Title: WHAT'S NEXT FOR THE NEUROBIOLOGY OF TEMPERAMENT, PERSONALITY AND PSYCHOPATHOLOGY?

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Abstract:
This paper represents the outcome of a multidisciplinary discussion on what works, what doesn't, and what can be improved, in on-going work on bio-behavioural taxonomies and their biomarkers. The authors of this paper, representing a wide spectrum of bio-behavioural disciplines (clinical, developmental, differential psychology, neurophysiology, endocrinology, psychiatry, neurochemistry, neurosciences), have contributed more extensive opinions to the Theme Issue "Neurobiology of temperament, personality and psychopathology: what's next?". The authors identified ten directions in international and multidisciplinary cooperation, and multiple insights for "what is next" for each of these directions.

WHAT'S NEXT FOR THE NEUROBIOLOGY OF TEMPERAMENT, PERSONALITY AND PSYCHOPATHOLOGY?

1. The long, multidisciplinary road to biobehavioural taxonomies.

Temperament and personality traits are derived from *consistent behavioural patterns* (CBP) [1, 2, 10] that have been proposed to reflect a continua of symptoms in psychopathologies. Inherent consistency in these patterns should ensure success in their classification and in identification of their biomarkers. Such was the hope at the dawn of the 20th century – with the emergence of differential psychology, psychophysiological experiments on nervous system typology, biological and psychiatric theories of temperament, and typology of mental disorders within the International Classification of Diseases (ICD) and later the Diagnostic and Statistical Manual of Mental Disorders (DSM). The intense attempts to classify CBPs continued with the creation of lists of personality descriptors (20,000+), the blossoming of the lexical approach, several personality theories, neuroimaging, electroencephalography (EEG), psychophysiology, neurochemistry, ten revisions of the ICD, and five revisions of DSM.

Nevertheless, a sober look at our current psychiatric and psychological taxonomies shows only modest progress. The more data that the biobehavioural sciences uncovered, the more it became clear that the subjects of the original CBP classifications – are transient, context-dependent and complex [1, 3-11]. It has taken several centuries for older natural sciences (e.g., physics, chemistry, biology, medicine) to derive their taxonomies, through an ongoing, long history of trial and error, analytic discussions, comparisons of hypotheses and alternative models, and multidisciplinary cooperation. Much younger sciences, such as psychology and psychiatry, are set for a similar course.

The current Theme Issue attempts to spark a multidisciplinary debate on what works, what doesn't, and what can be improved in our work on taxonomies and biomarkers of CBP. The authors of this integrating paper represent a wide spectrum of bio-behavioural disciplines (clinical, developmental, differential psychology, neurophysiology, endocrinology, psychiatry, neurochemistry, neurosciences, genetics) and have contributed more extensive opinions to this Theme Issue. These opinions differ on several issues and so we have not attempted a consensus, but provide here a summary of what our experts agree on: fully, partially, or not at all.

2. Taxonomies need principles, and principles need theory

The history of other sciences with successful taxonomies highlights the importance of a theory with principles that at least provisionally explain the organization of patterns of interest, why and how certain classes are used. In chemistry, for example, the periodic table is validated by atomic theory; in biology, the classification of species is becoming standardised through genetics and phylogeny; and in medicine, bodily systems and illnesses have become codified through functional and dynamic principles from physiology and cellular biology.

With regard to CBP, several models have been proposed (e.g., Big Five, Big Six, Big Seven, RDoC, HiTOP, FET [1-2, 12-13, 51]), some more heavily promoted by the American Psychological Association (APA). However, the validity of their underlying principles is rarely discussed. In differential psychology and psychiatry, a few well-founded theories have been offered in an attempt to gain a unified representation of *the parabolic elephant* that is CBP [1-2, 14-16]; however, clearly more explicit systematic work towards this is needed to derive a coherent, principle-driven theory [1, 9, 17].

Meanwhile, the principles of some taxonomic models amount to reiterating the psychometric requirements of test construction ("factor analysis said so"). CBPs are treated as output from a black box; without regard for the complexity of classify transient, context-dependent, biologically-based systems – with nonlinear feedback relations between their components [1, 10, 18-19]. At most, the Big Five model might reflect universalities in social perception and societal regulation (promoting interaction, cooperation, information processing, rule-driven and emotionally stable behaviour) as expressed in natural language. The main arguments for the validity of this model are cross-cultural comparisons of groupings of language descriptors (i.e., socio-cultural arguments), but not principles of neurophysiology. As Srivastava noted, the Big Five reflects principles of social perception and verbal-cultural processes; but not principles of biologically-based individual differences [12]. Moreover, recent studies show that the cross-cultural consistency of the Big Five model might be over-rated [20].

The HiTOP [13] and Positive-Negative Affect models, in addition to factor analysis, use arbitrary bipolar concepts from clinical practice, not rooted in neuroscience, and the validity of these organizing principles is rarely scrutinized. The differences between these and alternative biomarker-based models, are almost never analyzed, even though experimental research using such alternative models began before the dominance of lexical models [11]. Principles of organization underlying these alternative models include the architecture of functional systems [15], EEG biomarkers [15]; the Pavlovian principles of properties of nervous systems [14-15, 21-22]; neurochemical biomarkers [1, 16, 23], and a universal architecture of action construction and functional differentiation within neurochemical systems [1-2, 23]. A more comprehensive list of models can be found in the supplementary material of [24]. However, even this short list of alternatives suggests that these principles of biobehavioural taxonomies may be too diverse to assure a good convergence of models. Some authors suggest that a neuroscience-based taxonomy might be not possible (see [3]).

Therefore, a simple collection of CBP-biomarkers may not be sufficient without identification of the principles organizing the complexity of these associations. The lack of coherence between several models and the justification of principles underlying these classifications leads to significant variability and incompatibility of interpretations of experimental variables and results. Meanwhile, labels and classes in taxonomies directly affect the ways in which hypotheses and research questions are shaped. Indeed, as Wacker and Paul point out, the situation is further complicated by the fact that even with seemingly simple behavioural data, several equally defensible alternative analytic paths exist that can lead to markedly different interpretations [9, 25].

The vicissitudes of the human condition, such as adherence to ideology, dis/confirmation biases, use of "popularity" argument instead of theoretical justification of models, and variations in expertise, require particular effort from professional associations and journals to counter their influence. Restricting literature reviews to specialized journals is unlikely to spark the multidisciplinary collaboration needed to accelerate progress in biobehavioural taxonomies. Expanding the analytic part of the task of developing CBP taxonomies, prior to experiments, could save resources in investigating CBP-biomarkers. This is especially important in neurochemical investigations that tend to be invasive and sacrifice many animals' lives when used animal models. Tables 1 and 2 list our insights about "What's next" for bio-behavioural taxonomies.

3. Biomarkers of CBP are not just in the brain

There is a strong consensus among experts working on bio-behavioural taxonomies that they should be based on biomarkers. Biomarkers of CBPs, however, should not be restricted solely to brain morphology and function. Here are a few arguments to support this statement, with suggestions for "what's next" in the Table 1:

A) Neuroimaging, so far, has low reliability and low replicability of associations between specific brain structures and specific CBPs [9, 4, 26, 27]. The observed activation of brain structures might be associated with functions of behavioural regulation that are not part of the experimental design of a given study, and this could generate false attributions for the biomarkers. The same brain structure is often implicated in multiple, very different CBPs [8]. For example, the ventral striatum reportedly is activated in association with positive affect and reward processing [28, 29], negative affect [30], aggression, [8, 31], alcohol misuse [32], social rejection [27], extraversion [33] and the generation of the program of actions and habits regardless of emotional valence [2, 34]. Similar incompatibility of overlaps in CBP-biomarkers associated with neuroimaging were observed for other brain structures, especially the amygdala, medial frontal lobes and cerebellum. These overlaps might, of course, suggest the existence of a common behavioural denominator behind these CBPs (for example, preparation and anticipation of actions) and likely "ensemble" interactions between brain structures. However, the nature of regional activation/involvement may well vary across CBPs [11, 29] (see also B, below).

B) The differential involvement of brain structures in specific aspects of actions and contexts is thought to be due to differences in the neurochemistry of their innervation [1-2, 7-8, 23-24, 29, 35-39, 43-45]. Neurochemical systems include neurotransmitters (serotonin, dopamine, noradrenaline, acetylcholine, GABA, glutamate), neuropeptides including hormones and opioid peptides, and a spectrum of their receptors, transponders, transcription factors and other mediators. These neurochemical processes should be a focus in the search for biomarkers as much as the neuroimaging of well-identified brain structures [1-2, 7-8, 23-24, 35, 37-39]. The resource intensive nature of neurochemical studies does create significant obstacles for these studies. Moreover, neurochemical systems often act non-locally via extracellular "volume transmission" [40], questioning the validity of approaches that are strictly structure- or network-oriented. The diffuse nature of neurochemical processes presents a great methodological challenge in studying core biomarkers of CBPs. Neurochemical models of temperament [1-2, 16, 23-24, 39] give a chance to explore the contribution of molecular genetics to consistent dynamical features of behaviour [36].

C) Modern "gut psychiatry", endocrinology and neuroimmunology have demonstrated that some biomarkers of CBP maybe outside the brain [2, 39, 41-42, 46]. Gut microbiota [41-42, 46], immune and hormonal systems [7, 39, 41, 46-49] impact many aspects of behaviour, with emotional regulation as the most explicit example. Moreover, other psychophysiological and biological processes - physical touch [7], genes [21, 33, 50, 89], sunlight, diets, hormones response to perceived social support – were reported as making significant contributions to CBPs and indeed interact with enteric, immune and endocrinological systems to impact central nervous system function and CBP [41].

4. The structure of biobehavioural taxonomies should accommodate the concept of a dynamical continuum

One important challenge for the development of biobehavioural taxonomies is that CBPs do not have strict boundaries in their properties. Instead, individually-consistent behavioural patterns possess a dynamic, “fuzzy” rather than static nature, reflected in current psychiatric taxonomies [1-2, 5, 10]. SFor example, DSM-5 includes specific time frames for the onset and

periodicity of symptoms to make specific diagnoses. Current taxonomies, however, do not accommodate the fact that CBP can transit between several existing taxonomic categories. For example, people with post-traumatic stress (PTSD) often (but not always) have co-occurring Major Depression (MDD); neuroticism and sensation-seeking are not necessarily mutually exclusive, and neither are psychopathy and empathy [39, 52-53]. CBPs, therefore, could be presented *along multidimensional continua (spectra)* of the following types:

Clinical-health continua: the degree of behavioural deviations from severe to mild symptoms of psychopathology, and those that might or might not be seen as clinical symptoms and healthy temperaments [1-2, 5-6, 10, 13, 16, 19, 33, 53, 54). The classification of diagnoses as a function of severity is often difficult since severity fluctuates with time. There is also overlap, co-occurrence, comorbidity and phenomenological heterogeneity among diagnoses [4-6, 10] and the behavioral expression of normative temperament and personality traits. . The application of label- and category-oriented approaches to biobehavioural taxonomies, common in the early 20th century, showed that these approaches are not flexible enough to deal with the dynamics and the fuzzy boundaries between health and psychopathology [6, 54-55]. This led to the development of the dimensional and constructivism approaches [1-2, 13, 54].

Ontogenetic continua: There are well-documented age-related changes in neurophysiological, neuroanatomic and hormonal systems of behavioural regulation, making all age stages neurobiologically unique [5, 27, 35, 41, 56, 77, 89]. Maturation of biological systems (e.g., brain function) is seldom linear and varies as a function of sex [57-59]. The same individuals, as they age, change their values, interests, attitudes, etc. (i.e., essential components of personality). Through development, some aspects of CBP and symptoms of psychopathology are more transient, whilst others remain more stable [60]. Yet, relative to their peers, there are CBPs that distinguish one person from another, and there is continuity within each individual despite these age-related transformations. Even for individuals who exhibit comparable levels of specific traits at baseline, the longitudinal trajectories of these traits can vary markedly [5, 56, 89]. Several studies found inconsistencies in associations between specific traits and the activation of brain structures in samples using children and adolescents [8, 27], and in samples comparing adults and adolescents [27], illustrating the importance of considering brain maturation when understanding biomarkers of CBPs. Genetic factors vary in expression as a function of age [7, 89], as do parenting and peer interaction factors [7, 27, 77]. Moreover, epigenetic stress and nutrition have been shown to impact in-utero development, moderated by their time of onset [7, 56].

Intra-individual variability within CBPs: observed when the same people give variable responses to similar situations or in performing the same task. Such variability is often attributed to changes in context: indeed, by modelling trial-by-trial data, studies have demonstrated that both animals and humans dynamically adjust their representation of value to fluctuations in the context [5]. However, within-individual variability in behaviour [1, 4, 7, 19], neuroimaging patterns [4, 5] and neurochemical responses [1, 8, 35, 38] exists even when the context (such as experimental conditions) and age are relatively constant. This problem of variability was identified back in the 1930s by Bernstein as a degrees of freedom problem. He proposed that no single act is repeated twice, rather it is constructed anew [62]. This creates a methodological and analytic challenge in mapping the correlates of specific CBPs [1, 4-5, 7, 10-11]. Intra-individual variability diminishes the value of the "contrast" approach that compares only two contrasting conditions (for example, one control and one experimental) [4]. Moreover, it is typical that some of the intra-individual variability in behaviour is handled in research by excluding outlier

observations. Ideally the principles of a good taxonomic system should be able to explain outliers. This attention to outliers, is in fact, how the principles underlying models are tested in mature sciences.

Inter-species continua: similarities and differences in the ranges of CBP in humans as compared to other animals enables research in translational psychiatry, psychology and psychopharmacology [7, 61, 76]. A lesson learned from comparative, ecological and evolutionary branches of psychology over the past century is that a direct analogy of external behaviour between species is not always applicable. For example, communication is not always vocal in various species, and biting and roaring are not always signs of aggression. Yet, there is great potential in studying biomarkers and typology of consistent bio-behavioural differences using animals [76] because there are strong genetic similarities between humans and other species, as well as similarities in the main aspects of functioning. Non-human animals can be used to model autism, schizotypy, attention deficit disorder, and stress-resilience [76]. Animal studies appear to be especially useful for invasive neurochemical investigations (which are not allowed in humans) of the action of psychostimulants, drugs, physical and social stress on mother's physiology and of the impact of altered maternal behaviour on infants [7-8, 58, 61]. However, important differences between humans and animal models exist in the maturation and capacity of many 'higher-order' neurocognitive functions (e.g., executive, moral, self-referential domains).

5. Situational variability (context) should be a part of CBP taxonomies

The differential responsiveness of the same individual to different contexts is a well-documented phenomenon [3, 10, 19, 37, 78] (Figure 1). The diversity of personal life histories alters responses to the same context in different people and the responsiveness to different contexts in the same individual. These differences have psychophysiological bases, so they should not be ignored. For instance, stress induces changes in the immune system, such as raised inflammation that has been associated with individual differences in CBP (e.g., impaired cognitive empathy) [46]. Also, traditionally testosterone is associated with the propensity for aggressive behaviour [48], whilst oxytocin is proposed to decrease aggression [49]. However, testosterone has also been associated with prosocial behaviour, and may rather reflect a need to obtain social dominance – thus, its effects are differentially manifest depending on context [47, 39]. Also, in specific contexts, such as following provocation or in response to an "out-group", oxytocin may increase aggression (briefly reviewed in [8, 39]), especially in mothers protecting their young [39]. This might be understood as a role of oxytocin in facilitating accurate discrimination of threat [41], which is context dependent. Context dependency in CBP is present even prior to the impact of life experience. This is seen in the ability of infants to show jealousy, and in differential attachment patterns which depend on the context of caregiver relationships, documented with distinct neuronal biomarkers [7].

It is not a trivial task, therefore, to accommodate a typology of contexts or to choose "general and universal" experimental methods to study CBPs that could be applicable to the interpretation of individual differences in these contexts [1, 3-4, 10] (Table 2). Types of possible contexts go far beyond the short lists of conventional experimental contexts, such as stress conditions, social support and affiliations. For a given CBP, there should be a theory of the specific context features that are relevant with regard to moderating (and mediating) the expression of this trait [3]. The concept of Specialized Extended Phenotypes might be useful in this line of analysis [1-2]. Moreover, evolutionary aspects are fundamental to the mechanisms of

behavioural regulation, and so analysis of context should include systemic, evolutionary tendencies affecting CBP and their biomarkers [7, 61, 76].

6. Sex differences should be accommodated in the structure of taxonomies

Research over the past century demonstrated numerous sex differences in CBPs and their associations with biomarkers, both quantitative and qualitative [7-8, 36, 39, 41, 57-59, 63-64]. While science has recently begun to acknowledge that sex/gender is not a binary concept, previous research mostly investigated differences with regard to the traditional concepts of male versus female sex. For example, hippocampal volume predicted parent-reported aggression in healthy adolescents, but only in females (reviewed in [8]), whereas dysregulation in the MAO-A allele – amygdala-vmPFC coupling predicted increased harm avoidance and decreased reward dependence, but only in males (reviewed in [36]). Sex differences were also found in the impact of prenatal maternal antidepressant use on infant temperament; dampened reactivity in infant girls, heightened activity in boys (but a decline in distress to limitations) [reviewed in 7]. In adult samples, positive correlations between extraversion and the ratio of grey to white matter volume in the left hemisphere, or between neuroticism, extraversion, and conscientiousness and grey matter volume were only detectable in males, but not in females [reviewed in 36]. The analysis of sex-specific correlations is often exploratory (and sometimes tested and reported as if they were confirmatory). Reduction in *p*-hacking and promotion of confirmatory research in this domain might be facilitated by explicitly accommodating sex differences in current models.

Moreover, a binary division of sex groups appeared to be inadequate [63] and not reflect the diversity of sex as a construct reflecting sex-hormonal balance and related sexual needs. The interaction of sex with cultural standards emerges as gender, and this decouples sex-related variables affecting CBPs (Figure 2): biomarkers (hormonal systems), their interactions with physical factors, socio-interactive factors (such as mating, competition, dominance, possible to study on animal models) and impact of cultural factors, including sex-gender interaction in humans.

CBP taxonomies should, therefore, include a consideration of sex differences (Figure 1) and their interactions with three types of environments depicted in Figure 2.

7. Language biases and conflation disrupt terminology and require regular conceptual decluttering.

7.1. Jingle-jangle fallacies and language biases

When psychiatry and psychology emerged as sciences at the end of the 19th century, people viewed them as largely "talking and observing" professions, promoting reliance on verbal descriptors. The generation and manipulation of new jargon related to specific CBPs felt natural, even though there were calls for behavioural, experimental and biomarker justifications of emerging concepts.

In multiple revisions of psychiatric taxonomies, decisions on deleting, unifying or separating categories (as happened for depression, schizophrenia and OCD) were based on the opinions of clinicians operating by verbal descriptors, not on neuroscience that would demonstrate a need for such unification or separation. A hard lesson learned from these revisions was that special care should be given to the way that we use language, including naming and defining variables.

The first price that psychology and psychiatry paid for ignoring linguistic biases and arbitrary naming of behavioural patterns is the labels-overlap problem, or, as pointed by Brandt

and Mueller, "jingle-jangle fallacies" [3, 65, 66]. These include the faulty assumption that two different things are the same because they have the same labels (jingle fallacy) or that two (almost) identical things are different because they have different labels (jangle fallacy). Non-clinical examples include:

- the meaning of CBP "extraversion" (E) was transformed from the original temperament trait described by Jung as a type of behavioural orientation (to other people's influence) to Eysenck's interpretation of E as insufficient cognitive arousal forcing people to seek out stimulation (e.g. socialize), to Gray's interpretation as stronger Behavioural Activation over Behavioural Inhibition, currently coming to the mix of the concept of general arousal (following Gray, Cattell, Norman and McCrae's interpretation), plus positive affect and appetitive motivational systems [18, 38, 29]. In other words, E now has a meaning, which is almost opposite to that which Jung intended, and an inheritance of multiple interpretations in various models. Thus, several neurochemical hypotheses of extraversion have been proposed that vary in their definition of extraversion [2, 14, 29, 38];

- partial overlaps exist between the concepts and measuring scales of sensation-seeking, novelty-seeking, reward-seeking or reward-dependence [39, 16];

- empathy concept referring to both the representation of intentions/knowledge of others [“Theory of Mind”] and emotional responsiveness to the distress of others;

- overlapping functional processes referred to “trait anger” and “irritability”;

- the concept of "emotionality", which, despite its common use, is still defined circularly (“emotionality is how people express and feel their emotions”); and is known for having multiple components, biomarkers and conflicting theories [24, 39];

- the mix-up between concepts of "temperament" and "personality" as described below, which were also conflated with the concept of character [16], [Supplement in 24], [67].

Second, trust that common language objectively reflects consistent biobehavioural differences (known as Allport’s lexical hypothesis) still exists among the followers of the lexical approach even though the past century uncovered several language-related biases (see Supplement in [84]). These include a bipolarity of human verbal descriptors [69], a sociability bias of language, a pro-regulatory bias of language, emotionality and embodiment biases in cognition, and so on ([84]; see [18] for review). Language biases arise from the fact that a language is a society's tool to ensure (among other things): human interaction, cooperation, information processing, rule-driven and emotionally stable behaviour. Whereas these five pro-social functions of human language do not constitute the full list of these functions, due to their universality they influence the outcomes of the Big Five model of personality as the result of its lexical nature. Cross-cultural comparisons using this model, therefore, reflect universalities in verbal biases related to societies' needs. For good reasons, biological sciences don't verify their taxonomies based upon the cross-cultural consistency of opinions but use biomarker-based arguments [10, 17-18].

Third, bipolarity of human perception [69] can affect the way how we name clinical categories (positive-negative, external-internal, clinical-healthy) and perceive even the most abstract concepts [84]. Meanwhile psychophysiological systems induce a range of expression of every CBP. Moreover, as Blair and colleagues note, it became traditional to contrast control and experimental groups (also a sign of bipolarity in methodology) and interpret the observed results as showing the effects of experimental conditions [4-5].

Fourth, common language does not differentiate between descriptors related to CBPs with well-identified biomarkers (for example, tempo, or speed of actions) and "componential",

heterogeneous CBPs, that are likely the product of several more basic symptoms, whether in psychopathology (e.g., PTSD [21]; psychosis [5, 68], schizotypy [5, 27, 70], narcissism [27], aggression [8, 31, 48-49, 71], MDD [46, 53, 60], Generalized or Social Anxiety [53, 56, 79]), or in healthy CBPs (such as extraversion [14, 23, 33], or emotionality [3, 14, 24, 39, 77]).

Hierarchical models attempt to accommodate a multi-component approach to such "mixed" CBP, assigning strict associations of specific CBPs ("facets") to overa5ing categories ("factors"). This strict division of CBPs into categorical boxes generates multiple disagreements: for example, HiTOP uses classes of "internalizing" and "externalizing" disorders but doesn't include thought disorders to the internalizing class, detachment to the externalizing class and views (very different in aetiology) symptoms of MDD, PTSD and Generalized Anxiety as one class of "Distress" disorders [13]. As a non-clinical example, extraversion, as noted above, was historically associated with multiple CBPs, often explained by the concepts of general arousal and positive affectivity. Analysis of neurochemical biomarkers of several behavioural aspects attributed to extraversion showed that these aspects are based on different neurochemical ensembles and so require distinct concepts, to trace the CBP-biomarker associations [1-2, 23-24, 39]. .

7.2. Jingle-jangle fallacies related to concepts of "environments"

A division of factors contributing to CBP into biological vs. socio-cultural seems insufficient as both within-body and within-environment systems are of biological nature, and interactive and cultural factors induce neurobiological adjustments. The division of factors to within-body and environment-related is also not without flaws but at least it allows more informative setup of studies. There is, however, a conflation of several types of environments into one label of "environment", resembling jingle fallacy, as well as inconsistencies on how variables of environment could be partitioned, resembling jangle fallacy. Some researchers blend social interactions and cultural standards, but there are benefits in conceptually differentiating social environments (interactions with others – parents, peers, mates, competitors, prey, and predators, common in animals) from cultural environments (behavioural standards, values and knowledge). Moreover, factors of the physical environment influence the neurophysiology of behaviour and can contribute to CBPs. The example of COVID-19 showed that, factors in the physical environment (infection) can affect people's endurance and ability to focus (i.e., temperament traits) when people contracted COVID and increases anxiety after that (i.e., induces psychopathology), and there is not much that cultural factors can do about it [72]. Physical factors regulating CBPs depicted in Figure 2A can also include the amount of sunlight as it determines the release of hypothalamic orexins and so behavioural arousal [23], diets ([43-45]) and the use of common psychostimulants (alcohol, tobacco) .

Finally, probabilistic aspects of environments (such as novelty of events, probability of positive and negative events, estimated in/capacities to handle events (as a stress factor), commonalities and exceptions in events and object features) could be separated into different variables from cultural, socio-interactive, and physical factors of environments. Probabilistic challenges exist in behaviour of both humans and animals, and so possible to classify in translational and longitudinal studies and as conceptually different from cultural factors.

As a jangle fallacy, the way in which variables of environment could be partitioned, are inconsistent among researchers (see next section and Figure 2). Cultural training in humans leads to the development of non-biological but still consistent elements of CBPs, such as values, attitudes, national ID, religiosity, knowledge, self-image, sets of relationships, social roles. Many view these as traditional parts of personality, but others do not (see the next section). In fact, the

word "personality" came from the Latin word "*persona*", a mask worn by an actor to represent a character in a social performance [89]. These cultural components of personality make the personality concept difficult to apply to animal models or pre-cultural children.

As Figure 2 illustrates, separating physical, probabilistic, socio-interactive and cultural environments helps to identify psychophysiology-environment interactions (depicted as axes X and Y) for sex and age in a carefully differentiated and informative way (some described in this Theme Issue [7, 35, 56, 77] see also [50, 57, 72-73]. The same can be done for the separation of CBP biomarkers in their interaction with different environmental factors, as some researchers show [74, 75]. The jingle-jangle fallacies of the concepts of physical, social-interactive, and cultural environments happened probably because at the observation level, cultural impact is delivered through social interactions using physical objects and in physical environments. Delineating entangled types of environments (Figure 2A) would be similar to the approach in medicine, analytically distinguishing between cardio-vascular, respiratory and endocrine systems, even though these systems are entangled in every single act.

7.3. Jingle-jangle fallacies related to concepts of "temperament" and "personality"

The most controversial "blending" of concepts that has triggered intense discussion among the authors of this Issue relates to the concept of temperament, which is often conflated with the concept of personality. There are different views on the distinction between these terms, though all agree that socio-cultural factors interact with neurophysiological systems of behavioural regulation (Figure 2). Some authors propose that phylogenetic and ontogenetic development of brain systems (such as those that allow higher-order domain processing of sociocultural, executive, moral, and self-referential information) should be used to differentiate temperament and personality [2, 18, 41]. An analogy might be with temperament as an ever-growing trunk in a tree, whilst personality represents the diversity of branches that grow in different directions depending on the weather (i.e. socio-cultural environment). The differences between approaches stem partially from the different historic traditions in the definitions of these concepts: these differences mainly developed after the occurrence of bio-personality psychology and lexical approach in the mid-20th century. Views on the distinction between temperament and personality could be divided into the following groups:

1) The "common temperament theory" (Figure 2A, B) defines temperament as consistent biologically-based individual differences in behaviour that a) are observed in pre-cultural individuals (animals, infants), b) emerge from the beginning of life and observable before cultural training; c) are relatively consistent across life; d) relate to formal dynamic and not content aspects of actions; and e) are spontaneous, often not included in self-image [15, 18, 21-24, 35, 77]. The traits of Extraversion (E; described by Jung) and Neuroticism (N; described by Kagan [73]) were identified as temperament traits before their use in personality models [2, 6, 14, 21-24, 35, 37, 41, 56, 73, 76, 77, 80]. They indeed showed the highest associations with biomarkers even when these traits were called "personality traits" [29, 37, 41, 81], including in studies on animals [82-83].

This approach also consistently points to the distinct association of temperament with formal *dynamical* aspects of behaviour: endurance, speed of actions, ability for sustained attention, plasticity, stress reactivity/resilience, impulsivity, speed in learning [1-2, 15, 18, 21-22, 35]. Dynamical aspects of temperament (distinguished from "content" of behaviour, i.e. motives, social roles, attitudes) were identified in differential psychophysiology experiments on adult temperament conducted in Russia and Poland for decades during the 20th century [6, 10, 15, 18, 21-23, 35, 73, 80]. Temperament researchers also point to the benefits of distinguishing this

concept from personality since it allows temperament traits to be studied using animal models, following a long tradition of using the "temperament" concept in animal breeding and farming practices. Moreover, even in humans, consistent individual differences in the dynamical properties of CBPs, dispositional moods, stress resilience and behavioural orientation to mechanical or social objects, are present in very early childhood, long before cultural standards and knowledge are internalized by an individual, and thereafter during the individual's life. Temperament researchers point out that there are cultural standards and other environmental demands for dynamical (endurance, plasticity, tempo), orientational aspects (sensation seeking, empathy, probabilistic processing), and emotional reactivity of CBPs (Figure 2A). Temperament traits related to these aspects of behaviour interact with these demands, but the individual differences in these traits still remain, despite training and cultural disciplining. In this sense, interactive transformations with environments emerge as neuro-biological adjustments (for example) to stress or cultural training but individual differences in the listed aspects of temperament remain consistent in diversity of settings. Figure 2 lists some but not all temperament traits (see [1, 2] for a more complete model and Supplement for [24] comparisons of main models).

2) The "classic temperament approach" (not shown in Figure 2) includes the common temperament theory, but also draws inspiration from the original concept of "temperamentum" (as a mixture of bio-chemical fluids in the body), proposed by Hippocrates and Galen. This approach points to the contribution of neurochemical brain and body systems, immune, endocrine and gut microbiota systems [1-2, 8, 23-24, 35-39, 41-46] in CBPs. This approach differs from the first one only by the emphasis on neurochemical, neuroendocrine, neuroimmune and gut biota biomarkers of temperament. It suggests that neuroimaging should be combined with analysis of these biomarkers because different functionalities of brain areas could be linked to their different neurochemical compositions [2, 16, 24, 35, 39]. Having a neurochemical mapping of brain structures and a neurochemical model of temperament and psychopathology [1-2, 14, 16, 23-24, 29, 39, 53] (with the Functional Ensemble of Temperament model, as example [1-2, 23-24, 39]) opens up the possibility of tracing interactions between biomarkers of CBPs and physical environments.

3) "Bio-personality" psychology focuses on the individual differences that two abovementioned approaches call temperament but suggests that, while doing so noisily, modern personality scales can reflect such differences just as well as temperament scales do. This approach has emerged in mid-1950s when Eysenck offered a model, which called E and N temperament traits as "biologically-based personality traits". Such an overlap of bio-personality traits with temperament traits continued when Empathy and Sensation Seeking traits were identified in animals and were linked to specific biomarkers. This approach does not differentiate between socio-interactive (common in animals) and cultural factors (not present in animals) of environments (Figure 2C1), or between dynamical and content-related aspects of CBPs. It also does not differentiate between temperament and personality traits on the basis of the argument that in humans, temperament interacts with culture and becomes personality [18]. When the E and N temperament traits were observed in apes and monkeys, this approach attributed it to bio-personality traits, as components of the "Big Five" [82-83]. Moreover, this approach does not emphasize components of personality that depend on the cultural environment (values, attitudes, etc. – listed in the last right column of Figure 2A; and as depicted in Figure 2C1).

4) "Classic differential psychology" (Figure 2C2) considers personality as a broader concept, in comparison to the third approach and includes culturally-determined aspects of CBP

that make the behaviour of an individual consistent. These aspects include but not limited to: values, attitudes, national ID, religiosity, knowledge, self-image, set of relationships, and social roles.

5) The "lexical approach" started as a collection of all descriptors of behavioural individual differences by Allport, but the original list of these descriptors was arbitrarily reduced by removing 95%. The remaining 5% includes descriptors related to temperament (N and E), elements of cognition (as Openness to Experience in Big Five model), and traits affected by cultural standards (Figure 2C2). In the past 20 years Big Five researchers moved to studies of biomarkers associated with components of their models drifting closer to the third, bio-personality approach (Figure 2C1). Investigations using these lexically-derived models have contributed significantly to our knowledge of the universality of social perception [11, 20, 84], but progress in biobehavioural taxonomies will remain slow and unproductive if we continue relying on social perception to classify biobehavioural systems.

6) The "clinical approach" still uses the concept of personality in the names of the tests that have scales related to clinical diagnoses (for example, as in the MMPI, 16PF and CPI).

The concept of personality has, therefore, had multiple interpretations, and focused discussions on its content, including its differentiation from the concept of temperament are needed, especially in relation to the overlaps of E and N in both concepts. The arguments between temperament and bio-personality researchers also arise around the question of whether or not temperament traits could be observed, measured and separated from personality traits in humans who have a history of cultural integration of their biologically-based differences. Temperament researchers suggest that cultural standards produces behavioural strategies to meet these standards, but the individual differences in dynamical features of CBPs (e.g. endurance, plasticity or emotional reactivity) remain and constitute temperament traits. In fact, a dozen temperament traits appear to be identifiable by proper measurements [15, 53, 73, see Supplement in [24] for comparisons of temperament models], but development of behavioural methods is needed. Some studies showed that personality traits could be based on combinations of temperament traits [80], and temperament traits of endurance, tempo and neuroticism differentially impact the way how people attribute meaning to cultural constructs [84].

Moreover, there is a disagreement between these approaches on the degree, to which culture can change temperament and personality traits. Temperament researchers point to consistent individual differences in individuals exposed to the same cultural influences or stresses, and bio-personality researchers point to brain plasticity in response to cultural influences. Development of compensatory behavioural strategies under these influences decreases the deviation of CBPs from culturally expected norms but does not eliminate temperament differences. Also, temperament researchers point to the benefits of screening for temperament traits susceptible to the influences the factors of physical environments (exposure to sunlight, infections, toxins, novelty, variability) [72, 74-75]. COVID-19 symptoms are the example of the negative impact of this infection on physical endurance (as fatigue), mental endurance ("covid fog", inability to focus) and emotional sensitivity (increased symptoms of anxiety) [72].

Overall, a proper differentiation between concepts helps to define variables used in tracing the interactions between parameters of psychophysiology (depicted in an abstract way as Y-axis, Figure 2) and types of environments (X-axis, Figure 2). The diversity of opinions illustrates a need for conceptual clarity, not only for healthy but also for psychiatric CBPs. Phenotypes defined by the current psychiatric classification systems are also highly heterogeneous, and co-

morbidity is highly prevalent [3-5, 21]. The "simple" matter of picking and labelling a CBP appears to be neither straight-forward nor harmless. The way CBPs are partitioned (divided) into concepts and categories affects not only theories but also their operationalization in assessment tools or as variables in experiments and mathematical modeling. [2-6, 9-10, 19, 21]. Several directions for "what's next" for language biases and conceptual parcing are identified in Table 2.

8. Mathematics and psychometrics are the tools but not the leading advisers for taxonomic principles and biomarkers

There is a common belief among many practitioners and researchers, that measurement tools in psychology and psychiatry are well-tuned, universally applicable and measure what they claim to measure, just like tools in engineering, physics or chemistry. Meanwhile, there are multiple complaints about the low reproducibility and reliability of measurements in behavioral sciences [3-5, 9-10].

The complexity and variability of the phenomena that our tools are meant to measure certainly contribute to the challenge of reproducibility; however, there are several ways to handle this problem (Table 2). Much criticism in the biobehavioural sciences is directed to self-reports (questionnaires) and their dependence on their author's theories and arbitrary choices of items. The fundamental problem here, however, is not the self-reporting aspect of questionnaires but rather the lack of a scientific foundation of their association with biological entities [3, 10, IT]. After all, self-report is commonly used to access individual experience in many experimental methods (e.g., measurement of perception thresholds, assessment of emotional states), or documentation of psychiatric symptoms.

Main problem of assessment methods (including self-reports) is that they are the end product of the author's understanding (theories), and so ambiguities or deficiencies in these theories can compromise the resulting measurement tools. There are very few psychometric tests that have been validated with behavioural and psychophysiological markers (mostly methods for intelligence and neuropsychological assessments). Practically none of the self-report scales (with the exception of the STQ, derived from neurophysiological studies [15]) were validated this way. Instead, psychometricians are more concerned with "evidence" from confirmatory factor analysis criteria to pass a test, no matter how dubious the test items might be. To improve the quality of psychological assessment, it might be wise to shift the weight of requirements more to content validity of the scales (verifying it by complementary behavioural measures) and to differential validity (confirming the absence of correlations with unrelated aspects of behaviour).

Meanwhile, the historic preference for independence (orthogonality) of scales (whether in self-reports or testing batteries, as in intelligence testing) and the inherent difficulty of determining dimensionality limits the applicability of psychometrically derived taxonomies. [10, 18]. It is well-known that CBP biomarkers, whether brain structures or neurochemical systems, have multiple feedback loops that are contingent on each other's status and possess specific functionality, and, therefore, are partially interdependent.

Linearity in most statistical and psychometric methods is another problem. Regardless of whether a "nonlinear" or "Hierarchical" model is offered in factor-analytic (FA) studies, the analyses are based on matrices of linear correlations, whereas almost all psychological processes show nonlinearity in their associations [10, 18-19, 85]. Psychometrics provides instruments for our measurements, but cannot substitute analytic work required for hypothesis building. All of this suggests that too much trust in the past was given to psychometrics for proving or disproving proposed associations, whilst there has been too little education on the boundaries of psychometrics [3, 10, 18].

The consequences of employing simplistic or heterogeneous variables and of the limitations in our theories show up even when we move away from self-reports to using biomarkers. Neuroimaging reports also have low test-retest reliability [4-5, 9, 17, 33], and if variables relate to heterogeneous, poorly defined variables (such as extraversion or PTSD), this can contribute to poor replicability, especially in using fMRI [4, 17]. Due to overlaps between responsiveness of the brain regions to different CBPs, they provide little information about the underlying neural processes even though structural MRI can assist in causal explanations of CBPs when it is coupled with well-defined neurological variables. There is ongoing work of cataloguing 1:1 associations between biomarkers and CBPs [51]; however a simple collection of such associations would lead to the modest outcomes similar to the outcomes of the human genome project. It will provide massive information that triggers more questions than answers; that cannot be a desirable end point. We should work more on the evolutionary, systemic and functional principles helping us to classify the numerous CBP-biomarker associations.

More attention should be paid to the fact that biomarkers and CBPs could be classified at several levels of analysis (genes, their transcription factors and enzymes, hormonal and other neuroendocrine regulation, brain neurotransmitters and their receptors, temperament traits, more culturally-affected aspects of CBPs). Jumping over the levels of biobehavioural regulation (for example, measuring genes as possible correlates of culturally-affected components of personality and not temperament traits), might be a cause of the low replicability of results. As Brandt and Mueller noted, there might be a double-gap problem: one between the observed biological variable and the theoretical psychological process and one between the theoretical psychological process and the observed trait variable. In gene-personality investigations, associations between phenomena are probably mediated by too many intermediate psychophysiological and cultural factors. In contrast to personality traits, temperament traits - such as neuroticism, plasticity, endurance or impulsivity, have more potential for consistent associations with biomarkers [1-2, 7, 9, 17, 23, 35-38, 41, 53, 61, 73, 81, 89]. When conducting genetic studies of CBPs, therefore, it may be more straight-forward to use more neurochemically-based CBPs, such as temperament traits or symptoms of psychiatric disorders. Also, there should be more discussions about the formal analysis of gene-environment interaction [21, 33, 50, 89].

Mathematical, statistical and machine learning methods, while useful, are limited in capacity to represent complex transient phenomena, such as CBPs [1, 10, 17], and are only as good as the measurement tools. Merely performing calculations with arbitrary variables will not be fruitful. Thus, work is needed to "clean up" the content of variables and hypotheses. Alternative multivariate mathematical approaches, such as nonlinear methods, time series, Bayesian, and stochastic models, are currently being explored. These methods might help in dealing with context-dependence and variability of CBPs [5, 10, 54, 86-87]. Ensemble-like models such as process algebra [cited in 10, 19, 54] and functional constructivism [2, 24] have been proposed for the systematic analysis of functional relationships between biomarkers and individual-environment interaction [2, 5, 36]. However, these are all works in progress because current number systems can process only repetitive occurrences with defined parameters but not one-time occurrences, in which features emerge and disappear.[1-2, 10]

There is also a disconnect between training in neuroscience and psychology, which leads to misconceptions in neuroscience as to how psychological phenomena form CBP (mostly in behaviourist language) and misconceptions in psychology as to how the nervous system operates [1].

9. International cooperation and perspective methods

Research during the past century revealed the complexity and diversity of CBP, their contextuality, clinical, ontogenetic, inter-species continua, as well as variance coming from biochemical environmental factors (climates, diets, exposure to toxins, psychostimulants). Moreover, as noted above, biomarkers of CBP appear to involve not only the brain, but also neuro-immune, enteric, and endocrine systems. Multidisciplinary study of these systems and their dynamics is needed to arrive at a proper classification of CBP for healthy bio-behavioural traits and symptoms of psychopathology.

International cooperation and a structured approach to "big data" is, therefore, the next necessary step in this line of research. It is essential that future international projects consider approaches, methods and aspects of such cooperation listed in Table 1 and 2

10. Conclusions

To summarize, as a perspective on "what's next" in the development of CBP taxonomies, there is a consensus that this work cannot progress if psychology and psychiatry continue looping around the poorly defined and overlapping concepts within these sciences. Instead, multidisciplinary cooperation and adaptation of knowledge from other sciences is needed in the form of joint discussions, advanced study schools for specialists, forums, research, publications and online platforms. The need for a science of biomarkers underlying behavioural regulation and specific CBPs exists not just in terms of brain neuroimaging studies, but also in relation to other systems, such as endocrine, enteric and immune systems, and their interactions with brain neurochemistry. In addition to experimental research, analytic discussions should be expanded to generate testable theories and identify principles underlying these interactions, along with new methods for their analysis.

Several such principles have been identified, but have not yet been properly incorporated into the structure of psychiatric and psychological classifications: a continuum between health and psychopathology; an ontogenetic continuum; the importance of the context-dependence and intra-individual variability of behaviour; species-ecological continua explored through research using animals; sex/gender related variables; the constructive nature of behaviour; the contributions of regional environmental biochemical factors (e.g. amount of sunlight, diets and use of psychostimulants). A few of these principles are illustrated in Figures 1 and 2.

The history of physics, chemistry, biology and medicine demonstrates that it takes time to derive adequate taxonomies and their appropriate organizing principles. The multiplicity and complexity of the systems contributing to the consistency of behavioural patterns, the high transience and complexity of consistent behavioural patterns that differential psychology and psychiatry attempt to classify, suggest that there is still a long road ahead. The good news from this paper, then, is that we have reached a point where we can agree on our disagreements and so have taken the first step to solving them. More importantly this capacity to disagree rests on a substantial consensus and much common language that should provide a solid foundation for future work.

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Table 1. "What's Next" is needed for organizing and "continua" principles in CBP taxonomies

"What"	"How" for directions of analytic work	"How" for directions in research setups and measurement
Organizing principles of taxonomies Outlining hypotheses for CBP-biomarker associations Attention to biomarkers **beyond brain structure**s /beyond neuro-imaging	• Round tables between representatives of opposing theories of the organizing principles for taxonomies. • Creation of special sections in peer-reviewed journals for "competing hypotheses" of CBP-biomarker associations with side-by-side publications of opponents' and/or joint (between opponents) articles. • Requirement for alternative models and hypotheses to generate predictions instead of merely exploratory gathering of associations [9], and to explain outliers and negative results. • Division of the current Task Force (RDoC) [51] into *"topical"* streams (i.e. groups focused on either neuroimaging, or neurochemistry, or gut microbiota or neuroimmunology) and *"bridging"* streams integrating the topical findings. • Advanced Study Institutes (summer schools) for specialists from different biobehavioural sciences to teach each other most modern knowledge in their fields, and facilitate future multidisciplinary projects.	• An organized discussion of potential multimodal/multi-marker research setups where not one but several biomarkers (either several brain areas, neurotransmitter systems or gut-brain interactions) are investigated [2, 5, 4, 8, 17, 36, 41, 56] using various statistical approaches ([5, 10, 37]). • Organization of an online platform using interactive technology similar to Wikipedia and ArXiv, where alternative hypotheses are debated (with proposed name "Socrates", to underline the analytic, debate-oriented nature of this project). • Transparency of the work on taxonomies to the wide academic community with possible involvement of alternative multidisciplinary teams (using proposed platforms of Socrates and Hippocrates), instead of keeping the creative process within "closed clubs" of chosen scientists. • More prominent courses teaching neuroscience and measurement theory in psychology programs. • An international project (online platform) focused on "fluid" CBP biomarkers (neurochemical, endocrine, microbiota and psycho-immune), with proposed name "Hippocrates", honouring the author of the idea of biochemical origin of temperament. This platform could facilitate work on hypotheses, setups and coordination of research, funds raising and data exchange [1, 41]. • Genetic studies [8] of temperament traits since these traits represent neurochemically based regulation of behaviour [1, 23, 35-37, 62, 81] • Calls, with awards, for new insights into possible creative methodologies for non-invasive neurochemical research. • Multidisciplinary bridging using highly educated "scientific interpreters" who would adopt/translate knowledge between disciplines; more welcoming environment for "specialists-outsiders" coming from different disciplines.
Accommodation of the concepts of **clinical and ontogenetic** continua in taxonomies	• A topical Task Force offering new formalisms to handle the clinical-health and ontogenetic continua and CBP transitions along these continua. • Organization of round tables, Theme Issues of peer reviewed journals and discussions of offered formalisms (e.g. functional constructivism) [1, 2, 5, 10].	• Applying the same setups across clinical versus healthy samples matched by age and sex [4]. • Multi-generational cohort studies allowing natural experiments [56, 77]. • Formal, evidence-based structuring of information about professional and personal histories, consistent elements of everyday functioning (using reliable sources and not retrospective recall) to be incorporated into diagnostic criteria and assessment tools. • Investigations of the role of maternal psychophysiology on infant CBPs [7,56]

Table 2. "What's Next" related to contextuality, inter-species comparisons and conceptual parcing in CBP taxonomies

"What"	"How" for analytic work	"How" for directions in research setups and measurement
Consideration of **inter-species** continuum to improve studies using animal models	Evolutionary analysis and integration of animal (translational) studies to validate the organizing principles of CBP taxonomies including functional ecology of the tasks/contexts comparable between studied species.	• In human studies, dividing "socio-cultural" variables into "socio-interactive", "probabilistic" and "cultural", to improve compatibility with animal studies of socio-interactive (predator-prey, child-parent, dominance, group dynamics) and probabilistic (novelty, uncertainty) aspects of CBP (Figure 2). • Animal studies with behavioural tasks compatible with human temperament models to study culture-independent aspects of behaviour [7, 10, 61, 76]
Addressing the problem of significant **context**-induced variability of CBPs (Fig. 1)	• A topical Task Force on taxonomy /typology of contexts, with organization of round tables and Theme Issues of scientific journals. • Classification of the degree of individual's involvement, dependence on and access to informational and provisional resources, and to social- cultural infrastructure.	• Multi-regional international research project enabling comparisons of the impact of environmental biochemical factors (climates, diets, exposure to toxins and psychostimulants), probabilistic (e.g. uncertainty, forced changes inducing stress), socio-interactive and cultural factors contributing to CBPs. • A call for new formalisms and measurement approaches accommodating behavioural variability as a function of context [1-2, 5, 10]. • Continuous psychophysiological tracking for periods of time instead of single experimental measurements, to study interactions between CBP, consistent environmental and situational factors in everyday behaviour
A **conceptual decluttering** of specific CBP concepts and measures	• Addressing jingle-jangle fallacies in CBP concepts and associated assessment measures • Sorting out the conceptual disagreements among temperament and bio-personality researchers using a possible Socrates platform	• Resolving conceptual disagreements among temperament and bio-personality researchers related to: a) whether or not Neuroticism and Extraversion should be called temperament traits (as described originally) or personality traits (as referred in trait-personality psychology); b) can bio-personality group be integrated with temperament group? c) what is CBP consistency in light of brain plasticity under environmental (including cultural) factors? d) what is the best setup for a study that would delineate temperament and personality traits?
Statistical and/or mathematical approaches	• Organization of "reflections" round tables and journal Theme Issues systematically reviewing new or recent mathematical, statistical and measurement approaches, to make progress in this area more visible. • Calls for new formalisms, statistical or mathematical approaches for **multi-marker** interactions.	• In psychometrics, giving more weights to neuroscience-based justifications of the psychological measurement tools rather than to FA results. • Delineation of biomarkers that capture the modulatory effects of *continuous* changes in stimulus intensity/difficulty rather than binary (*contrast*) conditions [4] • Use of larger cohorts with independent samples [8, 9, 56] to ensure sufficient power, critical reflection of the collected measures, a more stringent testing • Evidence-based quantification and standardization of questions regarding individual's functioning in observer-based measures (e.g. parents to assess children, family members to assess elderly or disables) [21, 56] • Development of behavioural and quantitative methods [27, 37, 78]

Figure 1. Biobehavioural classifications should accommodate principles described in this paper, among which are clinical and ontogenetic continua; sex differences and context dependence (black arrows symbolize the affect of these factors on psychological measurement). The structure of DSM/ICD and many personality and temperament models, however, do not accommodate these principles, and this affects assessment tools and assessment outcomes.

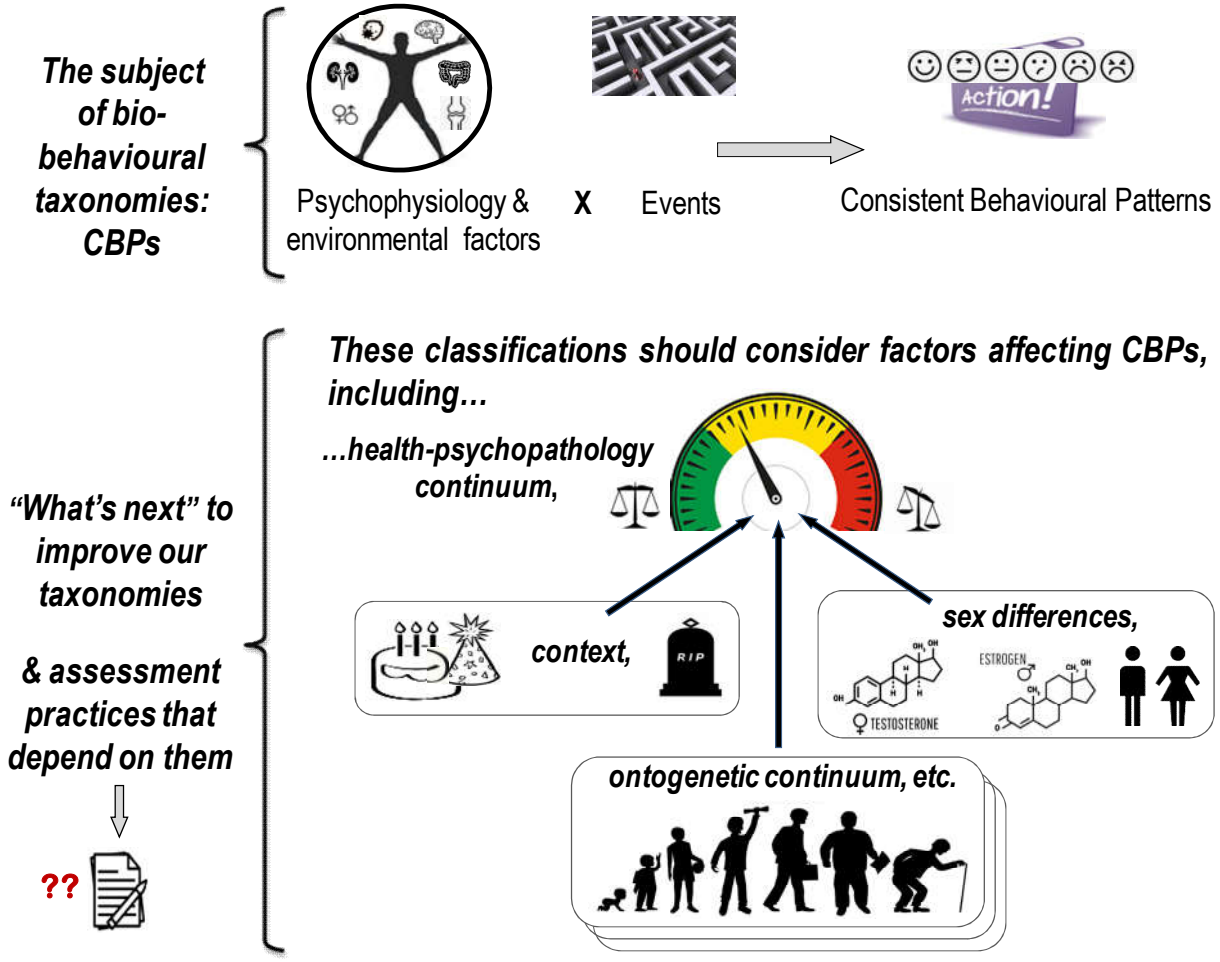
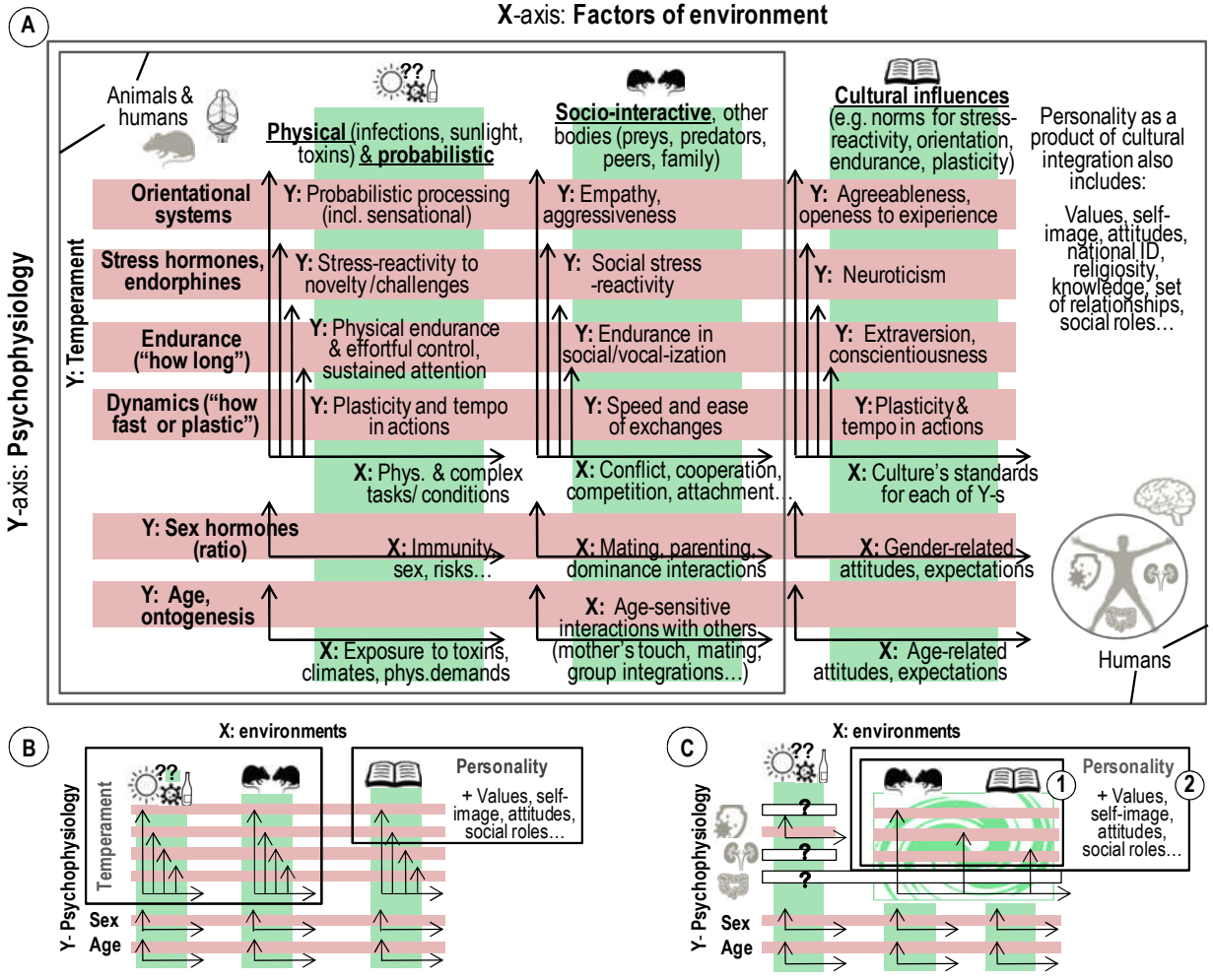


Figure 2. Illustration of different approaches to the definitions of temperament and personality and the use of these concepts to study associations between different types of environment (axis X, named in part A and depicted graphically in parts B and C) and three concepts reflecting psychophysiological systems (axis Y). To save space, physical and probabilistic factors of environment are grouped in one column, and the grouping of temperament or personality traits do not follow any particular model. Some models, for example, consider neuroticism (emotionality) as part of orientation [1, 2, 15] whereas others as a trait independent from orientation (for a comparison of temperament models see Supplement in [24]). **A:** A separation between socio-interactive and cultural factors of environment shows its benefits not just for sex and age studies but also in studies of temperament and personality. Rectangular shapes show the overlap and differences in X*Y processes in behaviour of animals and humans. The overlap opens perspectives for translational (animal) studies applicable for interpretation in humans, with careful consideration of functional ecology of studied animals. **B:** Temperament researchers' and **C:** two personality researchers views on the division between the concepts of temperament and personality marked by rectangular shapes. Both personality approaches do not differentiate between socio-interactive and cultural factors, overlap E and N personality traits with temperament traits of sociability and emotional reactivity and do not consider traits related to dynamics of behaviour (such as plasticity) as part of personality. Bio-personality view (C-1), in contrast to classic personality view (C-2) also does not include a list of characteristics in the last column (values… social roles) in personality. See Section 7 for details. Yet, temperament traits related to endurance, plasticity and stress reactivity in actions could be measured directly in behaviour and differentiate between healthy and clinical CBPs [1-2, 53] and so should be a part of biobehavioural taxonomies. X * Y graphs: more detailed presentation of parameters in temperament models allows more detailed and differentiated investigation of interaction between individual's psychophysiology and environments.


A
X-axis: Factors of environment
Y-axis: Psychophysiology
Animals & humans
Physical (infections, sunlight, toxins) & probabilistic
Socio-interactive, other bodies (preys, predators, peers, family)
Cultural influences (e.g. norms for stress-reactivity, orientation, endurance, plasticity)
Personality as a product of cultural integration also includes:
Values, self-image, attitudes, national ID, religiosity, knowledge, set of relationships, social roles…
Y: Temperament
Orientational systems
Y: Probabilistic processing (incl. sensational)
Y: Empathy, aggressiveness
Y: Agreeableness, openess to exiperience
Stress hormones, endorphines
Y: Stress-reactivity to novelty/challenges
Y: Social stress -reactivity
Y: Neuroticism
Endurance ("how long")
Y: Physical endurance & effortful control, sustained attention
Y: Endurance in social/vocal-ization
Y: Extraversion, conscientiousness
Dynamics ("how fast or plastic")
Y: Plasticity and tempo in actions
Y: Speed and ease of exchanges
Y: Plasticity & tempo in actions
X: Phys. & complex tasks/ conditions
X: Conflict, cooperation, competition, attachment…
X: Culture's standards for each of Y-s
Y: Sex hormones (ratio)
X: Immunity, sex, risks…
X: Mating, parenting, dominance interactions
X: Gender-related attitudes, expectations
Y: Age, ontogenesis
X: Age-sensitive interactions with others (mother's touch, mating, group integrations…)
X: Exposure to toxins, climates, phys.demands
X: Age-related attitudes, expectations
Humans
B
X: environments
Y- Psychophysiology
Temperament
Sex
Age
Personality
+ Values, self-image, attitudes, social roles…
C
X: environments
Y- Psychophysiology
Sex
Age
Personality
+ Values, self-image, attitudes, social roles…
1
2