

Cognitive-Affective State (CAS), an Ecological Component of Executive Function, Explains Variance between CAT scores and GCSE Grade Predictions

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<http://heeducation.webeden.co.uk/#/research/4574561474> (checked 24.3.2012)

Abstract

This study reviews data collected from cohorts of yr 10 students in the UK, across four different, independent learning environments, to identify potential correlations between learner-environment state and academic performance. The data was collected between December 2012 and December 2013 at four UK secondary schools. 496 Yr 10 students took part and more than 2,500 subject lesson assessments were made.

This study provides evidence that Footprints Rank, a measure of what we have titled in this study the learner's lesson-specific Cognitive-Affective State (CAS), correlates with a measure of general intelligence (g), CAT score. This supports the finding by Walker (2013) that Footprints Rank can be a measure of academic performance by measuring the adaptive cognition of a student to their learning environment. The study data also shows that this model of CAS explains variance in predicted GCSE grade that CAT scores cannot account for. On the basis of this, a model of the relationship between CAS and g is conceptualised and represented in a schematic diagram in which CAS describes the cognitive-affective state of the learner to their learning environment. CAS is conceived therefore as an ecological component of cognition.

A hypothesis called 'optimal CAS' is proposed whereby academic performance is influenced by both g and optimal CAS. Optimal and sub-optimal CAS have an influence on academic performance that explains variance within and in addition to CAT score.

Finally, a relationship between CAS and executive function (EF) is proposed, suggesting that CAS is an ecological sub-component of EF. CAS describes the management cognitive-affective state in response to the requirements of the learning environment.

Introduction: An ecological view of cognitive ability

Intrinsic models of learning emphasise the intrinsic cognitive ability of the learner. Traditional IQ models, for example, assume that a learner's cognitive ability (or general intelligence, *g*) can be measured in abstract and the resulting score will hold good for the learner whatever the context he is learning in.

More recently, the construct of executive function (EF) has been proposed to describe the relationship between *g* and the cognitive ability required to deal with *in situ* problems when handling novel situations (Banich 2009). EF is a generalised construct that sits over a range of elements that relate to the effective handling of novel situations (Miyake et al. 2000). These include events that involve planning or decision making; that involve error correction or troubleshooting; situations where responses are not well-rehearsed or contain novel sequences of actions; dangerous or technically difficult situations; situations that require the overcoming of a strong habitual response or resisting temptation. Growing evidence supports the conceptualisation that EF is a neurologically overlapping but distinct construct from *g* (Barbey et al. 2012; Brydges et al. 2012; Blair 2006; Bull, Scerif 2001; Burgess et al. 2006; Carlson et al. 2002; Crinella, Yu 1999; Lehto et al. 2003; Friedman et al. 2006; Gray et al. 2003; Blair 2006; Conway et al. 2003).

Assessing an adaptive component of Executive Function using the Footprints technology

Some authors have criticised current assessments used to measure executive function (EF). Burgess et al. (Burgess et al. 2006; Rabbitt 1997) argue that current EF tests are non-ecological in that they test for atomised characteristics in abstract rather than *in situ*. Ecological tests would take account of the environmental context of the behaviours, a recognition of the fact that EF is a construct which refers to agency *in situ*, the ability to respond to novel situations. They would also accept that psychological dimensions such as affective state, social role and personality should be incorporated into measures of EF.

Walker has developed an assessment (the Footprints assessment technology), which he claims may address some of these concerns, offering an ecological approach to testing some aspects of EF. The Footprints technology, described in the Method section, is an instrument developed on the basis of Walker's Human Ecology Theory. He regards learning as an interaction between the learner and the learning environment. Both the learner and the learning environment (constituted by peers, teacher, classroom etc) are active co-creating agents in the learning process (Walker 2009). The learner, therefore, cannot be studied in abstract or isolation; instead he must be looked at *in situ*, within the contexts in which he is learning (Walker 2013). The cognitive strategies that the learner deploys, refines and habituates must be understood as a situational response to the environmental opportunities and conditions within which he is engaged in learning. I deploy the term *Cognitive Affective State* to refer to this mental state that exists in the learner at any moment of interaction with their environment. Within this proposal, CAS is a responsive cognitive system by which the learner may adjust affective and cognitive state, upon receipt of an environmental cue, as a mode of environmental adaptation.

The Footprints technology provides an online assessment environment through which a learner simulates their interaction with their environment, within which CAS may be assessed.

Executive function, cognitive ability and academic achievement

This study seeks to extend our understanding of the relationships between Footprints scores, general intelligence as measured by a cognitive ability test (CAT) and academic achievement as measured by predicted grades in yr 10 students (aged 14-15).

General intelligence tests internationally show a strong correlation with academic achievement (Barber 2005). The CAT whilst not claiming to be a general intelligence test, claims an overall correlation with GCSE grades of 0.65 (GL Assessments 2012). Other environmental factors which determine variance between intelligence tests and GCSE grades include socio-economic

factors; family and domestic situation; life situations; quality of educational support; physical and mental health.

In this study these wider factors are controlled for. The cohort studied is a group of 60 yr 10 students from one school all of whom are eligible for free school meals. They represent a group from a similar socio-economic context and receive the same educational resource and teaching from the school. Our hypothesis is that this group will exhibit a higher degree of correlation between CAT score and predicted GCSE grades because these other factors have been controlled; therefore the influence of CAT score on GCSE grade will be greater because the overall variance will be reduced.

Outstanding variance between CAT scores and GCSE predicted grades may be largely attributed to within-school factors rather than between or outside school factors. If the Footprints technology measures the state of the learner in her various learning environments as claimed, one would expect Footprints scores to account for a significant proportion of the variance between CAT scores and GCSE predicted grades. We argue that the experimental design offers a reliable environment for assessing what additional proportion of variance can be explained by this technology which cannot be explained by CAT score.

Method

Data collection

The study involved one cohort of a 60 yr 10 students with CAT scores from school H. Three further yr 10 cohorts without CAT scores but with setting data, from schools B, E and M numbering 176, 121 and 55. All students undertook the Footprints assessments. Students undertook their baseline assessments within the context of an ICT session, and then a minimum of three further subject assessments including Maths, Science and English.

Assessment method

The Footprints assessment requires candidates to complete an online computer-based imagination exercise. The exercise involves a series of verbal instructions, listened to through headphones, which invite the candidate to imagine a space in their own imagination. See appendix for further explanation. The instructions enable the candidate to form the dimensions, shape, features and activities of a space they imagine in their mind. Having created their space, the candidate is then invited to score a set of multiple choice statements about their space. These answers give a baseline score against a model of a candidate's instinctive *Cognitive Affective State (CAS)*. Throughout the remainder of this paper, CAS refers to the model of CAS measured by the Footprints assessment.

Measuring student *imagined cognitive self-operation* in learning contexts

Having established the individual's baseline scores for *instinctive CAS*, the Footprints assessment instrument then leads the candidate through three sets of further enquiries about their space. Specifically, the candidate is invited to imagine, in turn, a particular learning context taking place within their space; for example, their maths lesson, or their science lesson.

The chosen learning context is one which the candidate experiences in reality within school. For example, if they are in maths set one in school, then in the Footprints imagination exercise, they imagine maths set one as the learning context within their space. The candidate is cued up by verbal cues to imagine how their space might be changed by each of the learning context taking place within their space and how their activity might change.

The candidate then scores a comparative set of statements to the first baseline statement which identifies how their instinctive CAS score modulates when participating in each learning

context in their imagined space. By this method, the Footprints assessments obtain four comparative sets of data about each candidate; their *instinctive CAS* as baseline and then their *situational CAS* when participating in three specific learning contexts.

Comparing situated student CAS with optimal CAS

Individual students were then ranked using the scoring of the *optimal CAS* model, as recorded in the Footprints Data Model. Walker 2013, 2014 c., describes the empirical and statistical development of this model which he has previously referred to as *ideal imagined cognitive self operation*. Each student was given a combined CAS Rank score for their engagement in three subjects of Maths, Science and English.

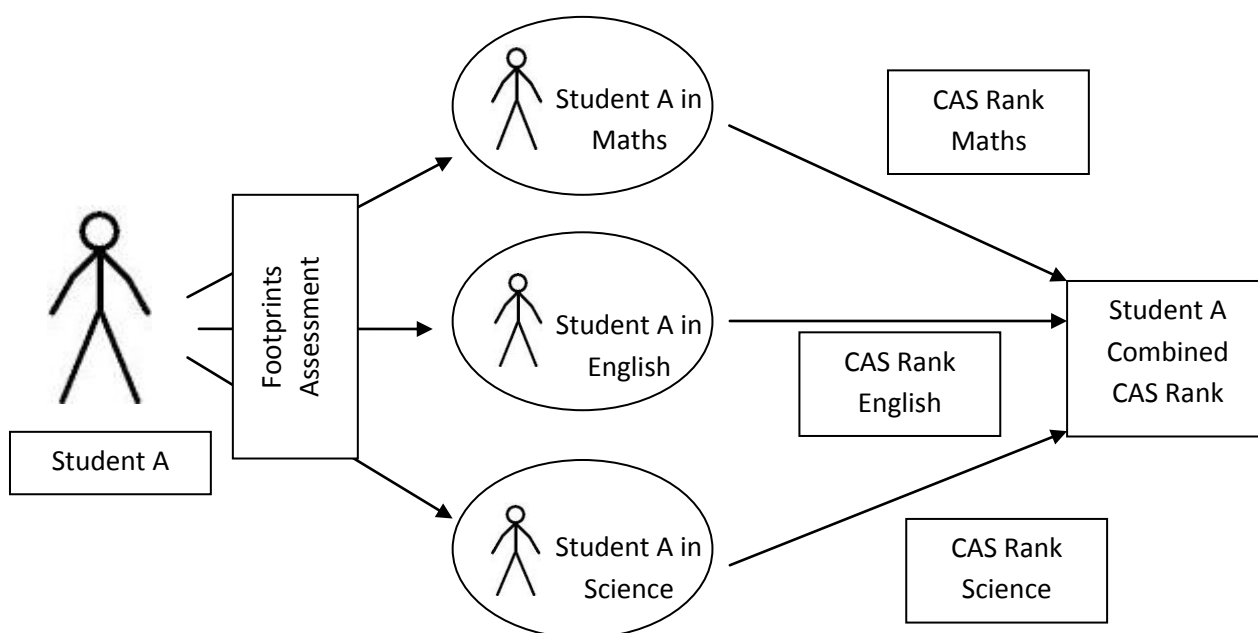


Figure 2 a. Schema of Combined CAS RANK generated from CAS Rank scores for Student A from Footprints assessments for Maths, English and Science

Data Model

The data model used in the study is composed of seven factors or elements involved in a model of cognition proposed by Walker (2009). The Footprints assessment looks at these seven factors which, Walker claims, provide one model of a student's Cognitive-Affective State (CAS).

The seven factors of data collected for each student in the Footprints assessment are:

1. *Trust of my self- how much I trust my own ideas, qualities and opinions in this lesson*
2. *Trust of others- how much I trust others' ideas, qualities and opinions in this lesson*
3. *Pace- how much pace, risk and change I like in this lesson*

4. *Disclosure- how willing am I share to share thoughts, ideas, opinions and questions in this lesson*
5. *Perspective- whether I see things from a detached or personal perspective in this lesson*
6. *Processing- whether I focus on making connections or following step by step in this lesson*
7. *Planning- whether I focus on the learning outcome or am open ended in this lesson*

Walker identifies these seven factors as forming two clusters:

Cluster one Learning posture (factors 1-4) which are social and emotional strategies:

1. *Trust of my self- how much I trust my own ideas, qualities and opinions in this lesson*
2. *Trust of other's- how much I trust other's ideas, qualities and opinions in this lesson*
3. *Pace- how much pace, risk and change I like in this lesson*
4. *Disclosure- how willing I am share to share thoughts, ideas, opinions and questions in this lesson*

Cluster Two Thinking strategy (5-7), which are cognitive strategies:

5. *Perspective- whether I see things from a detached or personal perspective in this lesson*
6. *Processing- whether I focus on making connections or following step by step in this lesson*
7. *Planning- whether I focus on the learning outcome or am open ended in this lesson*

CAS Rankings

Using the findings of Walker 2014 b, c rankings were ascribed to factors 5,6 and 7, showing relative ranking scores in Maths, Science and English lessons for exhibited combinations of scores for factors 5,6 and 7 (Figure 1.).

	Combinations of factors 1 and 2		
Ranking	Maths	Sciences	English
4	QsTo	QsTo	TsQo
3	QsQo	QsQo	TsTo
2	TsTo	TsTo	QsQo
1	TsQo	TsQo	QsTo

Legend

Factor 1 Trust in Self Ts= high trust in self Qs= low trust in self
 Factor 2 Trust in Others To= high trust in others Qo = low trust in others

Figure 1.

Using the findings of Walker 2013 rankings were ascribed to factors 5,6 and 7, showing relative ranking scores in Maths, Science and English lessons for exhibited combinations of scores for factors 5,6 and 7 (Figure 2.).

	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 2.

Factors 3 and 4 were not included in the CAS Ranking model because the significance of their role has not been clearly correlated with set or cognitive ability in any study.

Inter-lesson CAS Rank scores

A total inter-lesson CAS Rank score was given to each student, representing the addition of their individual lesson CAS rank scores in their English, Science and Maths lessons. This resulted in a student's inter-lesson CAS score of 5 being the lowest potential score and a CAS Rank of 20 being the highest potential CAS Rank score. CAS Rank is therefore seen as the measure of the optimality of a student's adjustment of CAS to the subject lessons they are engaged in.

Grade Ranking

Finally, students were given a predicted Grade Ranking for their total predicted grades in Maths, Science and English. In schools B and E Grade Ranking was no available. The alternative factor of Set was used as a measure of academic achievement.

Predicted GCSE grade	Ranking score
A	1
B	2
C	3
D	4
E,F,G	5

Figure 3. Predicted GCSE grades and Grade Rankings scores assigned in Maths, Science and English

A total Grade Rank score was given to each student for Maths, Science and English grade predictions, 3 being the lowest potential Grade Rank, and 15 being the highest Grade Rank score.

Analyses were performed using PSPP. Multiple regression analyses were performed to test for the relationship between CAT, Grade Rank and CAS Rank. Exploratory factor analysis was used to identify loading onto identified factors. Variance between inter-school CAS ranks was compared to identify what influence school environment had on CAS Rank.

Results

CAT score, CAS Rank and Grade Rank table at school H

Of the population of n. 60 students at school H, 5 students did not have valid grade predictions. A further 11 students had complex Footprints scores where the student scored equally for three or more of the CAS ranking combinations in more than one subject. I chose to discard this data as it was difficult to assign an overall CAS Rank to such scores with any degree of confidence. In addition, two students were twins and were removed from the study because they did not meet the same criteria of standardisation of external school factors as the wider cohort. These decisions reduced total ranked students to n 37.

Student	CAT	CAS Rank	Grade Rank
1.	75	9	13
2.	76	7	16
3.	77	7	13
4.	78	7	12
5.	78	12	10
6.	79	13	11
7.	79	7	10
8.	79	8	14
9.	79	11	9
10.	79	10	9
11.	80	10	14
12.	80	5	6
13.	82	7	9
14.	82	6	11
15.	82	6	11
16.	82	9	8
17.	84	8	8
18.	86	8	9
19.	88	9	11
20.	89	8	14
21.	90	8	11
22.	90	7	11
23.	91	7	10
24.	94	8	8
25.	95	6	8
26.	96	8	9
27.	97	8	9
28.	98	7	9
29.	102	11	7
30.	102	9	8
31.	106	7	8
32.	106	10	9
33.	107	10	8
34.	107	15	7
35.	107	13	4
36.	109	8	9
37.	112	15	3

Figure 4. Student scores for CAT, CAS Ranking and Grade Ranking

Correlation between CAT score, CAS Rank and Grade Rank

PSPP was used to perform multiple rank correlations. A strong correlation (0.6451) between CAT score and Grade Rank at school H was measured. A correlation of 0.6654 was measured when the CAS Rank was added to the CAT score indicating that CAT score + CAS rank gives a slightly stronger indicator of GCSE grade than CAT score alone.

A significant correlation of 0.3997 was measured between the CAS rank and Grade Rank at school H confirming that CAS rank correlates with grade rank. This compared to a slightly lower but still significant correlation of 0.3610 between CAS rank and CAT score.

Analysis of Variance between CAT score and CAS rank

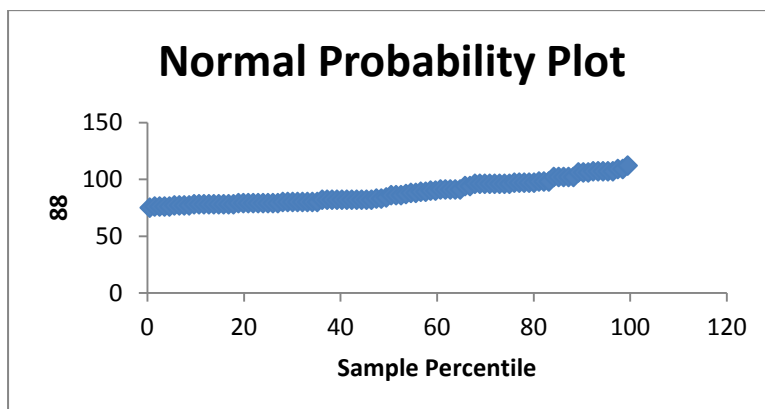
The CAS Ranking scores were then correlated against CAT score. CAT score is a categorical independent variable and CAS Ranking score is a categorical dependent variable; there are more than two levels of the independent variable, thus the appropriate analysis is the one way analysis of variance.

The relationship between CAT score and CAS Rank differed significantly $F(1, 96) = 13102$, $p = 0.0297$

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>			
Regression	1	502.049	502.049	4.871914	0.02968			
Residual	96	9892.767	103.0497					
Total	97	10394.82						

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	93.18433	2.436399	38.24674	6.58E-60	88.34812	98.02055	88.34812	98.02055
1	-2.84562	1.289221	-2.20724	0.02968	-5.40471	-0.28654	-5.40471	-0.28654

A regression analysis was performed to confirm the relationship of CAT score and CAS Rank $F(1,96) = 4.87$, significance $F = 0.02968$. The slope is significantly non-zero, indicating that there is probably a relationship between CAS Rank and CAT score.



Analysis of Variance between CAS rank vs Grade rank at school H

A one-way ANOVA was used to test for the relationship between CAS Rank and Grade Rank in school H. Grade Rank is a categorical independent variable and CAS Ranking score is a categorical dependent variable; there are more than two levels of the independent variable, thus the appropriate analysis is the one way analysis of variance.

The relationship between CAS Rank and Grade Rank differed significantly $F(1, 34) = 6.679, p = 0.0142$

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>			
Regression	1	34.64751	34.64751	6.689373	0.014154			
Residual	34	176.1025	5.179485					
Total	35	210.75						
	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	12.29009	1.420329	8.652993	4.13E-10	9.403639	15.17655	9.403639	15.17655
13	-0.37156	0.143658	-2.58638	0.014154	-0.6635	-0.07961	-0.6635	-0.07961

A regression analysis was performed to confirm the relationship between CAS Rank and Grade Rank, $F(1,96) = 6.689$, significance $F = 0.01412$. The slope is significantly non-zero, indicating that there is probably a relationship between CAS Rank and Grade Rank.

Analysis of Variance between CAS Rank and Set in school M

A one-way ANOVA was used to test for the relationship between CAS Rank and Set in school M. Set categorical independent variable and CAS Ranking score is a categorical dependent variable; there are more than two levels of the independent variable, thus the appropriate analysis is the one way analysis of variance.

The relationship between CAS Rank and Grade Rank differed significantly $F(1, 56) = 8.145, p = 0.0061$

	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>			
Regression	1	9.810609	9.810609	8.144521	0.006113			
Residual	54	65.04653	1.204565					
Total	55	74.85714						
	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	0.706286	0.596767	1.183519	0.241787	-0.49016	1.902732	-0.49016	1.902732
3	0.733003	0.256846	2.853861	0.006113	0.218058	1.247949	0.218058	1.247949

Factor Analysis of CAT score, CAS Rank 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 of CAT score and CAS Rank in Grade Rank predictions in schools M and H.

Variance between CAT score and Grade Rank in school H

Factor analysis confirmed that 97% of the variance between the two variables of Grade Rank and CAT score could be accounted by one factor. Variable 1 (CAT score) and Variable 2 (Grade Rank) loaded heavily onto this factor indicating that CAT score accounted for a high proportion of Grade Rank in school H, but also that there was a common element to both.

<u>Factor</u>	<u>Total</u>	<u>% of total variance</u>
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 CAS Rank and Grade Rank in school H

Factor analysis confirmed that 70% of the variance between the two variables of Grade Rank and CAS Rank could be accounted by one factor and 29% by a second factor. CAS Rank loaded heavily onto factor one (1.55). Grade Rank also loaded onto factor one (1.15) indicating that CAS Rank accounted for a significant proportion of Grade Rank in school H.

<u>Factor</u>	<u>Total</u>	<u>% of total variance</u>
1	8.99	70.27
2	3.80	29.73
<u>Rotated Factor Matrix</u>		<u>Factor 1</u>
Loading of CAS Rank		1.55
Loading of Grade Rank		1.15

Variance between CAT score, CAS Rank and Grade Rank in school H

Factor analysis finally confirmed that 98% of the variance between the three variables of CAT score, Grade Rank and CAS Rank could be accounted by two factors. Factor 1 accounted for 88% of overall variance, factor 2 for 9% of variance.

Variable 1 (CAT score) loaded heavily onto factor 1 but not onto factor 2. Variable 2 (CAS Rank) loaded heavily onto factor 2 (1.97) with Variable 3 also loading onto factor 2 (1.24) indicating that CAS Rank accounted for 9% of Grade Rank in school H.

<u>Factor</u>	<u>Total</u>	<u>Rotation % of total variance</u>
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 CAS Rank		-1.77	1.24

Overall school factors may suppress an individual's CAS Rank scores

Analysis of Variance between CAS Rank and Set at schools B and E

A one-way ANOVA was used to test for the relationship between CAS Rank and Set in schools B and E. Set categorical independent variable and CAS Ranking score is a categorical dependent variable; there are more than two levels of the independent variable, thus the appropriate analysis is the one way analysis of variance.

The relationship between CAS Rank and Grade Rank differed significantly $F(1, 153) = 1.958, p = 0.1655$. The relationship between CAS Rank and Set did not differ significantly indicating there is probably not a relationship between CAS Rank and Set at schools B and E.

ANOVA					
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>
Regression	1	7.21829	7.21829	1.958628	0.165526
Residual	153	294.8305	3.685381		
Total	154	302.0488			

	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	12.72212	0.413831	30.74233	4.56E-46	11.89857	13.54567	11.89857	13.54567
X Variable 1	0.143109	0.102257	1.39951	0.165526	-0.06039	0.346607	-0.06039	0.346607

The variance in CAS scores in Maths, Science and English for factors 1,2,5,6 and 7 across yr 10 cohorts was measured in all schools (Figure 5.).

	Factors				
School	1. Trust of own	2. Trust of others'	5. Perspective	6. Processing	7. Planning
B	2.381710076	2.381710076	1.831910477	2.381710076	2.381710076
E	2.269772088	2.269772088	2.118256575	2.269772088	2.269772088
M	2.434070803	3.36460499	2.924944595	1.945600599	2.767648307
H	2.68798987	3.820562646	2.082040292	2.664719901	2.461684021

Figure 5. showing the variances in schools B, E, M and H for CAS factors: Perspective, Processing, Planning, Trust of own ideas, Trust of others' ideas

In schools B and E the variance showed remarkable consistency between the five factors (0.0292). In schools M and H (combined as a group M,H) the variance differed between the five factors (0.3144). In comparing the variance of the two groups using a one-tailed t-test, $F(10.769)$ is greater than F Critical one-tail (3.179) therefore the variance between the populations of B,E and H,M is different.

In comparing the variance of the two groups, $F(10.769)$ is greater than F Critical one-tail (3.179) therefore the variance between the populations of B,E and H,M is different.

A comparison between the means of the five factors in schools B, E compared schools M, H shows that B, E (mean = 2.255) is lower than M, H (mean = 2.715). These outcomes together suggest that the CAS scores of the cohort of yr 10 students in schools B and M are determined by individual or inter-class factors, whilst in schools B and E CAS scores are determined by school-wide factors which suppress the variances of the individuals or class sets.

This result offers an ecological explanation for the non-significant correlation between Set and CAS Rank in schools B and E, in contrast to the significant correlation between Set/Grade Prediction and CAS Rank in schools H and M. Individual students would not be expected to exhibit a correlation between Set and CAS Rank in a school in which CAS Rank was principally determined by overall school factors.

These findings are discussed in greater detail by Walker in a further paper (2014b.)

Discussion

These results indicate that both cognitive ability as measured by CAT and CAS Rank contribute significantly to GCSE grade prediction in yr 10 students in school H.

Correlation data from this study suggests CAS Rank 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 in school H that cannot be assigned to CAT is 9%. In addition CAS Rank contributes to the 88% that can be assigned to CAT, indicated by the high factor loading of CAS Rank onto the factor onto which CAT score very largely loads.

The factor analysis of CAS Rank and Grade Rank indicates that a single factor accounts for 70% of the variance between the two, and that CAS Rank loads more heavily onto this one factor than Grade Rank.

From these results we can suggest that whilst CAS Rank contributes to CAT score, CAT score does appear to not contribute significantly to the distinctive factor of CAS Rank. CAS Rank is an ecological factor which correlates identifies a component of Grade prediction missing from the non-ecological CAT score which is to do with the learner-learning environment interaction.

Ecological and non-ecological measures

CAS Rank and CAT appear to be measuring overlapping but different factors that are involved in the prediction of academic achievement. The CAT test does not claim to be a test of general intelligence (I_g or g) test (GL Assessments 2012) but does measure constructs regarded as components of g; verbal, quantitative and nonverbal, as well as an element of spatial, ability. In a 5 year longitudinal study Deary, Strand et al. (2007) found an overall correlation of 0.69 between GCSE grades with CAT2s' factor for g.

Multiple environmental factors have been shown to affect the relationship between a child's score for g and their GCSE grades. These may include parenting, school environment, quality of teaching, socio-economic factors, health and wellbeing. In this study some of these environmental factors were controlled for by the experimental design. The cohort was drawn from the same school; school and teaching are therefore controlled for. In addition, this group were drawn from a similar lower socio-economic group as measured by their receipt of additional government support called pupil premium funding. One would therefore expect a higher correlation between CAT score and predicted grade with these variables controlled for.

However, this study suggests that a proportion of the variance in predicted student grade could not be accounted for by CAT but can be accounted for by CAS Rank. CAS Rank is an ecological measure of cognitive and social components of metacognition. It assesses the interactivity between the candidate and their immediate learning environment in relation to seven boundary factors identified in the Data Model. The score against these seven boundary factors constitutes what Walker calls the 'state' that the candidate is in when engaged in that learning environment. A candidate's CAS Rank is a measure of their ability to alter their 'Cognitive–Affective State', in terms of these seven factors, when engaging across a range of learning environments.

CAS therefore, can be conceptualised as representing the internal-external cognitive/affective interaction between the learner and their environment. A schema can describe the postulated relationship between CAS and g and the internal learning processes of the learner (i.e. their cognitive-affective state) and the external learning environment (i.e. the context in which the learner is engaging in the subject) (Figure 6.)

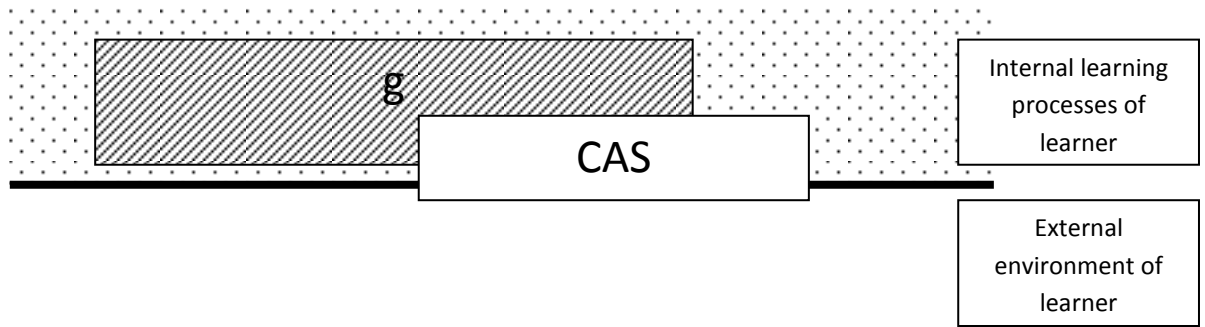


Figure 6. Schema of relationship between CAS, g and the internal processes and external environment of the learner

This study has shown that CAS is a dynamic cognitive-affective state which is potentiated to respond to the external environment. Shifts in CAS represent changes in cognitive-affective state as the learner engages in different learning environments. From this we can extend our schema to incorporate the sensory feedback loop which must exist between CAS and the external environment (Figures 7.)

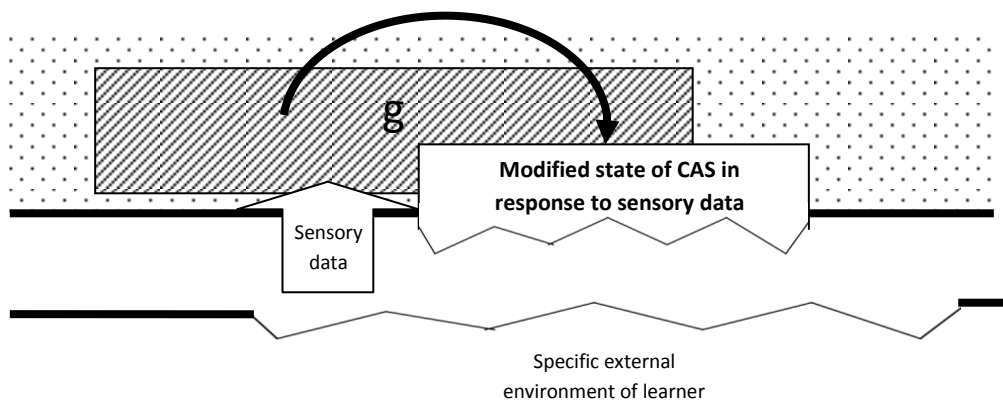


Figure 7. Schema of postulated feedback loop between CAS, g and the external environment of the learner

Sensory data from the external environment is detected by the learner. This is processed, we propose via *g*, a non-ecological construct of intelligence, via an interaction with the ecological function of cognitive-affective state, which we are here calling CAS, in order for the learner to respond to the learning environment.

In response to the data from *g*, the state of CAS may alter in order for the learner to adjust to the cognitive-affective requirement of the learning environment which has been detected.

Optimal CAS

Results from this study support the notion of **optimal CAS**. Optimal CAS is the cognitive-affective state of *F* which is optimally attuned or adjusted to the environmental task.

Evidence for this is obtained from the CAS Ranking scores. The CAS Ranking scores capture the patterns of adjustment in CAS made by individual learners when engaging in different subject lessons; the patterns are then ranked against pre-determined optimal patterns (Walker 2013a.) to give the CAS Ranking scores. This study shows that CAS Rankings correlate both with CAT score, as a

measure of g , and also with GCSE grade predictions but explain a component of GCSE grade prediction not explained by CAT score. The CAS Ranking score then, must be attributed to the internal-external attunement which we are calling CAS.

We can conceive of **Optimal/ Sub-optimal CAS** as follows:

Optimal CAS is the cognitive-affective state of CAS which is optimally attuned or adjusted to the environmental task.

Sub-optimal CAS is contrasted with sub-optimal CAS, in which the cognitive-affective state of CAS is non-optimally attuned to the environmental learning task (see Figures 8 and 9.)

Whilst optimal CAS correlates with high grade prediction, sub-optimal CAS correlates with low grade prediction. G remains the dominant predictor of the ability of the learner to learn from their environment but optimal / sub-optimal CAS has a secondary impact on academic performance which sits over the top of g .

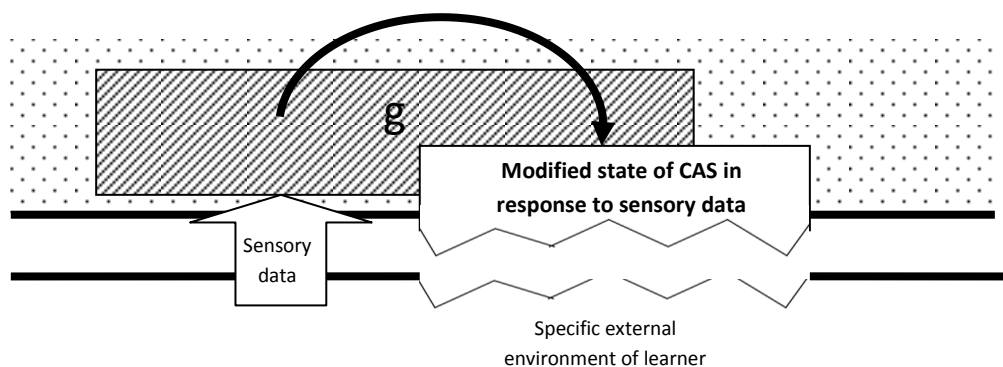


Figure 8. Optimal CAS is a cognitive-affective state in which CAS is adjusted, or attuned, to fit the demands on the learning environment at hand.

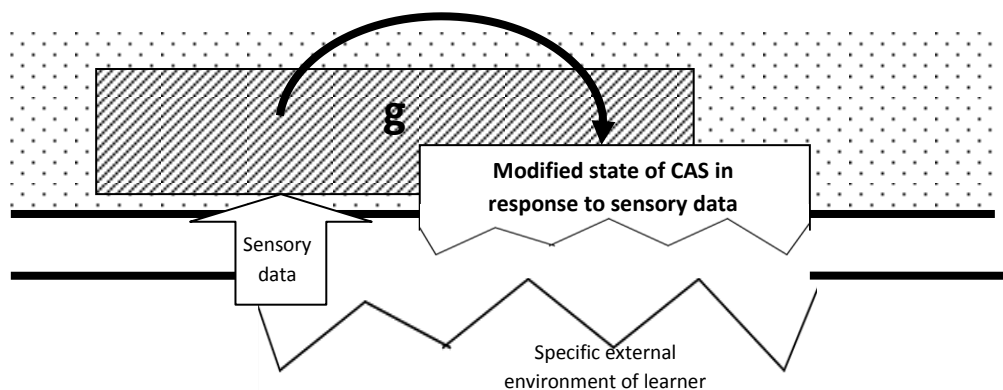


Figure 9. Sub-optimal CAS is a cognitive-affective state in which CAS is maladjusted, or mis-attuned, to the demands on the learning environment at hand.

Walker (2014b) discusses the influence of ecological factors on optimal CAS. He suggests that the optimal CAS model may not be conformed to in some schools environments. If CAS is an ecological function of EF then it may be influenced and potentially constrained by overall school culture.

For example, a school with a strong, uniform culture toward behaviour, teaching and learning imposed across all subjects Maths, Science and English may suppress subject-specific ecological learning features. If this were to be the case, it may impede or inhibit individuals adjusting their CAS scores to the optimal CAS model which identifies optimal subject-specific factor scores to compose an overall optimal CAS.

CAS and Executive Function

The function of CAS, then, can be conceived as an internal-external cognitive-affective tuning system by which the individual adjusts, shifts, regulates and directs attention and behaviour toward their environment.

Walker has previously cited evidence (2013) that less academically successful students fail because their cognitive-affective attunement is either inaccurate or inflexible. Inflexible students fail because they do not adjust their cognitive-affective state of CAS at all in different learning contexts. These students appear to lack contextual awareness and the cognitive flexibility. Other students, do adjust CAS but their attunement is inaccurate. In other words, they adopt a sub-optimal state of CAS for the learning contexts.

Metacognitive ability is regarded as closely related to the multi-component construct of Executive Function (EF) (Halloran 2011; Miyake et al. 2000; Fernandez-Duque et al. 2000). This study provides evidence that the ability to attune cognitive-affective state (CAS) to the immediate learning environment does correlate with academic performance as measured by grade prediction. Moreover, it explains a component of academic performance which is not explained by a measure of g (CAT score). Miyake and Friedman's theory proposes that there are three aspects of executive function: updating, inhibition, and shifting (Miyake, Friedman et al. 2000) 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). Walker (2014) has shown evidence that the ability to shift one's state of trust of one's self and of others in relation to the learning environment and, thereby learning task, correlates with one measure of cognitive ability. 'Adaptive state' of 'trust of self-others' correlates with higher CAT score.

In this study I identify five further constructs I propose influence the 'adaptive state' of the learner to their environment and provide evidence that the ability to adapt the state of one's CAS for the learning task in hand is a function of academic performance. The study supports a contribution of CAS toward EF, describing CAS as a dynamic cognitive-affective interface between the learner and their environment; the ability of the learner to interact with, adjust to and interpret and learn from environments in which they are placed.

CAS can be conceptualised as a subset of EF which is responsible for guiding the cognitive-affective engagement of the learner to their environment. CAS is responsible for the action of the learner, their agency toward the environment which can be seen as an embodied rather than merely cerebral posture (Figure 10.) The Miyake and Friedman model of executive function of updating, inhibition and shifting provides a consonant framework for understanding that conceiving of the relationship between g, CAS and the environment.

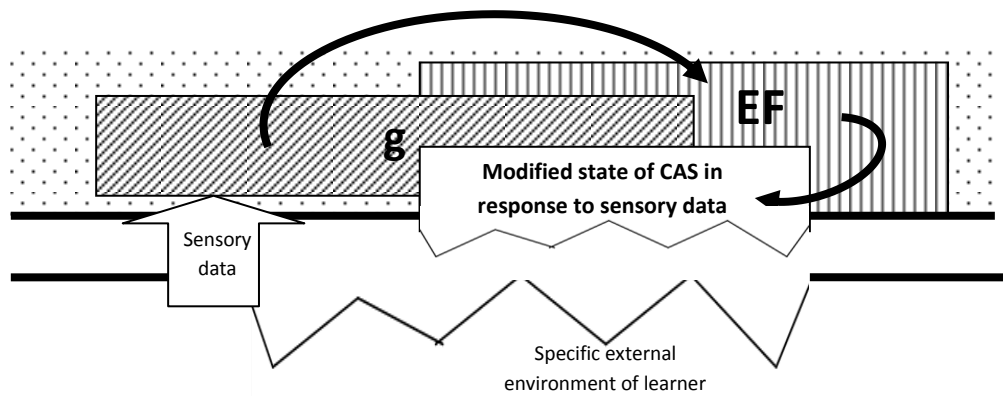


Figure 10. A postulated schema for the relationship between g, EF and CAS in guiding the cognitive-affective engagement of the learner to their environment

Conclusions

This study provides evidence that CAS Rank (CAS) in yr 10 students correlates with a measure of general intelligence (g), CAT score. This supports the finding by Walker (2013) that CAS Rank can be a measure of academic performance by measuring the adaptive cognition of a student to their learning environment.

In addition, in this study data shows that CAS explains variance in predicted GCSE grade that CAT scores cannot account for. On the basis of this, a model of the relationship between CAS and g is conceptualised and represented in a schematic diagram in which F describes the cognitive-affective state of the learner to their learning environment. CAS is conceived therefore as an ecological measure of cognition.

To explain this result a hypothesis is described whereby academic performance is influenced by both g and optimal CAS. Optimal CAS is attained when a student adjusts their cognitive-affective to ideal operation in Maths, Science and English. Sub-optimal CAS is attained when a student mal-adjusts their cognitive-affective state to the ideal operation in for those subjects. Optimal and sub-optimal CAS have an influence on academic performance that explains variance within and in addition to CAT score.

Finally, a relationship between CAS and executive function (EF) is proposed, suggesting that CAS is an ecological sub-component of EF. CAS describes the management cognitive-affective state in response to the requirements of the learning environment. This ecological proposal is supported by study data that evidences how a learning environment may suppress student adaptation of CAS. The study raises further questions around the relationship between CAS and EF and the ecological nature of CAS.

This was a relatively small study involving 496 participants. Conclusions were drawn from smaller cohorts after confounding effects were eliminated (n=245). In addition CAT score was measured in one of the cohorts of schools rather than all four whilst 'set' was used as a surrogate in the other three. Future studies should enlarge the sample cohort and ensure greater consistency of measure of academic performance.

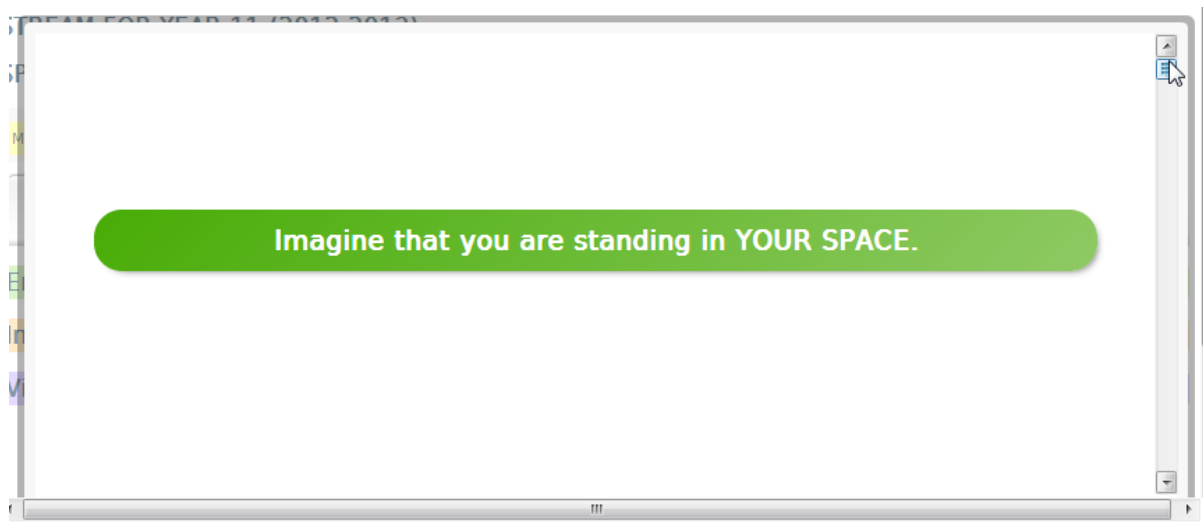
Disclaimer

The author acknowledges a conflict of interest through a commercial relationship with the manufacturers of the Footprints Assessment.

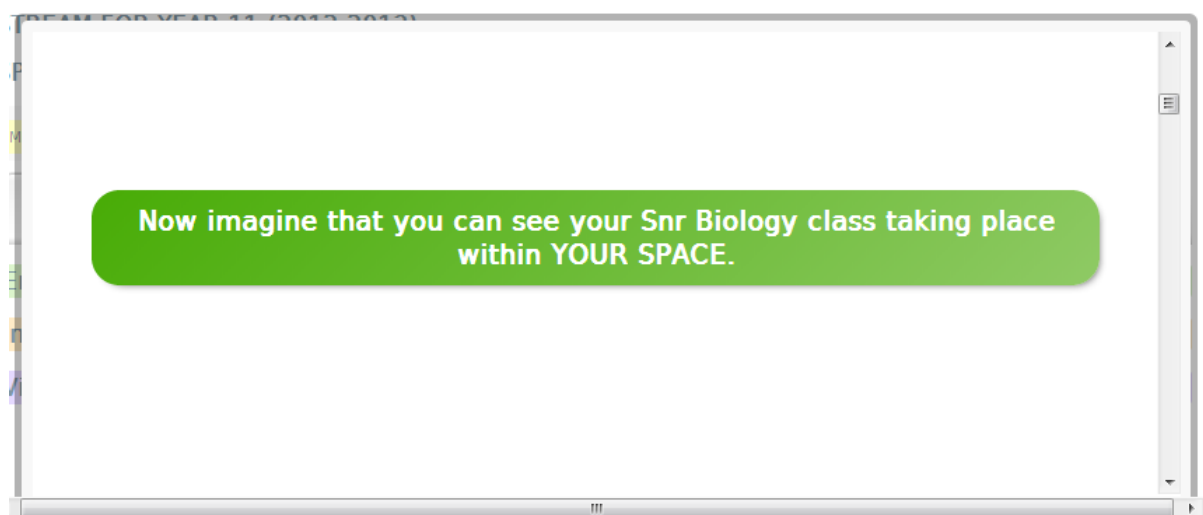
Appendix

The Footprints Technology: Measuring imagined cognitive self-operation

The Footprints assessment is a derivation of a projective test called the Personal Ecology Profile (Walker 2009). The psychological process involves triggering the imagination of the candidate to create a 'space' which they want to call their own through a series of neutral cues. The clean language of the assessment is important to allow the candidate to project their own, independent meaning and shape onto the cues.



Further verbal cues develop the imagined focus of the candidate on their previously created space, their imagined self-perception and self-operations



Further verbal cues then develop and explore the candidates' imagined self-perception and operation with the learning context present. A series of 28 statements then appear and are scored by the candidate. These relate to seven factors stated in the data model.

Has YOUR SPACE been changed by having the Snr Biology class in it?

Definitely not No Not really Maybe Yes Definitely

[Empty box]

Data Model

This study used Walker's conceptual model of Human Ecology Theory (Walker 2009) to define the cognitive self-operation. In the Footprints assessment four items score each factor. Each item is scored on a six point Likert scale as above. This results in twenty eight items measuring *cognitive self-operation* within a single learning environment.

The multiple learning contexts assessed therefore multiplies the number of times each item is scored.

A sample of three of the items is given below.

- *Do you need to know what is going to happen in YOUR SPACE when the keyword is with you?*
- *Does it help your learning in keyword when you can relate it to your own life?*
- *You need to make something in YOUR SPACE. Do you get lots of ideas popping into your head as you go along?*

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Centre for Human Ecology Theory, UK

www.humanecology.webeden.co.uk

The Centre for Human Ecology Theory was launched in 2013 and aims to develop insight into human behaviour using Walker's Human Ecology Theory as its major tool through its research projects. The Centre aims to bring together a community of practitioners from around the world committed to developing understanding of human behaviour and how to engender more humane, sustainable living through application of these ideas.

Walker's Human Ecology Theory was developed over a decade, from 2000-2010, by the author through his work initially carried out whilst doing postgraduate studies at Oxford University in the UK. Encompassing areas of human behaviour from personality theory, through to leadership, organisational dynamics, teaching and learning, coaching and market cycles, Walker's Human Ecology Theory claims to be a comprehensive human systems paradigm.

Resume of the researcher: Simon P Walker

Simon Walker taught at Wycliffe Hall, Oxford University between 2002-2009. He worked as a consultant to the corporate world from 2002 and founded in 2004 The Leadership Community, an alumni of graduates from his Undefended Leader course that grew to around five hundred over the next five years.

In 2011 he announced a refocus on the area of education and schools, with a commitment to develop a curriculum for social, emotional and cognitive development. Walker co-authored with Jo Walker, also his wife, the Footprints schools programme, a version of the Human Ecology Approach for children. He became a Coach in Residence at Monkton Combe School in 2012.

Walker is the author of several ideas about human behaviour including a distinctive theory which he calls 'Human Ecology Theory', described in a monograph 'A Brief Introduction To The Theory of Human Ecology.'

From his Human Ecology Theory Walker has developed a number of other ideas in the areas of leadership, learning and coaching. He published the idea of 'undefended leadership' in a trilogy of books launched at the Oxford Literary Festival. His ideas have had an influence on writers in the area of Christian leadership (MODEM) school leadership (Seldon) and power in leadership (Preece).

Walker has also set out a basis for being 'undefended' upon Christian spirituality which he calls the Undefended Life and has taught the principles of Undefended Life in Africa, Norway, India and Australia. This has stimulated numerous responses from other commentators in the church.

Over the years, Walker has developed and commercialised several proprietary psychological technologies and instruments to analyse and develop people using a Human Ecology Approach. These including the Personal Ecology Profile, Leadership Signatures, Footprints Assessments and Coaching Signatures. He has collaborated with Meredith Belbin on several projects.

Prior to his wider adult education career, Walker was ordained as an Anglican vicar in 1997 and served his curacy in Abingdon, Oxfordshire. He has bachelor degrees in Biology and Theology from Oxford, an MPhil in Applied Theology from Oxford. He has just submitted his DProf by Public Works at Winchester University in 2014, a review of his contribution to the adult education between 1997-2014. He is an accredited member of The Association of Executive Coaching and Supervision.

References at <http://humanecology.webeden.co.uk/#/who-is-simon-p-Walker/4575814295>