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Understanding the Role of Conscientiousness in Healthy Aging: Where Does the Brain Come In?

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In reviewing this impressive series of articles, I was struck by 2 points in particular: (a) the fact that the empirically oriented articles focused on analyses of data from very large samples, with the articles by Friedman, Kern, Hampson, and Duckworth (2014) and Kern, Hampson, Goldbert, and Friedman (2014) highlighting an approach to merging existing data sets through use of "metric bridges" to address key questions not addressable through 1 data set alone, and (b) the fact that the articles as a whole included limited mention of neuroscientific (i.e., brain research) concepts, methods, and findings. One likely reason for the lack of reference to brain-oriented work is the persisting gap between smaller sample size lab-experimental and larger sample size multivariate-correlational approaches to psychological research. As a strategy for addressing this gap and bringing a distinct neuroscientific component to the National Institute on Aging's conscientiousness and health initiative, I suggest that the metric bridging approach highlighted by Friedman and colleagues could be used to connect existing large-scale data sets containing both neurophysiological variables and measures of individual difference constructs to other data sets containing richer arrays of nonphysiological variables—including data from longitudinal or twin studies focusing on personality and health-related outcomes (e.g., Terman Life Cycle study and Hawaii longitudinal studies, as described in the article by Kern et al., 2014).

Keywords: conscientiousness, health, neuroscience, disinhibition, psychoneurometric approach

I appreciated having the opportunity to review this impressive series of articles, which effectively showcase advances in the understanding of relations between the personality construct of conscientiousness and health in various forms and provide valuable perspective on directions along which further advances are likely to be made. The articles cover a broad range of ground, from basic personality concepts to lifespan-developmental and behavioral–molecular genetic work to conceptually informed intervention strategies, and are uniformly thorough and scholarly. I learned a great deal from reading these articles and strongly recommend them to others interested in individual difference variables important to health and positive aging.

Notably, one topic emphasized to a limited degree in these articles consists of conceptual and empirical work on the role of brain systems in processes such as cognitive control, response inhibition, and goal setting of relevance to conscientious tendencies. Some articles contain reference to biological and brain systems (e.g., Friedman, Kern, Hampson, & Duckworth's, 2014, life-span model includes *biological base* and *physiology* components; Eisenberg, Duckworth, Spinrad, & Valiente's, 2014, developmental review cites work on neural systems presumed to be involved in effortful control). However, references of this kind are quite brief, resulting in limited coverage of neuroscientific concepts, methods, and findings. By contrast, one entire article (South & Krueger, 2014) is devoted to genetic approaches to investigating links between conscientiousness and healthy aging, and genetic findings and approaches are also discussed to a notable degree in the articles by Eisenberg et al. (2014); Friedman et al. (2014); and Roberts, Lejuez, Krueger, Richards, and Hill (2014).

The lack of reference to brain-oriented research in these articles was striking to me because my core interests lie in psychophysiological and neuroscientific approaches to the study of clinical problems and also because of the major initiative that has been launched by the National Institute of Mental Health to establish new conceptions of psychological disorders based around biological (in particular, neurobiological) methods and findings. Titled the *research domain criteria* (RDoC) framework, the initiative's goal is to "devise a system for identifying and integrating constructs for disordered cognitive, neural, genetic, or epigenetic processes that hold particular promise to [explain] psychiatric symptoms" (Sanislow et al., 2010). A particular focus of the initiative is on characterizing neural circuits relevant to psychological dysfunction and the role they play in observed symptoms. However, the RDoC framework as a whole is broader, spanning multiple levels of analysis from the genetic and cellular levels to the level of measurable behavior in laboratory and naturalistic settings (see the RDoC matrix, accessible online at http://www.nimh.nih.gov/research-priorities/rdoc/nimh-research-domain-criteria-rdoc.shtml#toc_matrix).

It seems likely that differing factors account for the limited coverage of neuroscientific research in the current series of articles. However, I suspect the main one is that neuroscientific research, including human work directed at processes of potential relevance to trait dispositions like conscientiousness, does not interface readily with the types of designs and databases that help make the current series of articles so impressive. Specifically,

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much of the work reviewed in this series (including the article by South & Krueger, 2014, on genetic methods and findings) consists of large sample size, etiologically informative studies using sophisticated analytic techniques to delineate replicable predictive relations between individual-difference variables and real-world behavioral outcomes of importance. Particularly inspiring in this respect were the conceptual article by Friedman et al. (2014), which describes an approach for combining existing databases to address larger scale questions that transcend the limits of individual study data sets, and the accompanying empirical article by Kern, Hampson, Goldbert, and Friedman (2014), which provides an illustration of the power of this approach.

By contrast, human neuroscientific research on clinical problems and related dispositions has traditionally used experimental designs focusing on small samples (e.g., 100 or less) with limited availability of collateral measures for characterizing participants, owing to logistic factors, including time demands of physiological testing. Further, work of this type has tended to focus on average effects for groups of individuals preselected to differ on clinical or dispositional variables, such that a continuous range of variability on individual difference factors of interest is often not represented. Reliance on small samples and select groups has been the norm for neuroimaging studies in particular, due to the high costs per participant and constraints on equipment usage (i.e., at many sites, a single scanner serves multiple investigative groups). Brain measures of other types (e.g., electrocortical) have been included more often in larger sample studies focusing on clinical problems or dispositional variables (for exceptions, see, e.g., Anokhin, Golosheykin, & Heath, 2008; Iacono, Carlson, Taylor, Elkins, & McGue, 1999; Posthuma, Neale, Boomsma, & de Geus, 2001), but studies of this type with samples of 1,000 or more and including multiple individual difference measures are not common. For these reasons, comparatively little is known about the psychometric properties of neurophysiological variables as indicators of traits and trait-related processes, relative to variables from other domains of assessment (e.g., self-report, other rating; cf. Patrick et al., 2013; see also Cronbach, 1957).

Given this state of affairs, few neurophysiological data sets exist that can be effectively integrated into the types of large-scale empirical-analytic frameworks featured in the articles of this special section. Consequently, conceptions of the role of neural systems and processes in causal paths modeled within frameworks of this sort are necessarily based on leaps of inference rather than quantitative-empirical specification. And, in turn, ideas about how to incorporate neurobiological findings into intervention strategies for altering dispositional tendencies to improve health outcomes are largely speculative. This makes behavioral or self-report indicators of psychological constructs with known links to outcomes more attractive and defensible as referents for designing treatments and evaluating their effectiveness.

In other words, there are good reasons to be cautious about characterizing the role that brain systems play, across development, in tendencies such as conscientiousness that are predictive of health outcomes. How can this knowledge gap be addressed? The National Institute of Mental Health's RDoC initiative, which focuses on ground-up construction of alternative conceptions for linking clinical outcomes to biological (including neural) systems, may serve as one route. However, an alternative approach that could be pursued in parallel with others such as RDoC—entailing incorporation of neurophysiological indicators into already-existing databases and future data collection efforts—is suggested by the current series of articles. In what follows, I briefly describe this alternative approach with reference to articles in this series and other recent developments in the field, and I present some specific examples of its implementation suggested by the current articles.

Extending Emerging Data Networks to Include Neurophysiological Indicators

The article by Friedman et al. (2014) in the current series serves to illustrate a potentially powerful strategy that could be used to systematically advance the understanding of the role of neurobiological systems in relations between dispositional variables such as conscientiousness in health and aging and the etiologic basis of those relations. Friedman et al. discussed the idea of a theory-based collaborative network for coordinating measures and combining data across differing longitudinal studies by establishing "metric bridges" in the form of converging operationalizations of target constructs, allowing for integrated analyses of data from multiple studies. This approach differs from the well-known approach of meta-analysis in that it provides for analyses at the level of individual participants (and perhaps, by extension, for the derivation of norms for interpretation of individual-level scores) as opposed to focusing on aggregate effects. Drawing on the classic idea that psychological constructs transcend specific observed-variable operationalizations (cf. Cronbach & Meehl, 1955; Loevinger, 1957), the approach recognizes that the network of relations among construct units within a particular study can be linked to networks of relations in other studies if sufficient overlaps exists among units across the differing study networks. It is important to note, per construct-network theory, that variable operationalizations need not be identical across studies to allow for linkages—only sufficiently similar to establish that variables index common constructs.

The accompanying article by Kern et al. (2014) provides a highly effective illustration of this strategy by demonstrating how two separate longitudinal data sets could be linked through non-identical but demonstrably similar operationalizations of the five-factor personality constructs, assembled from differing sets of trait-variable indicators. Analyses were then performed on the aggregate of the two data sets to address questions not addressable through the use of one data set alone. Notably, Kern et al. also highlighted potential limits to convergence across data sets that can be evaluated quantitatively (e.g., through tests of measurement invariance).

The collaborative network approach proposed by Friedman et al. (2014) and illustrated by Kern et al. (2014) could be extended to incorporate data sets containing neurophysiological (including electrocortical and neuroimaging) variables. What is needed are large-scale data sets containing variables of these types along with established indicators of individual difference constructs than can be used to establish metric bridges (cf. Friedman et al., 2014) to other study data sets containing richer arrays of nonphysiological variables—including data from longitudinal or twin studies focusing on health-related outcomes. Some large data sets do exist that contain neurophysiological along with dispositional and clinical outcome variables, including longitudinal-twin data sets (e.g., Iacono et al., 1999; Trouton, Spinath, & Plomin, 2002), that could

serve as starting points for linking efforts along these lines (see also Gordon, 2003, and http://www.brainnet.net/). Notably, a National Institutes of Health–sponsored resource exists to facilitate access to data from large-scale studies focusing on relations between genes and clinical phenotypes of differing types (Mailman et al., 2007; see http://www.ncbi.nlm.nih.gov/gap), and investigative consortia have been established for the broader purpose of delineating linkages across multiple levels of analysis (from genomic to brain cellular to psychological processes to behavior expression) in the study of psychological disorders (cf. Bilder, Howe, & Sabb, 2013).

However, as noted earlier, important challenges need to be addressed in attempting to integrate neuroscientific concepts and measures into individual differences assessment. Referents for individual difference constructs have traditionally been nonphysiological—that is, self-report variables in many instances (e.g., scores on tests of personality or interests) and performance-based variables in others (e.g., scores on tests of ability or knowledge). Contemporary models of personality include references to neurobiological systems, but the models themselves are based primarily on self-report data, with ideas about their connections to neurobiology formulated subsequently. Further, little systematic research has been done to evaluate the psychometric properties of physiological variables as individual difference measures. Two consequences of this existing state of affairs are that (a) physiological variables can be expected to correlate only modestly with individual difference characteristics as currently measured (cf. Campbell & Fiske, 1959) and (b) existing conceptions of individual differences tend to persist unaltered, rather than being reshaped by neurobiological findings.

A strategy for addressing these challenges predicated on the notion of psychological attributes as constructs that transcend specific domains of measurement is the *psychoneurometric* approach (Patrick et al., 2012, 2013). Figure 1 depicts this approach as applied to the trait construct of inhibitory control (denoted *Cont* in the figure), described further just below. The approach entails identifying reliable physiological indicators ($Phys_{var1}$, $Phys_{var2}$, etc.) of a target construct operationalized *psychometrically* (e.g., via a self-report scale measure) and then mapping interrelations among the differing physiological indicators of the construct, in order to (a) establish a statistically reliable *neurometric* measure of inhibitory control ($Cont_{neurometric}$) and (b) clarify brain circuitry and processes associated with individual differences in inhibitory control. Knowledge gained about the convergence of physiological indicators from differing experimental tasks and the brain mechanisms underlying this convergence in turn feeds back into conceptualization and psychometric measurement of the target constructs (large curved arrow on left side of figure). This process continues iteratively until a coherent set of neurometric tasks and measures exists for assessing the target construct reliably and effectively. Through this back-and-forth process, the original self-report-based conception of the trait shifts to accommodate findings for the physiological indicators.

Inhibitory Control as a Bridging Construct

The individual difference construct of inhibitory control, entailing variations in the tendency to restrain versus express impulses and emotions, is present in many theories of personality and

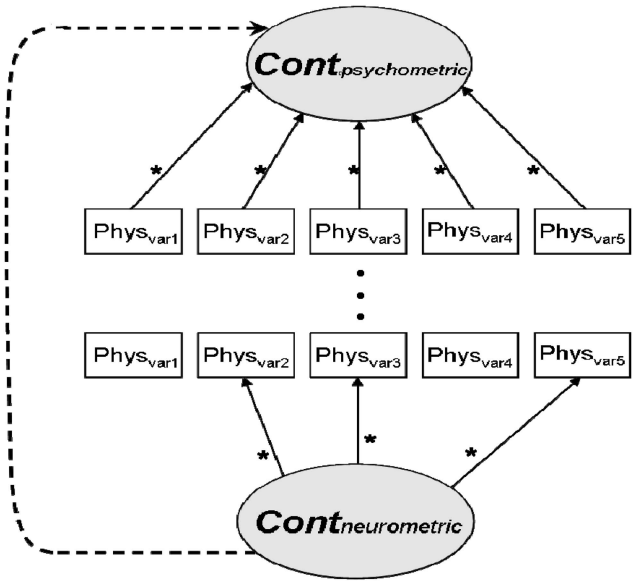

Figure 1. Schematic depiction of the psychoneurometric approach as applied to target construct of inhibitory control (*Cont*). Circles denote constructs operationalized as factors/factor scales, rectangles denote physiological (phys) indicator variables (var), and asterisks denote physiological indicators with significant loadings on factors.

development—and, as highlighted in the article by Roberts et al. (2014) in the current series, is considered part of the domain of conscientiousness. The construct also has clear referents in neurobiology. In particular, anterior brain structures including the prefrontal cortex (PFC) and anterior cingulate cortex (ACC) appear crucial for inhibitory control, with the PFC theorized to govern top-down processing (i.e., guidance of behavior on the basis of internal goal representations) and the ACC posited to invoke control functions of the PFC as needed to resolve conflict or uncertainty (Miller & Cohen, 2001). Regarding individual differences in these systems, recent cognitive science research has demonstrated that scores on cognitive control tasks of various types (i.e., memory updating, set shifting, response inhibition) load together on a common executive function factor (Miyake & Friedman, 2012) and that scores on this factor contain a substantial component of heritable variance that overlaps with heritable variance in disinhibitory problems as indexed by clinical interview (genetic $r \sim -.6$; Young et al., 2009).

As such, the construct of inhibitory control could serve as a valuable target for research aimed at connecting psychological conceptions of conscientiousness to brain systems and processes theorized to mediate behavioral control in the service of goals. As a foundation for work along this line in adults, a detailed measurement model exists for this construct as relevant to health outcomes in the form of the externalizing spectrum model and inventory (Krueger, Markon, Patrick, Benning, & Kramer, 2007; Patrick, Kramer, Krueger, & Markon, 2013). Scores on the general factor of the externalizing spectrum inventory, reflecting dispositional inhibition–disinhibition, show robust associations with a range of clinical outcome variables, including conduct problems in childhood, adult antisocial deviance, other personality pathology, alcoholism, and drug dependence (Patrick, Durbin, & Moser,

2012), and with general disinhibitory problems as assessed by clinical interview (Yancey, Venables, Hicks, & Patrick, 2013)—which, as noted above, covary genetically with executive capacity as indexed by cognitive tasks (Young et al., 2009). Scores on this general factor, which can be indexed using a brief item-based scale (i.e., 20 items; Patrick et al., 2013), also show robust associations with traits connected to the broad construct of conscientiousness (Patrick et al., 2013; Venables & Patrick, 2012).

Multiple brain response indicators of inhibition–disinhibition as indexed by the externalizing spectrum inventory have also been identified, including differing variants of the well-known P300 response to salient task stimuli (known to covary as well with interview-assessed disinhibitory problems; Patrick et al., 2006) and the cortical error-related negativity reflecting online recognition of mistakes in performance—and these differing brain indicators show convergence with one another (Nelson, Patrick, & Bernat, 2011). Given this convergence, it is possible to extract a common brain-response (i.e., neurometric; cf. Figure 1) factor from these indicators that predicts to clinical criterion variables (e.g., antisocial behavior or substance dependence symptoms) as well as to separate measures of brain response (Nelson et al., 2011; Patrick et al., 2013). Work of this kind serves to illustrate how the neurobehavioral construct of inhibitory control can serve as a vehicle for interconnecting self-reported dispositions, neurobiological systems and processes, and health-related outcomes.

Establishing Databases for Neurobiological Research on Trait Dispositions and Health

Systematic efforts are needed at the agency level to encourage investigators to capitalize on opportunities to integrate already-existing large sample size neurophysiological data sets with data from other existing studies to address novel questions regarding the brain's role in personality–health relationships and to create new data sets containing neurophysiological measures along with variables selected to serve as metric bridges to data from existing etiologically informative and treatment-oriented studies. Extrapolating from the approach described by Friedman et al. (2014), one can envision coordinated efforts to establish an integrated network of databases, including longitudinal and twin participant databases, containing metric bridges consisting of variables from multiple assessment domains (i.e., neurophysiological as well as behavioral and report based) to facilitate linkages at differing levels of analysis. For example, less costly electrocortical measures in two separate samples could serve as a bridge to analytic use of neuroimaging data available for only one of the samples—in the manner illustrated by Kern et al. (2014) for cardiac measures, available in only one of their two longitudinal samples.

It seems appropriate for the National Institute on Aging to serve as a facilitator of efforts along this line, given its mission to elucidate processes at differing levels of analysis contributing to optimal health across the lifespan. Articles in the current special series suggest fruitful avenues to pursue. As one example, the article by South and Krueger (2014) uses data from a twin sample to demonstrate differential contributions of genetic and environmental influence to alcohol problems as a function of differing levels along the trait continuum. The Minnesota Twin Family Study (MTFS) at the University of Minnesota (Iacono et al., 1999) includes electrocortical data for participants at earlier and later ages and measures of alcohol problems along with personality scale items that could be used to index conscientiousness. This data set could be used to evaluate whether a neurophysiological measure like the P300 brain potential response, known to covary both with alcohol problems and with low-conscientious (disinhibitory) tendencies due to common genetic influence (Yancey et al., 2013), might distinguish individuals exhibiting alcohol problems at high versus low levels of conscientiousness. As another example, focusing on bridging, data from the MTFS study could conceivably be integrated with data from the Terman sample used by Kern et al. (2014) by constructing measures of all five-factor constructs for the former sample and establishing metric equivalence with counterpart measures in the latter (as Kern et al., 2014, did with measures for the Hawaii sample). The combined MTFS/Terman sample could then be used to address questions regarding relations between neurophysiological variables and indices of dispositions and health outcomes as Kern et al. did. As a final example, working from the framework of the Magidson et al. (2014) article, electrocortical measures paralleling those available for the MTFS sample could be collected in an intervention study directed at modifying conscientiousness-related tendencies through behavioral activation treatment, as a starting point for bridging between data from etiologically informed process studies and data from treatment outcome studies.

Concluding Note

The current articles highlight important avenues that can be pursued to advance understanding of dispositional factors affecting health outcomes at differing ages. One fruitful avenue would be to direct resources toward systematically incorporating neural systems indicators into large-sample data networks containing variables at other levels of analysis (including behavioral or report-based measures of trait dispositions and health outcomes). This would permit statements about the brain's role in processes and outcomes of interest to be based around observed relations among measured variables rather than conceptual inference. As suggested by the specific examples just above, investigators knowledgeable about data from etiologically informed studies and directly involved in high-level analytic work focusing on health outcomes across the lifespan are in a good position to capitalize on opportunities afforded by existing data sets and to help identify priorities for collection of new data.

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