processing, retention and application.

4.3 The location of epistemic self-regulation

In their paper, (Stanovich, West 2008) observe that in 7 different studies, a large number of thinking biases are uncorrelated with cognitive ability. These thinking biases include some of the most well-studied biases in the heuristics and biases literature (conjunction effect, framing effects, anchoring effects, outcome bias and several others). However, they do find that cognitive ability does correlate with a tendency to avoid some negative biases. Stanovich and West propose a conjectured tripartite mind in which the effortful slow process 2 mind is seen as having two components- an algorithmic and a reflective component (Stanovich 2011, 2009). The reflective component provides the capacity for epistemic self-regulation, a component which some authors argue is the seat of epistemic and metalogical norms and can be seen as central to framing effects (Overton, Ricco 2011). However, this study evidences that a component of cognitive-affective self-regulation is not found within mind/system/process 2 but in what, in the heuristics literature is called the autonomous mind 1/process 1. Epistemic self-regulatory steering is a capacity of the heuristic mind; it is the capacity to bias cognitive affective state such that the quality of data being retrieved from the external environment is accurate.

Interestingly, this proposal of self-regulatory epistemic steering appears to incorporate two of the other meta-functions widely accepted alongside inhibition as components of 'executive functions'. The first is shifting, described as cognitive flexibility to switch between different tasks or mental states; second is updating, the continuous monitoring and addition or deletion of contents within one's working memory (Halloran 2011; Miyake et al. 2000; Fernandez-Duque et al. 2000).

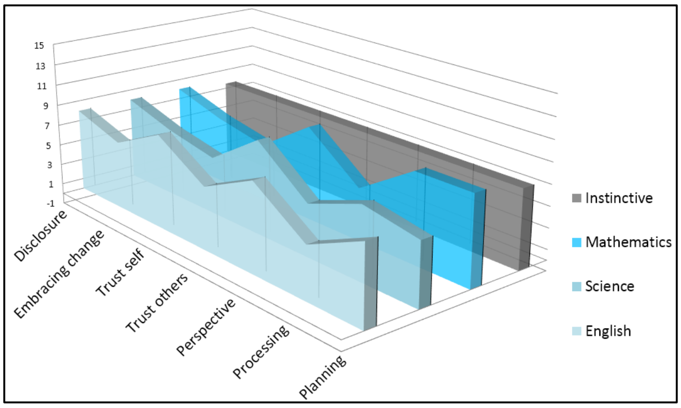

Figure 11. A visual map of the optimal heuristic biases for maths, science, english subjects in GCSE students identified by cognitive-affective-social state bias regulation data. No optimal instinctive bias was found.

4.4 Bias is only negative is knowledge is flat

One of the central, and largely unquestioned, assumptions that has underpinned the heuristic bias orthodoxy is that knowledge is flat. By this I mean that it is assumed that the acquisition of different kinds of knowledge does not require epistemic bias. Within the world of education, and potentially in wider life, it is not clear this assumption holds. For example, science involves studying empirical data, in which testable hypothesis evidence understandings of a material properties- molecular structure, biological processes or physical properties. Science may be described as a discipline in which the mental task of the science student is to put aside their own personal feelings or experiences and submit to the evidenced outcomes of a body of practice and knowledge. A similar epistemic property would apply to maths, whilst the opposite epistemic property would apply to english. Arts subjects essentially involve the recruitment of one's personal, subjective perspective as an 'author' of the dialogue with the subject.

In affective-social aspects, english requires the assertion of a perspective which is underpinned by a student's ability to trust their own voice, ideas, opinions. By contrast, the hard sciences and maths require a subordination of their own perspective in favour of obtaining a wider body of evidence through good scientific method. Maths, at secondary school level, is largely a closed subject requiring competence in a set of closely prescribed, tight mathematical sequences, protocols and procedures. By contrast, science at the same adolescent teaching stage, is open-ended and investigative. In relation to english, neither a high planning bias or a low planning bias would be predicted to have a greater benefit than the other as different activities within the subject would require different modes of planning.

Knowledge is not flat and even; rather some knowledge is hard whilst other knowledge is soft and can be impressed into a form. Knowledge landscapes are not identically traversed. The heuristic orthodoxy, that bias introduces error, is true if we imagine knowledge to be a flat, level and even topography. Seen as such, heuristic bias is the swerving of the careless driver, being caught in cognitive trapping studies. The intervention of the censorious mind/process 2 driving instructor, sitting quietly in the passenger seat, is costly, restraining the mis-direction of the heuristic driver for a period of time before he cedes control again to the incumbent heuristic driver. However, it is possible this is only a narrow view, built on limited data from cognitive crash sites, which is in fact part of a wider epistemic story.

If we take a look a little further from the crash site, the surrounding landscape may be telling us something different. The epistemic landscape we face is not a flat, level metalled road requiring repetitive cognitive action. It is a contoured, highly featured, irregular epistemic topography which requires continuous adjustment of epistemic speed and direction. The driving that is successful on this rugged journey is the alert agility of the off-road pioneer. Perhaps it is better described, not as cognitive driving, but as cognitive trekking.

5.1 Further questions

In this study, significant relationships to academic outcome were identified in two of the three factor groups, cognitive and affective, of the 7 factor model. The third group, social factors (3 embracing change and 4, self-disclosure) did not exhibit optimal biases for these subjects. However, it is likely that biased states for these social factors may play roles in other within-lesson learning activities such as peer coaching, group work or independent work. Future studies may identify such optimal biases.

Tracking cognitive-affective state regulation may represent a new research technique by which to investigate the role of heuristic bias in cognition. In this study a narrow set of contextual simulations were investigated- english, science and maths lessons. However, tracking cognitive-affective state within other contextual simulations, such as peer interactions, stress conditions and wider cognitive challenges, could reveal further data about the role heuristic bias plays in the cognitive processing. One particularly interesting possible route would be to investigate the longitudinal effects of sustained contextual cognitive-affective states on emergent developmental traits. Such investigations may illuminate the process by which sustained cognitive-affective states could become crystallised to become fixed traits.

6.1 Conclusions

Heuristic bias has been largely assumed to introduce error into human thinking. This study provides evidence that heuristic bias contributes to both cognitive accuracy and cognitive steering; heuristic investment may be a way of 'peering down the road'. Evidence showed that students who did not alter their heuristic gaze by responding to the different kinds of demands of different kinds of epistemic terrain (maths, science and english) made less progress across the landscape (academic gains). One implication of this study is that epistemic self-regulation may be located in mind/process 1 of a dual-mind model rather than mind/process 2. This study suggests that heuristic bias may be better described not as a *separate* process but a *first* processor serving as a cognitive conduit through which data is passed through to deeper neural functions which processes and retain meaning. Results support the claim that bias-regulation of that conduit determines a proportion of what a person ultimately retains and is then able to retrieve and use. If heuristic biasing plays this filtering conduit role, then deeper cognitive processes will never be able to get past the limits of its bias and will always be enhanced by the accuracy of it. As the business intelligence industry phrase puts it ‘Rubbish in, rubbish out’. The heuristic bias story that has emerged from this cognitive-affective state tracking data opens up a vista for a wider role for heuristic bias in cognition. Heuristic biasing may be a basis for, rather than the enemy of, accurate epistemic navigation of a varied world.

7.1 Disclosure

The author acknowledges a commercial relationship with the developer of the cognitive-affective-social state bias regulation assessment. This research was funded by the Human Ecology Education Footprints Programme for Schools.

Appendix

A.1 Statistical analysis of heuristic bias assessment data

Instinctive and contextual heuristic bias assessment data was collected from 496 secondary year 9 and 10 school students in 2013 from four secondary schools in the UK. Each student completed the assessment for maths, science and english lessons. In all 1271 lesson assessments were analysed for descriptive statistics, reliability and principal component analysis using PSPP and Prelis.

A.1.1.Descriptive and reliability Statistics

Construct		**N**	**Mean**	**Std. Deviation**
DISCLOSURE	VAR001	1271	7.39	2.75
TRUST SELF	VAR002	1271	7.48	2.55
PACE	VAR003	1271	7.12	2.54
TRUST OTHERS	VAR004	1271	9.33	3.14
PERSPECTIVE	VAR005	1271	7.40	1.98
PROCESSING	VAR006	1271	7.53	2.45
PLANNING	VAR007	1271	6.33	2.60

Cronbach's Alpha	0.73
N of Items	28

A.1.2 Principal Component Analysis Variance Explained

Component	Initial Eigenvalues	% of variance	Cumulative % of variances
1	8.58	16.24	16.42
2	5.53	10.58	27.00
3	4.72	9.04	36.03
4	3.11	5.96	41.99
5	2.38	4.56	46.55
6	2.22	4.25	50.80
7	1.98	3.79	54.59

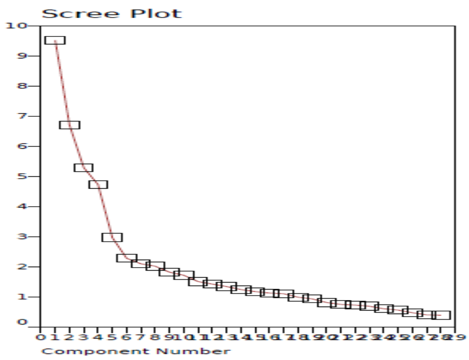

Figure A.1 Scree plot of PCA rotated solutions

Prelis was used to extract Promax and Varimax Rotated Factor Loadings for the seven factors. This was conducted in two batches: Variables 1-16 in the first batch and variables 17-28 in the second to represent the affective (batch one) and cognitive (batch two) constructs the theory predicts.

Latent variables	Obs vars	Factor 1	Factor 2	Factor 3	Factor 4	Unique var
Disclosure	VAR1	0.560	-0.018	-0.170	-0.020	0.730
Disclosure	VAR2	0.381	-0.209	0.223	0.157	0.776
Disclosure	VAR3	0.119	0.226	0.092	-0.134	0.866
Disclosure	VAR4	0.661	0.063	0.000	0.039	0.525
Trust self	VAR5	0.034	-0.829	0.063	-0.065	0.365
Trust self	VAR6	0.134	0.634	0.053	-0.316	0.397
Trust self	VAR7	0.248	0.418	0.287	-0.153	0.431
Trust self	VAR8	0.138	-0.743	0.007	-0.132	0.485
Trust others	VAR9	-0.028	0.037	0.742	-0.069	0.431
Trust others	VAR10	-0.022	0.019	0.633	-0.101	0.455
Trust others	VAR11	0.077	0.022	-0.471	-0.404	0.656
Trust others	VAR12	-0.144	-0.033	0.545	-0.194	0.703
Pace	VAR13	-0.090	-0.432	-0.088	-0.247	0.661
Pace	VAR14	0.195	0.047	0.472	0.108	0.634
Pace	VAR15	-0.165	-0.016	0.098	-0.471	0.743
Pace	VAR16	0.053	-0.027	0.070	-0.449	0.790

Figure A.2 . Batch one. Rotated promax loadings for items (variables 1-16) onto the four factors identified by PCA, showing the latent theoretical factor loadings highlighted in batch one.

Latent variables	Obs vars	Factor 5	Factor 6	Factor 7	Unique var
Perspective	VAR17	0.555	-0.182	-0.024	0.659
Perspective	VAR18	-0.283	0.724	0.081	0.390
Perspective	VAR19	-0.194	0.565	0.226	0.592
Perspective	VAR20	0.733	-0.047	-0.070	0.456
Processing	VAR21	0.063	0.262	0.154	0.904
Processing	VAR22	-0.043	0.207	0.425	0.775
Processing	VAR23	-0.192	0.366	0.456	0.621
Processing	VAR24	0.025	0.125	0.170	0.955
Planning	VAR25	-0.063	0.159	0.681	0.507
Planning	VAR26	-0.181	0.549	0.322	0.562
Planning	VAR27	-0.155	0.235	0.618	0.539
Planning	VAR28	0.016	0.058	0.603	0.633

Figure A. 3 Batch 2. Rotated varimax loadings for items (variables 17-28) onto the three factors (5,6,7) identified by PCA, showing the latent theoretical factor loadings in batch two.

Factor loadings for factors 1,2,3,4,5 and 7 show strong association with the variables associated with the latent factors of the personal ecology model. Factor loadings for 6 (processing) shows the weakest association with its latent factor variables, with other variables from perspective and planning also loading onto it. This may account for the scree analysis which identifies six clear factors, the seventh being marginal.

A. 1.3 Factor Correlation

Divergent construct validity was then assessed at first an item and then latent construct level. Varimax factor correlations for item data for batch one and batch two were performed to identify the degree of factor divergence using Prelis 9.1.

Batch One. Factor Correlations				
	Factor 1	Factor 2	Factor 3	Factor 4
Factor 1	1.000			
Factor 2	-0.399	1.000		
Factor 3	0.349	-0.381	1.000	
Factor 4	-0.354	0.176	0.181	1.000

Batch Two. Factor Correlations			
	Factor 5	Factor 6	Factor 7
Factor 6	1.000		
Factor 7	-0.429	1.000	
Factor 8	0.341	-0.195	1.000

Figure A. 4 Factor correlations for batches One and Two.

Varimax factor correlations for construct data for batch one and batch two were performed to confirm the degree of factor divergence of the factors using Prelis 9.1.

	Disc	Trust self	Pace	Trust other	Persp	Process
DISCLOSURE	1.000					
TRUST SELF	-0.043	1.000				
PACE	0.218	0.097	1.000			
TRUST OTHER	0.237	-0.218	0.269	1.000		
PERSPECTIVE	-0.117	0.060	-0.068	-0.046	1.000	
PROCESSING	-0.101	0.202	0.115	-0.009	0.002	1.000
PLANNING	0.102	-0.090	0.192	0.038	-0.101	-0.119

Figure A. 5 Correlation Matrix of factors having been related to latent factor names

Inter-factor correlations show weak correlation for six of the factors, with 'trust of others' showing weak to moderate correlation with 'disclosure' (0.237) and 'pace' (0.269). Overall, this analysis suggests that the seven factors measured are largely independent, divergent factors with a small degree of overlap.

A.1.3.1 Convergent validity

Convergent validity cannot currently be attributed to the heuristic bias assessment. Measures of learning state, both cognitive and affective, for adolescent students should be considered as possible convergent test comparison.

A.1.3.2 Divergent validity

Eigenvalues and scree plots support the existence of seven latent factors within the data, accounting for a minimum of 54% of the total variance. Indications from some sample schools suggest this % may increase with larger population sizes which would control for intra-school variance suppressive factors. Strong divergent construct validity, indicated by low inter-factor correlations support the divergent validity of the seven largely independent factors. Confirmatory Factor Analysis is currently being carried out on this seven factor model.

A.1.3.3 Predictive validity

These studies provide evidence that heuristic bias assessment scores correlate with cognitive ability test scores in year 10 students and with GCSE grade predictions. In addition, factor loadings indicated that ability to modulate heuristic bias explains a significant element of variance between intra-school GCSE predicted grades and cognitive ability test scores. The claims of instrument to refer to a cognitive-affective state component of cognitive ability are supported.

A.2.1 Optimal heuristic bias model

	Combinations of factors 5, 6 and 7		
ranking	Maths	Sciences	English
4	DCT	DCT/DCO/DSO	PCT/PST
3	DST/DCO	DST	PCO/PSO
2	PCT	PCT	DST/DOT
1	PCO/PST	PCO/PST	DSO/DCT/DCO

Legend

Factor 5 Perspective	D = Detached perspective	P = Personal perspective
Factor 6 Processing	C= Connecting	S = Sequencing
Factor 7 Planning	T = Outcome focused	O= Open ended

Figure A. 6. The optimal cognitive-affective-social state model for factors 5,6 and 7 in relation to maths, science and english lessons

A.2.2 Factor Analysis of CAT score, optimal heuristic bias and grade rank

LISREL 9.1 was used to perform factor analysis using PCA and rotated Varimax solutions to identify the relative variance loaded to the factors 'CAT score' and 'optimal heuristic bias' in grade predictions in schools M & H.

A.2.2.1 Variance between CAT score and grade rank in school H

Factor	Total	% of total variance
1	130.0	96.9
2	4.05	3.02

Rotated Factor Matrix	Factor 1
Loading of CAT score	11.26
Loading of grade rank	-1.77

A.2.2.2 Variance between optimal heuristic bias and grade rank in school H

Factor	Total	% of total variance
1	8.99	70.27
2	3.80	29.73

Rotated Factor Matrix	Factor 1
Loading of optimal heuristic bias	1.55
Loading of grade rank	1.15

A.2.2.3 Variance between CAT score, optimal heuristic bias and grade rank in school H

Factor	Total	Rotation % of total variance
1	130.8	88.23
2	5.52	9.32
3	3.43	

Factor Matrix	Factor 1	Factor 2
Loading of CAT score	11.26	0.35
Loading of grade rank	0.91	-1.97
Loading of optimal heuristic bias	-1.77	1.24

Publication bibliography

Barone, David F.; Maddux, James E.; Snyder, C. R. (1997): Social cognitive psychology. History and current domains. New York: Plenum Press (The Plenum series in social/clinical psychology).

Barrouillet, Pierre (2011): Dual-process theories and cognitive development: Advances and challenges. In *Developmental Review* 31 (2-3), pp. 79–85. DOI: 10.1016/j.dr.2011.07.002.

Baumeister, Roy F.; Bratslavsky, Ellen; Muraven, Mark; Tice, Dianne M. (1998): Ego depletion: Is the active self a limited resource?, Vol 74(5), May 1998, 1252-1265. In *Journal of Personality and Social Psychology* 74 (5), pp. 1252–1265.

Buckner, John C.; Mezzacappa, Enrico; Beardslee, William R. (2009): Self-regulation and its relations to adaptive functioning in low income youths. In *American Journal of Orthopsychiatry* 79 (1), pp. 19–30. DOI: 10.1037/a0014796.

De Neys W. (2010): Heuristic Bias, Conflict, and Rationality in Decision-Making. In Britta Glatzeder, Vinod Goel, Müller, Albrecht A C von (Eds.): Towards a theory of thinking. Building blocks for conceptual framework. Heidelberg, New York: Springer (On thinking), pp. 23–33.

Deary, Ian J.; Strand, Steve; Smith, Pauline; Fernandes, Cres (2007): Intelligence and educational achievement. In *Intelligence* 35 (1), pp. 13–21. DOI: 10.1016/j.intell.2006.02.001.

Decety, Jean; Grèzes, Julie (2006): The power of simulation: imagining one's own and other's behavior. In *Brain Res.* 1079 (1), pp. 4–14. DOI: 10.1016/j.brainres.2005.12.115.

Evans, Jonathan St.B.T. (2011): Dual-process theories of reasoning: Contemporary issues and developmental applications. In *Developmental Review* 31 (2-3), pp. 86–102. DOI: 10.1016/j.dr.2011.07.007.

Evans, J. S. B. T.; Stanovich, K. E. (2013): Dual-Process Theories of Higher Cognition: Advancing the Debate. In *Perspectives on Psychological Science* 8 (3), pp. 223–241. DOI: 10.1177/1745691612460685.

Evans, Jonathan St B T; Frankish, Keith (2009): In two minds. Dual processes and beyond. Oxford, New York: Oxford University Press.

Fernandez-Duque, Diego; Baird, Jodie A.; Posner, Michael I. (2000): Executive Attention and Metacognitive Regulation. In *Consciousness and Cognition* 9 (2), pp. 288–307. DOI: 10.1006/ccog.2000.0447.

Fiske, Susan T.; Taylor, Shelley Elizabeth (1985): Social cognition. New York: Random House (Topics in social psychology).

Frank, Lawrence K. (1939): Projective methods for the study of personality. In *The journal of psychology 8, 389-414* 8, pp. 389–414.

Gaesser, Brendan (2012): Constructing memory, imagination, and empathy: a cognitive neuroscience perspective. In *Front Psychol* 3, p. 576. DOI: 10.3389/fpsyg.2012.00576.

Garry, Maryanne; Polaschek, Devon L.L. (2000): Imagination and Memory. In *Current Directions in Psychol Sci* 9 (1), pp. 6–10. DOI: 10.1111/1467-8721.00048.

Gigerenzer, G. (2008): Why Heuristics Work. In *Perspectives on Psychological Science* 3 (1), pp. 20–29. DOI: 10.1111/j.1745-6916.2008.00058.x.

Gigerenzer, Gerd; Hertwig, Ralph; Pachur, Thorsten (2011): Heuristics: Oxford University Press.

Gigerenzer, Gerd.; Todd, Peter M. (1999): Simple heuristics that make us smart. New York, Oxford: Oxford University Press (Evolution and cognition).

Goldstein, Daniel G.; Gigerenzer, Gerd (2002): Models of ecological rationality: The recognition heuristic. In *Psychological Review* 109 (1), pp. 75–90. DOI: 10.1037/0033-295X.109.1.75.

Grove, David J.; Panzer, B. I. (©1989): Resolving traumatic memories. Metaphors and symbols in psychotherapy. New York: Irvington Publishers.

Halloran, Roberta Kathryn (2011): Self-regulation, executive function, working memory, and academic achievement of female high school students. In *ETD Collection for Fordham University*, pp. 1–139. Available online at http://fordham.bepress.com/dissertations/AAI3452791.

Hattie, John (2009): Visible learning. A synthesis of over 800 meta-analyses relating to achievement. London, New York: Routledge.

Kahneman, D.; Tversky, A. (1973): On the psychology of prediction. In *Psychological Review* 80 (4), pp. 237–251.

Kahneman, Daniel (2011): Thinking, fast and slow. 1st ed. New York: Farrar, Straus and Giroux.

Kahneman, Daniel; Slovic, Paul; Tversky, Amos (1982): Judgment under uncertainty. Heuristics and biases. Cambridge, New York: Cambridge University Press.

Keller, Carmen; Siegrist, Michael; Gutscher, Heinz (2006): The Role of the Affect and Availability Heuristics in Risk Communication. In *Risk Analysis* 26 (3), pp. 631–639. DOI: 10.1111/j.1539-6924.2006.00773.x.

Lawley, James; Tompkins, Penny (2000): Metaphors in mind. Transformation through symbolic modelling. London: Developing Company Press.

Miyake, A.; Friedman, N. P.; Emerson, M. J.; Witzki, A. H.; Howerter, A.; Wager, T. D. (2000): The unity and diversity of executive functions and their contributions to complex \"Frontal Lobe\" tasks: a latent variable analysis. In *Cogn Psychol* 41 (1), pp. 49–100. DOI: 10.1006/cogp.1999.0734.

Muraven, Mark; Baumeister, Roy F. (2000): Self-regulation and depletion of limited resources: Does self-control resemble a muscle? Psychological Bulletin 126 (2), pp. 247–259.

Overton, Willis F.; Ricco, Robert B. (2011): Dual-systems and the development of reasoning: competence-procedural systems. In *WIREs Cogn Sci* 2 (2), pp. 231–237. DOI: 10.1002/wcs.120.

Reyna, Valerie F.; Brainerd, Charles J. (2011): Dual processes in decision making and developmental neuroscience: A fuzzy-trace model. In *Developmental Review. DOI:* 10.1016/j.dr.2011.07.004.

Ricco, Robert B.: Dual systems Competence â†•-â†' Procedural processing: A relational developmental systems approach to reasoning, checked on 9/22/2014.

Saklofske, Donald H.; Reynolds, Cecil R.; Schwean, Vicki L. (©2013): The Oxford handbook of child psychological assessment. Oxford, New York: Oxford University Press (Oxford library of psychology).

Sarbin, Theodore R. (1986): Narrative psychology. The storied nature of human conduct. New York: Praeger.

Schacter, Daniel L. (2012): Adaptive constructive processes and the future of memory. In *Am Psychol* 67 (8), pp. 603–613. DOI: 10.1037/a0029869.

Schacter, Daniel L., Addis, Donna Rose and Buckner, Randy L. (2007): Remembering The Past To Imagine The Future: The Prospective Brain. In *Nature reviews Neuroscience* 8 (9), pp. 657–661.

Sherman, D. K.; Kim, H. S. (2002): Affective Perseverance: The Resistance of Affect to Cognitive Invalidation. In *Personality and Social Psychology Bulletin* 28 (2), pp. 224–237. DOI: 10.1177/0146167202282008.

Siegelman, Ellen. (1990): Metaphor and meaning in psychotherapy. New York: Guilford Press.

Stanovich, Keith E. (2009): What intelligence tests miss. The psychology of rational thought. New Haven: Yale University Press.

Stanovich, Keith E. (2011): Rationality and the reflective mind. New York: Oxford University Press.

Stanovich, Keith E.; West, Richard F. (2008): On the relative independence of thinking biases and cognitive ability. In *Journal of Personality and Social Psychology* 94 (4), pp. 672–695.

Stanovich, Keith E.; West, Richard F.; Toplak, Maggie E. (2011): The complexity of developmental predictions from dual process models. In *Developmental Review* 31 (2-3), pp. 103–118. DOI: 10.1016/j.dr.2011.07.003.

Stanovich Keith E. West Richard F. (2014): What Intelligence Tests Miss. In *The Psychologist* 27 (2), pp. 80–83.

Sunstein, C. R. (2006): Behavioral analysis of law.

Thaler, Richard H.; Sunstein, Cass R. (2008): Nudge. Improving decisions about health, wealth, and happiness. New Haven, Conn: Yale University Press.

Vohs, Kathleen D.; Baumeister, Roy F. (2011): Handbook of self-regulation. Research, theory, and applications. 2nd ed. New York: Guilford Press.

Walker, Simon, P. (2007, 2009): A Brief Introduction to the Theory of Human Ecology. UK: Human Ecology Partners.

Walker, Simon, P. (2009): The Ecology of Coaching. A New Model of Transformational Coaching. UK: Human Ecology Partners.

Winkielman, Piotr; Zajonc & Norbert Schwarz, Robert B. (1997): Subliminal Affective Priming Resists Attributional Interventions. In *Cognition & Emotion* 11 (4), pp. 433–465. DOI: 10.1080/026999397379872.