# GERMANY/HONG KONG JOINT RESEARCH SCHEME
# THE PROJECT REPORT

*(for Project Completion)*

**Project Number: G_HK012/12**

**Title**

Neural underpinnings of individual differences in cognitive abilities

**Particulars**

| | Hong Kong team | German team |
|---|---|---|
| Name of Project Co-ordinator (with title) | Dr. Changsong Zhou | Prof. Werner Sommer |
| Name of Co-Investigator (if any) | | |
| Institution or Institutional affiliation | [ ] CityU [ ] HKU<br>[ ] CUHK [ ] HKUST<br>[x] HKBU [ ] LU<br>[ ] HKIEd [ ] PolyU | [ ] University of _____<br>[ ] Others: Humboldt-University at Berlin |
| Other project team members (if any) | | |

**Funding Period**

| | 1st year | 2nd year (if applicable) |
|---|---|---|
| Start Date | | Jan 1, 2013 |
| Completion Date | | Dec. 31, 2014 |

**Objective(s) as per original application**

1. What are the neural underpinnings of individual differences in general cognitive functioning, mental speed, face perception and face memory, and perception and memory of emotional facial expressions?
2. How does trial-to-trial variability of neural processing relate to performance measures representing these abilities?
3. How does the neural background activity moderate the relationships above?

**Details of Report** [Please attach relevant document(s)]

**i) Outline of proposed research and results obtained**

Humans differ widely in their cognitive abilities. However, the neural underpinnings of individual differences remain poorly understood, especially in terms of their temporal dynamics. Such inter-subject variability may be closely related to the intra-subject variability in single trial processing, which is influenced by dynamical ongoing brain states and activities. The proposed research aimed to apply and further develop a new method for neural data analysis, called Residue Iteration Decomposition (RIDE), developed by the two PIs as a result of their complementary expertise, to obtain a better understanding of the temporal dynamics of the brain processes underlying individual differences in cognitive abilities.

This collaborative project turned out to be very successful and productive, especially for the establishment of the capacity for long-term collaborative projects. The two project coordinators visited each other annually. Young researchers visited the labs of each other for extended periods to carry out collaborative works. New research collaborations with Prof. Andrea Hildebrandt from University of Greifswald have been established. The main outcomes are:

1) We further developed our RIDE methods and toolbox and demonstrated their applicability using the data in this project. Two papers have been published [1,2].
2) A patent has been filed for the method RIDE.
3) RIDE has been applied to existing data on emotional effects. The paper is published [3].
4) We further analysed the impact of variability on conditional effects [4] and on source-localization [5]. The papers are under preparation.
5) A joint research proposal was submitted in March 2013 during the visit of Dr. Changsong Zhou to Berlin and secured 444,000 Euro from DFG (German Science Foundation) in 2014, which extended for the research problems outlined in this project. The DFG grant has started to collect new data.
6) A new proposal to further extend the research on individual difference in this project and in DFG project to Alzheimer's diseases has been submitted to the group linkage grant of the Alexander von Humboldt Foundation to further strengthen the research collaborations.
7) We co-organized a few workshops and symposium in international conferences to promote our method RIDE and interdisciplinary collaborations between physical sciences and neurocognitive researches.
8) We co-supervised several students and established a joint PhD program between Hong Kong Baptist University and the Humboldt University at Berlin,
    a. Dr. Ouyang Guang (HKBU; graduation 2014)
    b. Hadiseh Nowarast-Rostami (HU-HKBU Joint PhD, expected graduation 2015)
    c. Rajan Kashyap (HKBU, expected graduation 2015)
    d. Alf Mante (HU)

**ii) Significance of research results**

The highly interdisciplinary research collaborations between the two coordinators and the co-supervision of young researchers contribute to develop new method for the separation of event-related brain potentials (ERPs) based on single trial latency variability and its application to study individual difference from the perspective of dynamical processing. In this project, RIDE was further developed to allow exploring variability information (amplitude and latency) in the single trials.

This method (residue iteration decomposition, RIDE) is a great advancement in the methodology for ERP analysis. RIDE has solved long-standing problem of component mixing and smearing in ERP analysis, and importantly can provide much more dynamical information from experimental data. The updated method RIDE in this project allows the extraction of ERP components related to particular sub-processes. RIDE can reconstruct ERP waveforms as most probably observed in single trials and obtain the distributions of latencies and amplitudes of each component among single trials. Applying RIDE, EEG data can now be explored in a much broader scope to study brain-behavior relations.

The method and open-access of the toolbox shall have strong potential and impact for the large community of ERP research. It opens new perspectives to study the brain dynamical activity underlying performance variability, individual difference and disorders. In fact, the newly funded projects by DFG and AvH all use RIDE as core methodology to address new questions, which are otherwise not accessible by conventional ERP analysis.

**iii) Research output**

Papers published:

1. Guang Ouyang, Werner Sommer* and Changsong Zhou* (2014) A toolbox for residue iteration decomposition (RIDE)—A method for the decomposition, reconstruction, and single trial analysis of event related potentials. *J Neurosci Methods*, http://dx.doi.org/10.1016/j.jneumeth.2014.10.009

2. Guang Ouyang, Werner Sommer* and Changsong Zhou* (2015) Updating and validating a new framework for restoring and analyzing latency-variable ERP components from single trials with residue iteration decomposition (RIDE). *Psychophysiology* 52, 839–856

3. Hadiseh Nowparast Rostamia*, Guang Ouyang, Mareike Bayer, Annekathrin Schacht, Changsong Zhou, and Werner Sommer (2015) Dissociating the Influence of Affective Word Content and Cognitive Processing Demands on the Late Positive Potential. *Brain Topography*. DOI 10.1007/s10548-015-0438-2, (2015).

Papers under preparation:

4. Guang Ouyang, Suiping Wang, Werner Sommer* and Changsong Zhou*, Latency variability smears ERP conditional effects. (PDF attached)

5. Rajan Kashyap, Guang Ouyang, Changsong Zhou* and Werner Sommer*, Neuroanatomic Localization of Priming Effects for Famous Faces with Latency-Corrected Event-Related Potentials. (PDF attached)

Patents:

**Zhou, C.S.,** Ouyang, G., Sommer, W. "Method for separating and analyzing overlapping data components with variable delays in single trials" U.S. Patent 14/210,321, March 13, 2014.

Grant secured:

Project title: *"Neurocognitive mechanisms underlying the distinction between Speed and Accuracy Abilities in face and object cognition"*.
PIs: Andrea Hildebrandt (Ernst-Moritz-Arndt University Greifswald) & Werner Sommer (Humboldt-Universität Berlin)
Collaborators: Changsong Zhou (Hong Kong Baptist University) & Oliver Wilhelm (University Ulm)
Grant code: Part Sommer - SO 177/26-1 & Part Hildebrandt HI 1780/2-1
Grant size: EUR **444,000**.00; Funding source: German Science Foundation (DFG).
Starting date: Nov. 2014
End date: Oct. 2017

The grant will support our Joint PhD student Hadiseh Nowarast-Rostami to continue as research assistant and PhD graduate and developer of RIDE (Dr. Guang Ouyang) from HKBU as postdoc for two years for

further collaborations.

Conferences/workshop organized:

a. International workshop on "Biological underpinnings of cognitive abilities in health and disorders", April 1-3, 2014, Beijing Computational Science Research Center, organized by Changsong Zhou and Werner Sommer.
b. Focused workshop on "Residual Iteration Decomposition (RIDE) – a new Method for the Decomposition of ERPs based on Latency Variability: Principles and Applications", April 4, 2014, Beijing Normal University, organized by Changsong Zhou and Hua Shu (BNU)
c. Symposium (accepted) "Residual Iteration Decomposition (RIDE) – a new Method for the Decomposition of ERPs based on Latency Variability: Principles and Applications", Sep 23- 27, 2014, 17th World Congress of Psychophysiology (IOP2014) at Hiroshima, Japan, organized by Werner Sommer and Changsong Zhou
d. ICTS focused workshop "EEG/ERPs in Language and Face Cognition: New Methods and Findings", Jan 21, 2015, Institute of Computational and Theoretical Studies (ICTS), HKBU, organized by Changsong Zhou and Werner Sommer

**iv) Potential for or impact on further research collaboration**

The Germany-Hong Kong Joint research project helped to initiate and build foundation for long-term further research collaborations based on the complementary expertise of the two teams.

1) DFG project:

Dr. Changsong Zhou is a cooperation partner in the DFG-project of Prof. Hildebrandt and Prof. Sommer, which investigates the factorial structure of face and object cognition and its neural underpinnings basing on the ERP and the variability in reaction time and single trial latency of the RIDE-separated central process. In this project about 250 participants will be investigated in speed and accuracy tasks with faces and objects in independent psychometric and EEG sessions. We will co-supervise research assistants Hadiseh Nowarast-Rostami and Guang Ouyang to carry out the collaborative work.

2) AvH Group Linkage project

Prof. Werner Sommer (Humboldt University) and Prof. Andrea Hildebrandt (University of Greifswald), and Dr. Changsong Zhou (HKBU) submitted a proposal for Research Group Linkage from the Alexander von Humboldt Foundation (AvH), 55,000 Euro. Project title: "APOE polymorphism effects on (face) cognition in young healthy adults and their neurocognitive mechanisms". With minor changes to provide details of work plan and budgets, the proposal will be granted middle June, 2015.

This project will use many of the data in this project and in the DFG-project, but address a complementary research question related to the description of risk carriers of Alzheimer's Disease as compared with non-risk carriers.

3) RGC initial proposal on brain signal variability

Dr. Zhou as PC (Principal Coordinator) submitted CRF (Collaborative Research Fund) initial proposal entitled "*Accounting for behavioral reliability by neural variability: dynamical principles and relevance to brain health and disorders*", Co-PI: Michael Wong (HKUST), international Collaborators: Werner Sommer (Humboldt University), Andrea Hildebrandt (University of Greifswald) and Daoyun Ji (Baylor Colleague of Medicine).

In perspective we aim to synergize computational and analytical studies on the dynamical mechanisms of signal variability and response reliability in generic neural network models with experimental tests of the

predicted relationships at different scales (Gene, Neuron, Local Circuit, Brain Systems, and Beha ·). Dr. Zhou has suggested a model that accounts for generic local neural circuits of excitatory and inhibitory (E-I) neurons, linked to the activity and functions at both lower (neuronal) and higher (e.g., EEG) levels in biologically plausible ways. The model aims to show that larger variability (e.g. multiscale entropy, MSE) improves the cost efficiency of networks, yielding faster and more reliable neuronal responses to inputs and more efficient learning and memory. We will quantify variability and stability of neural processing using dynamical measures and elucidate the dynamical mechanisms and biological foundations (e.g., E-I balance) underlying the co-variation of neuronal variability and response stability and study the relationship to variability in pre-stimulus EEG. At the performance level the variability of local neural circuits could translate into more accurate, faster and less variable, that is, more stable behavior. These relationships are supposed to hold for different conditions within the same brain (person) but also across different individuals and across healthy and disease states and will be tested in experimental data from healthy humans, and in risk-carriers for Alzheimer's Disease in humans.