“Cognitive Training of Attention and Microbiome Control as Prerequisites for Human Capital Development”

A V Dzyuba¹ and V A Dzyuba²
¹Neuro trans-skills Center, Moscow, Russia
²KnASU, Komsomolsk, Russia

E-mail: dzyuba.alexander@gmail.com

Abstract. The paper discusses the role of gut microbiota control in human capital development. Using the analysis of existing literature authors suggest mutual entanglement of attention training practice and presence of certain microbiota population. Based on this conclusion recommendations for shaping future cognitive trainings is given. Authors also present a method for microbiome accounting in datasets where only dietary data is collected. Based on this approach possible association between microbiome and well-being domain of human capital is evaluated.

1. Introduction
One of the main drivers of modern economy is human capital. In the course of the last 30 years this asset’s share in world’s wealth has been steadily growing. Nowadays it reaches 70-80% of gross national wealth for developed countries and around 50% in case of developing ones [1]. This expanding role of investments in nation’s knowledge-skills endowment draws special attention to education in this sector. Considering the era of 4th industrial revolution, stakeholders at different levels share a viewpoint that personal development requires systematic training approaches based on state of the art and scientifically proven methods. For the last 20 years a good deal of innovations boosting human efficacy have been coming from the cognitive neuroscience and social psychology fields [2]. Investigations in these areas have been consistently uncovering neurophysiological and psychological correlates of improved well-being, transferable skills and other important aspects of human mastery.

Particular focus in these studies has been on the development of attentional networks, which appeared to be one of the pillars of human flourishing [3]. A range of tools to work with those brain structures have been shaped up recently, but surprisingly a few of the most efficient methods to train attention have been already known for centuries. It appears that contemplative approaches like sitting meditation and moving meditation (qigong) are especially productive in rewiring brain towards happiness and efficacy [4]. These traits are crucial components of human capital development and thus contemplative practices are actively implemented into the organizational ecosystems. Success of meditation-based approaches also leads to a number of ongoing studies that strive to develop mind’s cognitive training procedures further on. This interest has even kindled a foundation of a new scientific field called contemplative neuroscience [5].

We in this manuscript are proposing an innovative approach for cognitive training. Namely, we are advocating for the gut microbiome tuning to be one of the crucial prerequisites that could take human capital development to a new level. Our proposal is based on the growing body of research suggesting...
that coherent multi-channel signaling between brain and gut governs a wide range of cognitive, behavioral and emotional patterns in humans [6]. This broad-range bi-directional communication appears to be vulnerable to a number of factors (lifestyle, environment, etc.) and thus could be potentially utilized as a catalyst for the neural transformations occurring in the course of cognitive intervention [7]. At the same time, during most of scientific experiments dealing with training of attention not only the gut state is not manipulated concurrently with mental practice (e.g. mindfulness), but moreover the participants’ microbiotic footprint is not usually controlled for.

Our working hypothesis is that gut microbiota interferes with neural transformations caused by cognitive intervention itself. We believe that accounting for microbiome population may explain observed discrepancies and null-findings in the meditation-related research as well as help to develop a more efficient human capital development program. Paper also contains data conversion method (into microbiome-sensitive one) that allows probing currently available datasets. Conversion is based on a well-known fact that one of the crucial factors affecting microbiome state is dietary habits. Diet-related questionnaires are often collected to characterize a lifestyle of the participants, and thus if carefully analyzed could be used as a reflection of the gut state. Finally, we provide the details of this analysis and briefly test this approach on the existing large longitudinal dataset collected in USA and Japan (MIDUS) [8].

2. Methods

2.1. Healthy eating index

To access microbiome state using dietary data we used the notion of Healthy Eating Index developed by the US Department of Agriculture. This parameter is based on the assessment of the daily calorie intake of certain type of products. Usually the following constituents are recorded: Vegetables, Fruits, Grains, Oils, Diary, Meat and Fish. After being collected through the questionnaire the calories values are calculated (converted) into indexes taking into account the level of physical activity and mass/height ratio under the “Dietary guidelines for Americans” by USDA. Then indexes are summed to provide the estimation of the diet quality. However, this approach being valid from the metabolic point of view, does not directly correspond to any neuro-physiological mechanisms of the gut-brain interaction. Taking into account existing studies related to the subject we are suggesting that rather than concentrating on the energy-based paradigm it is more descriptive to characterize the microbiotic composition of the intestine. This conceptual pivot may provide a more evidence-based and consequently effective route to understand the relation between personal well-being and consumer’s food basket structure. While the full picture of this coexistence is still under investigation, several publications point out at the crucial difference between plant-based diet and animal-based diet in terms of macrobiotic population and cognitive-behavioral outcomes. Driven by this fact we constructed (instead of the Healthy Eating Index) two new variables: plant-based and meat-based indexes. The former is a sum of calculated indexes for Vegetables, Fruits and Grains. The latter is a sum of Meat products indexes. Also we should note, that for a brief preliminary analysis of this manuscript, dairy and other types of products are not included, but could be added during later stages of the study.

2.2. Psychological well-being scale (PWB)

To probe our approach we have chosen the main human capital related questionnaire in MIDUS – Psychological Well-Being scale. This questionnaire is based on a theoretical model of well-being consisting of six dimensions: Autonomy, Environmental Mastery, Personal Growth, Positive Relations with Others, Purpose in Life, Self-Acceptance and described elsewhere [9] in details.

2.3. Analysis

The confirmatory analysis has been done based on our working hypothesis of association between microbiome and neural transformations resulted in cultivation of personal skills and traits. We used the MIDUS project dataset since it is one of the largest and most consistent publicly available datasets.
Moreover, it combines data on a wide range of psychological factors and potentially could be utilized to expand on ideas presented in the paper. The analysis included 359 individuals (those who have both correct dietary and PWB data) and was based on regression (age and sex adjusted) with account of multiple comparisons. Outliers’ inclusion was performed based on three sigma rule. The R software was used to perform analysis.

3. Results
Typical box plots for psychological well-being’s autonomy subscale and meat-based index are presented in Figure 1. Figure 2 exhibits typical regression analysis outcome. The results of analysis are aggregated in Table1. It appears that diet (reflection of the prevailing microbiota population type) is associated with personal traits characterizing well-being of the participants. We review and analyze these results further in the Discussion section.

![Box plots for typical distributions of meat-based healthy eating index (left figure) and autonomy subscale of PWB (right figure). Solid line represents three sigma cutoff, dotted – two sigma.](image1)

**Figure 1.** Box plots for typical distributions of meat-based healthy eating index (left figure) and autonomy subscale of PWB (right figure). Solid line represents three sigma cutoff, dotted – two sigma.

![Regression plot of association between meat-based diet and PWB subscale (autonomy).](image2)

**Figure 2.** Regression plot of association between meat-based diet and PWB subscale (autonomy).
The presence of gut parasites (e.g. toxoplasma gondii) may provoke obsessive-compulsive disorder, attention deficit disorder and Tourette's syndrome [18]. Diet regulation has indeed been shown to provoke obsessive-compulsive disorder, attention deficit disorder and Tourette's syndrome. The observed effects vary from minor alterations, e.g. mood swings [15], to profound shifts, e.g. change in neuroplasticity [16, 17]. The presence of gut parasites (e.g. toxoplasma gondii) may additionally provoke obsessive-compulsive disorder, attention deficit disorder and Tourette’s syndrome [18-20]. Even though there is a general lack of the microbiota-related studies that utilized imaging techniques, certain neurological underpinnings that could be associated with microbiotic shifts are already highlighted. Resting state MRI data suggested that probiotics intake leads to the reorganization of the midbrain connectivity and to the reduction of the task-related response in the regions that control central processing of emotion and visceral sensation. In the same paper researchers also tracked the reduced reactivity and shift from the arousal based network towards the regulatory network activation [21]. The prevailing bacterial type (prevotella or bacteroids) for two cohorts of participants appeared to be associated with the differences in the regions that govern emotion, attention, and sensory activity. The prevotella group was characterized by less hippocampal reactivity to the negative images, while the bacteroids group showed a greater gray matter prominence in the cerebellum, frontal regions, and the hippocampus [22]. It is crucial to notice that the prevotella and bacteroids bacterial types are signatures of the plant-based and animal-based diets respectively. These bacterial types may coexist in the gut, but their relative shares’ equilibrium is shifted based on the products consumed.

In tune with these results, our analysis also shows that plant and animal-based diets affect human mind in different ways. Participants with higher consumption of plant-based products report higher trend for personal growth and development, feel that their life is more purposeful and have more solid objectives. At the same time both plant and animal-based diets are associated with decrease in independence of views and increased tendency to rely on judgements of others. These outcomes suggest that plants-reach diet may promote well-being and consequently human capital fostering. However, vegetables, fruits and grains products should be “diluted” with other foods. Probably oils, nuts or dairy could be added to the daily intake. Though we have not run these additional analyses to avoid multiple comparison problem, future researches may build upon these ideas further. In general, our results point out that the dietary choice could be handy for the efficacy of the contemplative training, where microbiome tuning is one of the training nodes. Diet regulation has indeed been demonstrated to promote a healthier brain and mind in a numerous studies. Sugar consumption for example leads to the inflammation and impairs the hippocampus-dependent memory within one week in rats [23]. The other example is concerned with healthy adults, who ate a high fat diet for one week performed worse on the tasks measuring attention and speed of retrieval, than they had prior to the diet change [24]. In the longitudinal study among 255 adults it was found that a lower intake of the nutrient-dense foods and a higher intake of the unhealthy foods are each independently associated with

| PWB’s subscale         | r (Pearson) | p (n=356) | r (Pearson) | p (n=356) |
|------------------------|-------------|-----------|-------------|-----------|
| plant-based            |             |           | meat-based  |           |
| Growth                 | 0.1         | 0.05      | ----        | ----      |
| Autonomy               | -0.1        | 0.038     | -0.22       | 0.0003    |
| Purpose                | 0.12        | 0.018     | ----        | ----      |
| Positive relations / well-being | ----   | ----      | ----        | ----      |

### 4. Discussion

The last decade has yielded a substantial body of publications linking the “intestine microbiota-brain axis” to well-being. It has been discovered that the state of the microbiome has an immense influence on the physiological, cognitive and behavioral aspects of the nervous system activity [10-14]. The observed effects vary from minor alterations, e.g. mood swings [15], to profound shifts, e.g. change in neuroplasticity [16, 17]. The presence of gut parasites (e.g. toxoplasma gondii) may additionally provoke obsessive-compulsive disorder, attention deficit disorder and Tourette’s syndrome [18-20].
the smaller left hippocampal volume [25]. Furthermore, the dietary choice itself was shown to be associated with the certain traits [26, 27] some of which are interrelated with our results.

Detailed consideration of microbiota-related neural transformations allows one to take a deeper look at cognitive training approach itself. It appears that among the plethora of described findings, the effects of microbiome alterations are somewhat similar to those of meditation. Surprisingly, the regions and networks affected by microbiotic alternations – in particular amygdala, cerebellum and hippocampus - are also known to be affected by mindfulness practice [28-30]. In general, similarity in altering immune response, neurogenesis and regulation of emotion suggest that cognitive training and control of gastrointestinal system state may be complimentary practices and could be the nodes of the unified training. Concurrently recent years exhibited some publication reporting null findings or presenting controversial data in experiments with meditation intervention. Based on the ideas presented in the discussion section of this manuscript we argue that accounting for microbiota of participants with the same scrutiny as for the demographics characteristics for instance, may reveal more balanced analysis outcomes for future publications.

In conclusion, despite of all accumulated scientific evidence microbiome control has often been overlooked in human capital development interventions. Moreover, gut state is usually not taken into account as a crucial prerequisite in modernized eastern practices. We suggest that accounting for the diet and the microbiome-related procedures has a potential to increase the effectiveness of these trainings and to provide more stable and consistent outcomes of corresponding scientific investigations.

5. References
[1] Lange G M et al 2018 Changing wealth of nations World Bank Group report 2018 Homepage https://openknowledge.worldbank.org/handle/10986/29001 last accessed 2020/09/13
[2] Heckman J J 2007 The economics, technology, and neuroscience of human capability formation Proceedings of the National Academy of Sciences 104(33) 13250-13255
[3] Anderson N D et al 2007 Mindfulness-Based Stress Reduction and Attentional Control Clin Psychol Psychother 14 449-463
[4] Wang . et al 2013 The Effects of Qigong on Anxiety, Depression, and Psychological Well-Being: A Systematic Review and Meta-Analysis Evid. Based Complementary Altern ID152738
[5] Tang Y Y et al 2015 The neuroscience of mindfulness meditation Nat Rev Neurosci 16 213-225
[6] Palacios-Garcia I and Parada F J 2020 Measuring the Brain-Gut Axis in Psychological Sciences: A Necessary Challenge Front Integ Neurosci 13 ID73
[7] Singh R et.al 2019 Lifestyle-Induced Microbial Gradients: An Indian Perspective Front Microbiol 10 ID2874
[8] Midlife in the United States (MIDUS) National longitudinal study of health and well-being Homepage http://midus.wisc.edu/ last accessed 2020/09/13
[9] Ryff C D and Keyes C L M 1995 The Structure of Psychological Well-Being Revisited Journal of Personality and Social Psychology 69(4) 719-727
[10] Clapp M et al 2017 Gut microbiota’s effect on mental health: The gut-brain axis Clin Prac 7(4) 131-136
[11] Martin C R et al. 2018 The Brain-Gut-Microbiome Axis Cell Mol Gastroenterol Hepatol 6(2) 133-148
[12] Aroniadis O C et al.: A Perspective on Brain–Gut Communication: The American Gastroenterology Association and American Psychosomatic Society Joint Symposium on Brain–Gut Interactions and the Intestinal Microenvironment Psychosom Med 79(8) 847-856
[13] Dinan T G and Cryan J F 2017 The Microbiome-Gut-Brain Axis in Health and Disease Gastroenterol Clin North Am 46(1) 77-89
[14] Verdi S et al. 2018 An Investigation Into Physical Frailty as a Link Between the Gut Microbiome and Cognitive Health Front in Aging Neurol 10 ID398
[15] Kim N et al 2018 Mind-altering with the gut: Modulation of the gut-brain axis with probiotics *Brain Behav Immun* 56(3) 172-182
[16] Leung K and Thuret S 2015 Gut Microbiota: A Modulator of Brain Plasticity and Cognitive Function in Ageing *Healthcare* 3(4) 898-916
[17] Diaz Heijtz R et al 2011 Normal gut microbiota modulates brain development and behavior *Proc Natl Acad Sci* (USA) 108(7) 3047-3052
[18] Flegr J and Horáček J 2017 Toxoplasma-infected subjects report an Obsessive-Compulsive Disorder diagnosis more often and score higher in Obsessive-Compulsive Inventory *Eur Psychiatry* 40 82-87
[19] Khademvatan S et al 2018 Toxoplasma gondii exposure and the risk of attention deficit hyperactivity disorder in children and adolescents *Pediatr Infect Dis J* 37(11) 1097–1100
[20] Akaltun I et al 2018 Seroprevalance Anti-Toxoplasma gondii antibodies in children and adolescents with tourette syndrome/chronic motor or vocal tic disorder: A case-control study *Psychiatry Res* 263 154-157
[21] Tillisch K et al 2013 Consumption of Fermented Milk Product With Probiotic Modulates Brain Activity *Gastroenterology* 144 1394-1401
[22] Tillisch K et al 2017 Brain structure and response to emotional stimuli as related to gut microbial profiles in healthy women *Psychosomatic Medicine* 79(8) 905-913
[23] Beilharz J E et al 2016 Short-term exposure to a diet high in fat and sugar, or liquid sugar, selectively impairs hippocampal-dependent memory, with differential impacts on inflammation *Beh Br Reserch* 306 1-7
[24] Edwards L M et al 2011 Short-term consumption of a high-fat diet impairs whole-body efficiency and cognitive function in sedentary men *FASEB J* 25(3) 1088-1096
[25] Jacka F N et al 2015 Western diet is associated with a smaller hippocampus: a longitudinal investigation *BMC Medicine* 13 ID215
[26] Keller C and Siegrist M 2015 Does personality influence eating styles and food choices? *Direct and indirect effects. Appetite* 84 128-138
[27] Pfeiler T M and Egloff B 2018 Examining the “Veggie” personality: Results from a representative German sample *Appetite* 120 246-255
[28] Holzel B K et al 2008 Investigation of mindfulness meditation practitioners with voxel-based morphometry *Soc Cogn Affect Neurosci* 3(1) 55–61
[29] Boccia M et al 2015 The Meditative Mind: A Comprehensive Meta-Analysis of MRI Studies *Physiological Effects of Mind and Body Practices* ID419808
[30] Fox K C et al 2014 Is meditation associated with altered brain structure? A systematic review and meta-analysis of morphometric neuroimaging in meditation practitioners *Neurosci Biobehav Rev* 43 48-73