Broadening the Construct of Cognitive Flexibility and its Relevance to Academic Achievement and Creativity

Tong, K.¹, Uchiyama, R.², Fu, X.¹, Hoo, N.P.¹, Lee, K. M.¹, Robbins, T. W.³, Sahakian, B. J.³, Kourtzi, Z. ³, Chen, S. H. A. ¹, Leong, V.¹,³, and the CLIC Consortium¹

Summary

A broad battery of tests of cognitive flexibility (CF) was administered to a large young adult population, together with tests of working memory, inhibitory control, and verbal fluency to evaluate the construct of CF. Factor analysis confirmed the CF factor, although the extracted factor could not accommodate a test of probabilistic reversal learning. CF was predictive of a measure of verbal creativity based on semantic network analysis and was also associated with an academic index of reading (but not maths) attainment. These findings suggest that a broader application of the CF construct may encourage a renewed focus on CF training for educational purposes.

CF tasks in CLIC Phase 1 Studies

Trail Making Test (TMT): Expected switching between given rules

Task Set Switching (TSS): Random cued switching between given rules

Wisconsin Card Sort Task (WCST): Learn the rules and decide when to switch to a new rule from deterministic feedback

Probabilistic Reversal Learning (PRL): Learn the rules and decide when to switch to a new rule from probabilistic feedback

“Unity-and-Diversity” EF models

Fig 2. With the broadened CF construct, the CLIC Phase 1 adult data supported the “Unity-and-Diversity” EF conceptualization (Miyake et al., 2000). The three-factor EF model (upper) and “Bifactor” EF model (lower) outperformed the Unitary EF model and independent factors EF model (see Supplementary Materials). Solid lines and bold indices indicate significant relationships, dashed lines indicate insignificant relationships.

CF’s relationship with outcomes of interest

Fig 3. After controlling for intelligence, CF is a significant predictor of Reading scores, but not Maths scores. Solid lines and bold indices indicate significant relationships, dashed lines indicate insignificant relationships.

Fig 4. Visualization of group-level semantic networks for the high- and low-CF subsets. Each node represents an animal name, and each connection represents an association between two animal names. The network of the high cognitive flexibility group exhibits greater connectivity (shorter average shortest path length, ASPL) and network flexibility (lower modularity).

Key references


Author affiliations: 1. Nanyang Technological University, 2. University of Tübingen, 3. University of Cambridge. The CLIC Phase 1 Consortium member list is available in Tong et al. (2023). https://doi.org/10.1371/journal.pone.0286208.

Contact: Ke Tong (ke.tong@ntu.edu.sg)

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Assessing the Relationship between Creativity and Cognitive Flexibility in Infants
Hoo, N. P., Fu, X., Teo, L. Z., Leong, V., and the CLIC Consortium

What is Creativity?
Creativity is our ability to generate **new, original, and meaningful** ideas that are valuable in the current context.

- **DIVERGENT** thinking: combining information in new ways to generate many different ideas (i.e., thinking outside the box)
- **CONVERGENT** thinking: organising disparate ideas logically to formulate one novel and effective solution

Creativity Tasks

**UNUSUAL BOX TEST**
- Coming up with original and unique ways to interact with the box

**MUSIC PLAY**
- Expressing creativity through movement

**OBJECT PLAY**
- Expressing creativity through actions performed with the toy

**EXPLORATORY PLAY**
- Creative exploration within a physical environment

Cognitive Flexibility Task

**ATTENTION SET SHIFTING TASK**
- Assesses the infant’s ability to shift their attention from a highly salient dimensional property (shape) of the object to a less salient (compressibility) one

How do we measure Creativity?

**Fluency**: Number of novel ideas generated in a given period of time

- Here is an example of the fluency scoring sheet for UBT:

<table>
<thead>
<tr>
<th>Action</th>
<th>Fluency</th>
<th>Originality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Film</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Book</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Stick</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Ball</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Pen</td>
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<td>Sheet</td>
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<td>2</td>
</tr>
<tr>
<td>Pencil</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

- **Fluency score**: 19

**Originality**: Relative novelty of the generated ideas (weighted against the scores of the sample)

- The more unique the action performed, the higher the score, vice versa

Correlation Between Creativity and Shifting Performance

**Creativity is Positively Associated with Cognitive Flexibility**

- Mental flexibility is our ability to shift and adapt to new situations. During childhood, our social environment helps us to develop flexible thinking, which fosters creativity (Arán Filippetti & Krumm, 2020).
- Mental flexibility helps us break out of routines and habits that are no longer beneficial and become open to new opportunities in the environment that lead to creative changes.

**Key references**


**Contact**: clicbaby@ntu.edu.sg

1 Nanyang Technological University
2 University of Cambridge

"This research project is funded by the National Research Foundation (NRF) Singapore under its Campus for Research Excellence and Technological Enterprise (CREATE) programme."
Cognitive Flexibility in Adolescents
Fischer, N.L.¹, Fu, W.L.¹, Ting, G.O.S.¹, Tripathi, S.¹, Ellefson, M.², Hung, W.L.D.³, Seow, P.³, Teo, C.L.³, and the CLIC Consortium

Introduction

What is Cognitive Flexibility?
Cognitive Flexibility (CF) refers to the ability to shift between different tasks or thoughts and adapt to changing circumstances. CF is one of the main executive functions that helps us to optimise goal-directed behaviors in different situations.

How to measure CF?
At the Centre of Lifelong Learning and Individualised Cognition (CLIC) we measure CF with game-like cognitive tasks. We use different tasks to probe different aspects of CF such as:
- Responding to different rules
- Switching between concepts

Some tasks we use to measure cognitive flexibility:

- **Task Set Switching**
  - Based on the shape (circle or square), respond to either the letter or number on the screen.
  - Key measure: Switch cost
  - Switch Cost: Time loss from switching between paradigms

- **Wisconsin Card Sorting Task**
  - Sort the cards to the correct deck based on an unknown rule. The rule may change during the game.
  - Key measure: Number of perseverative errors
  - Perseverative Error: Errors made due to inability to switch after rule change

Our preliminary findings are:
- CF correlates significantly and positively with working memory, fluid intelligence performance on the Ravens Standard Progressive Matrices (RSPM), fluency in a divergent creative thinking task (alternate uses task – AUT), and stochastic performance in a probabilistic reversal learning (PRL) task. It does not correlate significantly with inhibitory skills;
- Hierarchical multiple regression analysis showed that the model that better explains CF variance in adolescents is the one that accounts for the adolescents’ performance in RSPM (i.e., fluid intelligence index) and adolescents’ stochastic performance in PRL.
- Mediation analysis showed that, in adolescents, CF has a direct effect on fluency performance in AUT (i.e., index of creativity), and this is not mediated by their performance neither in RSPM nor working memory tasks.

References

¹ Centre for Research and Development in Learning (CRADLE), Nanyang Technological University
² Faculty of Education, University of Cambridge
³ National Institute of Education (NIE), Nanyang Technological University

Contact: clic_school@ntu.edu.sg

*This research project is funded by the National Research Foundation (NRF) Singapore under its Campus for Research Excellence and Technological Enterprise (CREATE) programme.*
Singapore's social life is characterised by a diverse linguistic fabric. We here assess this rich linguistic environment (called "contextual multilingualism") and examine its association with perceived social support and tendency to cooperate.

METHODOLOGY
- The Contextual and Individual Linguistic Diversity Questionnaire (CILD-Q) captures an individual's contextually influenced linguistic experience and includes three subscales:
  - Multilingualism in Context (7 items)
  - Multilingualism in Practice (7 items)
  - Linguistic Diversity Promotion (6 items)

- Language entropy captures the day-to-day use of various languages in the individual and takes into account self-rated proficiency, extent of exposure, duration, and usage frequency of each language.
- High language entropy indicates a more balanced exposure to multiple languages.

REFERENCES

RELATIONSHIP BETWEEN MULTILINGUALISM AND SOCIAL FACTORS
- Multilingualism is positively correlated to tolerance of uncertainty and perceived social support.
- There is a significant indirect effect of contextual multilingualism on perceived social support via receptiveness to opposing views.
- However, this is a partial mediation model, suggesting that other factors may contribute to the relationship between contextual multilingualism and perceived social support.

RELATIONSHIP BETWEEN LANGUAGE ENTROPY AND COOPERATIVENESS
- Regression analysis used to test the effect of cooperativeness on language entropy in different communicative contexts.
- Cooperativeness negatively predicts language entropy when interacting with strangers.
- This suggests cooperative individuals tend to have a dominant usage of one language when interacting with strangers.

A second regression analysis used to test the effect of cooperativeness on exposure to different languages in different contexts.
- Interaction found between language (English vs. Singlish) and communicative context (Family vs. Strangers).
- This reveals that cooperative individuals tend to use/be exposed to English only when interacting with strangers.

This research project is funded by the National Research Foundation (NRF) Singapore under its Campus for Research Excellence and Technological Enterprise (CREATE) programme.
The increasingly volatile job markets require flexibility from the modern workforce. We examine how Cognitive Flexibility (CF) affects flexible career development & transition. We used both task-based (“objective”) and self-assessed (“subjective”) measurements of CF to examine its effect on aspects of career-related adaptability, efficacy, and behaviour of young Singaporean adults who have not yet entered the workforce.

Introduction

Why change jobs in 12 months?

- Higher pay, 45%
- Work-life balance, 35%
- Skill advancement, 34%
- Seek flexibility, 30%
- Seek novelty, 25%
- Culture / Value mismatch, 25%

*N = 4976 across 25 countries (Adecco, 2022)

Roles that are highly susceptible to automation by AI

- 81% Agriculture
- 94% Construction
- 96% Manufacturing
- 98% Service Delivery
- 98% Transportation

Image credit: Yahoo Finance

90% of Singaporeans ready for change care (Oracle, 2021)

Ready for a Career Change?
Sam, Y. L.¹, Tong, K.¹, Yap, H. S.¹, Chen, S. H. A.¹, Leong, V.¹², Kourtzi, Z.², Robbins, T. W.², Sahakian, B. J.², Hendriks, H.², Christopoulos, G.¹, and the CLIC Consortium

References

Are young Singaporeans ready for new (and nearly constant) career transitions?

- Adaptability: A vital psychosocial competency that influences how individuals cope with transitions and navigate challenges during career growth.

- Flexibility is crucial for developing adaptability and competencies in career decision-making. Individuals who demonstrate greater adaptability are better equipped to anticipate novel situations and proactively prepare for changes.

“Change is the law of life. And those who look only to the past or present are certain to miss the future.”
— John F Kennedy

“...lifelong learning will be key. Not just upskilling once and being done with it, but multiple times, to become more adaptable and resilient, well-equipped and confident to face the future.”
— Lawrence Wong

“A new type of thinking is essential if mankind is to survive and move toward higher levels”
— Albert Einstein

Contact: sa000100@e.ntu.edu.sg

1 Nanyang Technological University, Singapore
2 University of Cambridge, United Kingdom

"This research project is funded by the National Research Foundation (NRF) Singapore under its Campus for Research Excellence and Technological Enterprise (CREATE) programme."
Structure Learning is a task designed for participants to learn stochastically from seeking patterns in stimuli without explicit feedback. In CLIC Work Programme 0.2, we aim to evaluate the impacts of Structure Learning training in enhancing cognitive flexibility and its transferability to other cognitive abilities. A multi-modality approach was adopted, such that cognitive-behavioural, social and neuroimaging data were collected.

INTRODUCTION

Structure Learning Training and its Potential Impact on Cognitive Flexibility

Koo, E. W. S.1,2, Koo W. L.1,2, Shukla, D.1,2, Tan, J. Y. J.1,2, Ubani, M. B.1,2, Gulyas, B.1,2, Suckling, J.2,3, Chen, S. H. A.1,2, Kourtzi, Z.2,3, and the CLIC Consortium

RESULTS AND DISCUSSION

Key variables of Structure Learning

Performance index (PI) relative: Minimum overlap between participant responses’ distribution and symbol distribution within the sequence

Strategy Integral Curve Difference (ICD): Strategy index that places matching and maximizing on a continuous scale

Key variables of Structure Learning

Learning strategy classification by Sex

Sex

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Ethnicity

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Education level

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Age

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<td>35</td>
<td>6</td>
<td>8</td>
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</tbody>
</table>

 learners: PI relative change > 0 between Session 3/6 and Session 1

Non-learners: PI relative change < 0 between Session 3/6 and Session 1

Slow-learners: PI relative change differs between S6-S1 and S3-S1

Strategy Class

1. Mixed: ICD ≤ -0.05

2. Matching: -0.05 < ICD < 0.05

3. Towards Maximising: ICD ≥ 0.05

Classification of Training participants by Learner and Strategy Class

N = 108 (Control = 54; Training = 54)

• Positive relationship between strategy ICD and inverse temperature parameter for IED and PRL - indicates a possible transfer effect of SL training such that participants who maximised during SL are more likely to choose the option with higher reward in IED and PRL

• Successfully classified training participants by Learner and Strategy type, with the majority as Learners and Maximisers

References


1 Nanyang Technological University, Singapore
2 Centre for Lifelong Learning and Individualised Cognition
3 University of Cambridge, UK

*This research project is funded by the National Research Foundation (NRF) Singapore under its Campus for Research Excellence and Technological Enterprise (CREATE) programme.*
In CLIC work program 0.2, we aim to investigate the impact of structure learning training on individual’s cognitive flexibility and its transferability to other cognitive abilities, that pose significant implications in learning. To investigate the effect of training at neural level, we adopted a multimodal imaging approach comprising whole brain functional connectivity patterns, microstructure-myelination and neuro-metabolite concentration in the frontal brain regions.

**Methodology**

Cognitive plasticity and learning dependent changes in frontal brain regions

<table>
<thead>
<tr>
<th>Effect of Structural Learning on neuro-metabolites</th>
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</table>
| Each MRS voxel in the left and the right DLPFC are transformed from local space to standard MN152 space. | Standard DLPFC mask is designed using combined Brodmann areas BA-46 & BA-9.
| MRS voxel positioning on DLPFC in the Left and Right regions across pre- and post-training sessions did not differ. | MEGA-PRESS edited MRS spectra for each regions were checked and cleaned for visual artefacts, Cr linewidth in the OFF-spectra, poor fitting and head movement resulting in displaced voxel position during data acquisition.
| Good quality data L-DLPFC (NC=46; NT=48) and R-DLPFC (NC=47; NT=48) in post-training session were used in analysis. |

**Results & Discussion**

Relation between neuro-metabolites and cognitive scores

<table>
<thead>
<tr>
<th>Correlation of GABA+ &amp; Glx levels with SL scores (post training)</th>
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<tbody>
<tr>
<td>R-DLPFC GABA+ correlation with SL</td>
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<tr>
<td>Pre-training</td>
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<tr>
<td>R-DLPFC GABA+</td>
</tr>
<tr>
<td>R-DLPFC Glx</td>
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