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Author's Response

Measurable Like Temperature or Mereological Like Flocking? On the Nature of Personality Traits

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Abstract: Some commentators wholeheartedly disagreed with the central tenet of the network perspective on personality, namely that traits are the result of mutual interactions between thoughts, feelings and behaviours. In this rejoinder, we primarily focus on these commentaries by (i) clarifying the main differences between the latent versus the network view on traits; (ii) discussing some of the arguments in favour of the latent trait views that were put forward by these commentators; and by (iii) comparing the capacity of both views to explain thoughts, feelings and behaviours. Some commentators were by and large positive about the network perspective, and we discuss their excellent suggestions for defining components and linking these to genes and other biological mechanisms. We conclude that no doors should be closed in the study of personality and that, as such, alternative theories such as the network perspective should be welcomed, formalised and tested. Copyright © 2012 John Wiley & Sons, Ltd.

Key words: latent trait perspective; personality traits; network models

'No doors should be closed in the study of personality'.
(Allport, 1946)

What are traits? To this question, there are almost as many answers as there are personality psychologists. Our target article was a first attempt at formulating a novel *theory* of personality (and not, as **Schimmack and Gere** suggest, merely a new analysis tool) in which traits do have a place. The difference with existing perspectives is that we do not see traits as *causes* of thoughts, feelings and behaviours (i.e. personality components)—the idea that has come to dominate personality psychology in the past decades—but as *consequences* of the interactions between such thoughts, feelings and behaviours. Thus, rather than reflective latent variables, personality traits are better conceived of as formative variables: summaries of relevant cognitive, affective and behavioural components that interact with one another in myriads of ways. We hypothesised that clusters of more strongly correlated components, typically interpreted as *signs* of underlying factors, in fact signal components that are particularly strongly interconnected. The coordinated behaviour of these components thus *emerges* from the local interactions between them, just like flocking emerges from the local interactions between birds.

The commentaries we received are dividable in two general response categories: the first contains commentaries that were by and large positive, including very helpful suggestions for improving the precision and scope of the network perspective (**Costantini & Perugini; Denissen, Wood & Penke; Furr, Fleeson, Anderson & Arnold; Read & Miller**). The second class consists of commentaries that were (sometimes wholeheartedly) dismissive of our proposal, mainly because of reluctance to let go of the idea that personality traits *necessarily* are latent entities (e.g. **Guillaume-Hanes, Morse & Funder; Schimmack & Gere; Terracciano & McCrae**). The primary focus of this rejoinder pertains to this latter collection of commentaries. More specifically, we aim at (i) clarifying the main differences between the latent versus the network view on traits; (ii) discussing some of the arguments in favour of the latent trait view that were put forward by commentators; and (iii) comparing the capacity of both the network view and the latent trait view to explain thoughts, feelings and behaviours. Finally, we discuss some of the commentators' excellent suggestions for defining components and linking these to genes and other biological mechanisms.

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TEMPERATURE VERSUS FLOCKING

Why do some aspects of personality, such as party-going behaviour and liking people, cluster together? In the latent trait view, they do so because they are *caused* by the same underlying trait (extraversion in this example). This definition of a personality trait, as a cause of behaviours, thoughts and feelings, has come to permeate the field of personality psychology under many different names (source traits: Cattell, 1950; genotypic traits: Eysenck, 1967; $trait_2$: Wiggins, 1984) and is mathematically formalised in the generic latent variable model. In such a latent variable model, a personality trait and its items are associated with one another analogously to the relation between temperature and thermometers (see also Borsboom, 2008): differences in temperature cause differences on thermometer readings via a well understood process by which particles exchange kinetic energy. If multiple thermometers are used (in the personality case: extraversion causes party-going behaviour and liking people), thermometer readings are *measurements* of a common latent variable, namely temperature (extraversion is measured by items such as party-going behaviour and liking people).

The hypothesised measurement relation between a trait and its items features prominently in the five-factor theory of personality, most vehemently advocated by **Terracciano and McCrae**. Importantly, this and comparable factor models come with the assumption of *local independence* (Holland & Rosenbaum, 1986; Lord, 1953; McDonald, 1981): in the temperature analogy, a high correlation between the readings of two thermometers at the same time can be (almost perfectly, depending on the reliability of both thermometers) explained by the underlying cause of these readings, namely temperature. That is, if differences in temperature function as the *common cause* of differences in the thermometer readings, then there can be no direct relation between the two thermometers (i.e. changing the reading on one thermometer does not cause a change in the reading on the other thermometer and vice versa). In a measurement model, this is a highly sensible requirement. However, in our view, it is not a very plausible model for the relation between, say, conscientiousness and being in time for appointments.

This neither implies that factor models are useless nor that the results of factor analysis and related techniques cannot be reinterpreted along different lines. As such, **Ashton and Lee** are free to advocate their own non-causal definition of a factor as 'a common element shared by its defining variables' (e.g. all birds have feathers), and we agree with **Ashton and Lee** that non-causal interpretations of factors are compatible with a network perspective. For pragmatic reasons, it may also be useful to aggregate co-varying individual differences into larger components and neglect the more stringent assumptions of factor analysis. However, we do not see how the assumptions of factor analysis sit with the idea that factors can be identified with *common elements*. The factor model does not hypothesise that there is a common element among indicators but that they share variance; moreover, that they share variance for a very special reason, that is, because they depend on the same latent variable. And *this* is what the psychometric model *is* consistent with, as the latent variable functions precisely as an unobserved common cause (e.g. having feathers is what causes certain animals to be birds; Pearl, 2000).

When adhering to a latent variable model-based explanation of the clustering of certain items, one cannot evade the local independence assumption: although it is technically not a problem to fit a one-factor model in which certain items are allowed to correlate, in addition to and independent of the relation that they share via the latent factor (i.e. to have a *direct* relation, a weaker form of the above-mentioned strict local independence assumption), the more such correlations are allowed to exist in the model, the less convincing is the case for an underlying trait that explains the majority of covariance between the items. Thus, when **Terracciano and McCrae** argue, in *defence* of the latent trait view, that liking parties is caused by both liking people and extraversion, they actually shoot themselves in the foot by admitting the existence of *direct* relations between the items of extraversion. If direct relations are allowed, factor analysis ceases to be a credible tool for identifying unobserved causes because that interpretation is crucially dependent on the assumption of local independence.

Naturally, other ways of tweaking this basic model of temperature are possible, and we acknowledge (again) that we fitted the simple model without distinguishing between first-order and second-order factors (e.g. **Ashton & Lee; Terracciano & McCrae**). However, **Terracciano and McCrae** are not committed to these more complex models either when they maintain their position that extraversion causes party-going: there is no distinction between first-order and second-order factors in this statement. Certainly, one may fit a much more complex model to the data with cross-loadings and *lower order* latent causes. However, in our view, this implies that to meet the assumption of local independence, one then introduces many extra, untested hypotheses. The alternative is to drop the unlikely assumption of local independence. As shown by van der Maas and colleagues, a network of interdependent components can provide a valid alternative for a well-fitting complex factor model. We stress that, in practice, factor analysis merely identifies clusters of items that correlate more highly with one other than with items outside the cluster. Hence, items that *load on the same factor* may be taken to identify networks of mutually reinforcing components (see van der Maas et al., 2006). In that case, a factor is not a latent trait with causal power but a summary statistic for how a set of items are influenced by one another (see Cramer, 2012). This idea resembles Tellegen's (1991, pp. 15) assertion that 'A trait dimension is . . . a population concept representing an orderly statistical structure of covariation', as well as Mischel's (1973) thesis that traits are 'summary terms. . .applied to observed behavior'.

Pertaining to the network perspective, some commentators were under the impression that we dismiss traits or that we equate traits to a single item (e.g. **Asendorpf**). We do not. **Steyer** is absolutely right when postulating that trait theory and the network perspective are not incompatible. That is, if one is willing to let go of the idea that a personality

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trait necessarily is a *latent cause* of thoughts, feelings and behaviours, then traits and the network perspective are perfectly fit for marriage. We may have added to the confusion by discussing individual personality components in which we endowed them with state-like or trait-like properties. Importantly, we do not hypothesise that single components/items are traits; we did want to argue that personality components can be stable (i.e. trait-like) as well as being subject to change (i.e. state-like). In that respect, there is indeed some overlap between the network perspective and the latent state-trait model, as was noticed by several commentators (**Costantini & Perugini; Rothmund, Baumert & Schmitt; Steyer**). However, contrary to the network perspective, the latent state-trait model is a *temperature* model in which individual items are caused by a latent state variable, which is, in turn, partially caused by a latent trait variable. In this respect, it is useful to distinguish between factor analysis as a pragmatic tool to organise data and the results of factor analysis as a model to explain data. Although it is unlikely that factor analysis of personality items would result in a credible explanatory model, this does not imply that it cannot be a useful statistical tool. As such, although we think the explanatory power of the latent state-trait model is limited, we acknowledge its usefulness as a statistical tool that can help in determining which personality components exhibit more state-like properties compared with others.

In the network perspective on personality, there is ample space for traits such as extraversion and neuroticism, if these are interpreted as clusters of mutually reinforcing components. The main difference with current trait theories is that from this perspective, traits do not function analogous to temperature nor do the items function analogous to thermometers. Instead, we postulate that the constellations of components that we designate as signs of underlying traits in fact result from the direct, local interactions between personality components. These may or may not be equated to single items (a subject we will return to in the final paragraphs of this rejoinder). We used the flocking behaviour of birds as an analogy, which needs, given some of the comments, some additional clarification. It is important to stress here that we did not invent the idea that birds, and other species, display flocking behaviour because of local rules. Many simulation studies have confirmed that from a set of simple rules–for example, steer towards average heading of neighbouring birds–a complex flocking pattern (e.g. a V-shape) can occur (e.g. Hartman & Benes, 2006). Thus, there is no underlying flocking instinct (**Terracciano & McCrae**) or a latent *seasonal change* variable (**Schimmack & Gere**) that explains the flocking behaviour of birds. **Schimmack and Gere** are right when they stress, in defence of the latent trait view, that flocking behaviour is not '. . .an independent entity that exists apart from the individual birds. . .' but that is exactly the point: in our view, that applies to personality traits as well. That is, extraversion is not an independent entity that exists apart from the individual extraversion components: instead, just as flocking, personality traits *emerge* out of the interactions between personality components. As such, from a network perspective, the relationship between a trait and its components is not one of measurement but one of *mereology*: that is, extraversion components do not measure extraversion; the interactions between these components are what constitute extraversion.

What does this mean? For one, extraversion and other personality traits cannot be understood by meticulously studying the inner workings of a single personality component. We think that virtually all commentators would agree with this: we cannot, for example, understand neuroticism by discovering all there is to know about a single component such as feeling jittery. However, that is what the latent trait, temperature, model, implies: most of what we know about temperature (what it is and how it is related to thermometers) can be discovered by precisely investigating how it is related to one particular thermometer (a mercury thermometer for example).

THE PRAGMATIC, BIOLOGICAL PLACEHOLDER: DEFENDING THE LATENT TRAIT VIEW

In defence of the latent trait view, some commentators deny the reification of latent traits. That is, they adhere to a factor model-based temperature view of personality traits but claim to refrain from endowing the latent variables with any realist connotation. When having a temperature model in mind and when philosophising about the nature of personality traits, is it unavoidable to reify the latent variable (see also **Wilt, Condon, Brown-Riddell & Revelle**)? In principle, no. From a *pragmatic* point of view, it is possible—as **Lee** points out in the case of mathematical ability—to work with latent variable models without believing that the latent factor has a material referent. However, the moment one searches for biological determinants that correlate with the latent variable, or for heritability of the latent variable, one wades into the murky waters of reifying the latent variable at least to some degree. Although not explicitly—the majority of commentators would likely refrain from endorsing the statement that neuroticism resides in a particular structure in the brains of individual people—many personality psychologists implicitly reify the latent variable when claiming that neuroticism is highly heritable or that gene X is associated with being extraverted. For what would be the use of searching for genetic determinants of something one does not believe to exist in some shape or form? One cannot pinpoint the *location* of temperature either, yet climatologists who claim that a permanent increase in average temperature is associated with an upslope tree line shift do believe that temperature is a real and causal phenomenon, although they cannot directly observe or touch it. As such, although we agree with **Steyer** that strong reification of the latent variable of the sort that personality traits are believed to be in the minds of individual people might not be what the vast majority of personality psychologists think *when asked* (although Allport and his followers do commit to the hypothesis that traits are real, that they exist *in our skins*; Allport, 1968, pp. 49; Funder, 1991), when correlating latent variables (by their sum score proxy) with all sorts of (non-) biological phenomena and by engaging in statements such as 'women are more extraverted than men'; however

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(see also Kievit et al., 2011), they do grant the latent variable a status that comes undeniably close to reification.

In fact, that quest for biological and/or genetic mechanisms is often fueled by the desire to endow the latent variable with some realist connotation. In this vein, **Terracciano and McCrae** defend the latent trait view with an argument along the following lines: personality traits are heritable, they are thus biologically based mechanisms; and because they are biologically based, personality traits exist. First, it is misguided to use heritability as evidence for the hypothesis that some aspect of human functioning is reducible to *specific* underlying biological processes. Turkheimer (1998) contrasts the silence of an ascetic monk and an aphasic individual as an example: both religiosity and aphasia are heritable traits, but everyone will agree that in the case of the monk, his/her silence, which is a *symptom* of his/her religiosity, is not due to specific brain structures or processes (e.g. *religious silence is caused by a lesion in Brodmann area's 16 and 24*), whereas in the case of an individual with, say, Broca's aphasia, we know that his/her silence is caused by a lesion in Broca's area. Thus, the fact that neuroticism is heritable does not imply that neuroticism is reducible to/associated with specific biological mechanisms. Second, the more *general* statement that personality traits are biologically based mechanisms without implicating any specific structure or process is utterly uninformative. Ultimately, all behaviour is biologically caused in some sense (i.e. the result of biological processes), and as such, biological reductionism of mental phenomena such as personality traits is pointless unless one would want to maintain the hypothesis that certain behaviours, thoughts and/or feelings are not ultimately grounded in the brain of the individual who experiences or displays them (see also Greenberg & Bailey, 1993; Kendler, 2005).

For some commentators, it is not so much the supposed *biological reality* of personality traits that prompts them to defend the latent trait view. Rather, in what we call the *placeholder* argument, personality traits cannot be something other than latent variables because that is the only way to understand why certain behaviours/thoughts/feelings (i) are present in some but not all humans (**Terracciano & McCrae**); and (ii) that do not appear to be causally related but are correlated (**Guillaume-Hanes, Morse & Funder**). In this view, the latent variable functions as a placeholder for everything we do not (yet) understand (i.e. latent variable as an *unknown* phenomenon), which is notably different from the interpretation of the latent variable as it figures in measurement and structural models (viz, as an *unobserved* phenomenon). What is wrong with the placeholder argument? For example, **Terracciano and McCrae** argue that because some birds display flocking behaviour whereas others do not; it *must* be so that an underlying *flocking instinct* exists that causes these behavioural differences between bird species. Let us translate this hypothesis into an example that pertains to humans: some women prefer high heels whereas others do not; thus, it must be so that an underlying *instinct to wear high heels* exists that causes these behavioural differences between women. This obviously makes no sense. Although it may well be that we do not (fully) understand why it is that some women prefer high heels whereas others do not, the reasons we can think of do not justify the need for an underlying instinct: high heels are not practical in certain jobs, some women wear high heels to look taller, high heels cause back problems in some women, etc. Naturally, there are examples where the latent placeholder would be more defensible, but the thesis that behavioural differences *necessitate* the existence of an underlying instinct/tendency is, in our opinion, highly questionable.

Now, suppose we would find a positive correlation between wearing high heels and working on the top floor of a skyscraper. According to **Guillaume-Hanes, Morse and Funder**, this correlation can only be understood by introducing an underlying tendency, in this example something such as *elevation tendency*, because there is no sensible way in which one can justify a direct relation between the two behaviours. The latter part of this argument is true. Likewise, in their own example, it is virtually impossible that ice cream eating causes children to seek their teacher's approval as well as the other way around. Besides methodological reasons why ordinary correlations do not necessarily imply a true relation between two variables (e.g. large sample size that causes low correlations to become significant, partial correlation might reveal that correlation is caused by a third (non-latent) party, etc.), **Guilllaume-Hanes et al.** ignore another reason why two seemingly wildly removed phenomena are correlated, which does not involve latent entities: for example, most women who work on the top floors of skyscrapers take the elevator. And because they take the elevator, they are not bothered by the discomfort of wearing high heels when climbing stairs. As a result, these women more readily wear high heels than women who take the stairs to reach their lower floor offices or the other way around: some women in highly successful companies with predominantly male employees like to accentuate their femininity by wearing high heels. And successful companies often occupy the most expensive floors in skyscrapers, the top floors. As such, at the inter-individual level, two behaviours can be related through a *causal chain* that involves directly observable, non-latent variables.

NOT AS STRAIGHT AS AN ARROW: THE REAL TROUBLE FOR THE LATENT TRAIT VIEW

Interestingly, the potentially most compelling argument in defence of the latent trait view was not once articulated by any of the commentators. That argument would have been that it is known how latent traits influence behaviours, thoughts and feelings; that is, that we know what the *arrows* in the measurement model signify. Consider again the analogy with temperature: we know exactly what the arrow between temperature and a measurement with a mercury thermometer means, namely, that an increase in ambient temperature results in an increase in the temperature of the mercury causing (in a linear fashion) the mercury in the glass tube to expand. For personality traits, however, it is no surprise that this argument was not articulated because no one really knows how, say, neuroticism causes *feeling jittery* and *worries easily*. As Mischel and Shoda stated (1994), if

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traits generate distinctive behaviour, then evidence for this claim needs '...to be stated explicitly and announced clearly'. Yet, to the best of our knowledge, this evidence is not unannounced, it simply is not there. Naturally, there are theories of how traits and behaviour are linked, for example, the trait theory as postulated in McCrae and Costa (1995). However, the meaning of the arrows in their model is shrouded in mystery: they are not really discussed nor empirically verified and are endowed in the model with the vague label *dynamical processes*. So, when **Rothmund, Baumert and Schmitt** state that '...without theories about the nature of these causal links among components, it seems premature to refuse the classical trait models', they forget that for these very classical trait models, not one empirically verified theoretical model about the causal links between traits and concrete behaviours exists.

Thus, as Pervin (1994) rightly pointed out, personality traits are regarded as explanatory concepts, yet '...explanations are not offered in other than trait terms', resulting in circular arguments such as extraversion causes party-going; John likes to go to parties because he is extraverted. Why is it that trait theorists have not searched for how personality traits exert their supposed causal powers onto lower level behaviours, thoughts and feelings? There are probably many reasons—beyond the scope of the present rejoinder to discuss—but one reason might have to do with the manipulability of the supposed latent traits. An important way of investigating the explanatory power of a theory is to manipulate the hypothesised cause of a certain phenomenon X after which one assesses the impact of that manipulation on X. One problem with personality traits, besides the obvious ethical constraints on such a research design, is that to manipulate a trait, one has to have a fairly good idea of what a trait is. And, although regarded as a *human universal* (McCrae & Costa, 1997), we have already argued in earlier paragraphs that in current trait theory, there is no validated hypothesis on the nature of personality traits. Also, trait theorists themselves strongly argue in favour of the stability of these traits (Terracciano, Costa, & McCrae, 2006). That is, especially after age 30, personality traits are supposedly relatively stable and thus relatively insensitive to external manipulation (if possible at all). On a final note, when reviewing the literature, it also seems that trait theorists are generally not very interested in answering the question of how traits cause behaviour. In fact, McCrae and Costa (1995), for example, consider the causal link between traits and behaviour as self-evident and, as such, seem to obviate any need for formulating and testing explicit hypotheses about this link:

> '..., the causal argument is in principle clear: traits as underlying tendencies cause and thus explain (in general and in part) the consistent pattern of thoughts, feelings, and actions that one sees. This kind of argument is so consistent with philosophical construals of disposition (...), with the theories of psychologists from Allport to Eysenck, with the assumptions underlying classical psychometrics, and with common sense that it is hard to understand why it should be problematic'.

In our view, future research into the network perspective on personality should commit itself to the systematic identification and analysis of causal links between personality components at both the inter-individual and intra-individual levels. In our target paper, as **Asendorpf** rightly notes, we have only scratched the surface of the many possible interactions between personality components and how one can go about in analysing possible causal mechanisms. For some relations at the inter-individual level, the causal mechanism probably operates at a more psychological level (those examples were most frequently discussed in our target paper): in general, liking to meet new people causes some individuals to seek out events where new people can be met, and therefore, these individuals frequent parties. And in these cases, there is no need for reducing this mechanism to a more *biological* explanation (e.g. neuron group X firing in region A causes neuron group Y in region B to fire). In other cases, biological mechanisms will be more important (e.g. in psychopathology and how not sleeping causes fatigue). And in these cases, we welcome the suggestions of **Read and Miller and Wilt, Condon, Brown-Riddell and Revelle** for how to incorporate biological mechanisms into the network model, for example, by positioning such mechanisms between genes and personality components.

Between-subject generalisations do not necessarily correspond to causal mechanisms that characterise within-person functioning. As **Furr, Fleeson, Anderson and Arnold** show in the case of borderline personality disorder, causal mechanisms for developing the disorder might be very different for two people with the same diagnosis. Pertaining to normal personality, it might well be, for example, that in general, party-going behaviour is predominantly caused by liking to meet new people, but that John likes to go to parties because he wants to be the centre of attention and that Chris frequents parties because he wants to raise money for his next film (**Asendorpf**). So, when **Asendorpf** criticises the network perspective by arguing that people might vary in the causes of their party-going behaviour, he inadvertently mentions a phenomenon (i.e. intra-individual differences in why certain behaviour is present) that flows naturally from the basic premises of the network theory. In the network theory, the personality networks of John and Chris can be structured entirely different with the same end result: both men are extraverted. In John's case, his party-going behaviour is caused by another personality component, wanting to be in the centre of attention; in Chris' network, his party-going behaviour is caused by an external event (an upcoming film). Thus, there may be as many sources of *extraversion* as there are events that cause people to like parties or lead them to make friends easily. Importantly, this is not readily explainable by the latent trait, temperature, view. For in this view, personality traits cause behaviour in the same way in every individual, just as temperature causes a reading on a mercury thermometer in exactly the same way regardless of whether the temperature is measured in the Himalaya Mountains or in someone's backyard.

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THE PIECES THAT MAKE UP THE PERSONALITY PUZZLE

So, if traits are not the *fundamental units of personality* (**Wilt, Condon, Brown-Riddell & Revelle**) what are the basic pieces that make up the personality puzzle? We have suggested that personality components might fulfil that role: behaviours, thoughts and feelings that are associated with a unique causal system. Naturally, and as we have stressed, this definition of personality components is a first step; there is ample opportunity for refining this definition. A good refinement would be to consider more than items from self-report questionnaires (e.g. **Guillaume-Hanes, Morse & Funder; Rothmund, Baumert & Schmitt; Wilt, Condon, Brown-Riddell & Revelle**). For example, **Denissen, Wood and Penke** suggest the inclusion of functionalist components such as the reward value of social situations. With that said, it can be debated whether such functionalist variables act as components in a personality system or, instead, function as external forces that push the personality system towards a certain attractor (e.g. as a moderator that influences the strength between two personality components). Another potential refinement of our original definition is to consider a component as consisting of multiple items. For example, **Costantini and Perugini** suggest that personality components might be better defined at the level of facets (i.e. sub traits one level below the Big Five, for example, assertiveness). We agree that in certain cases, multiple items might be part of the same component, and in that sense, a component might be a facet, and the resulting network might be considered to be a higher level sub-network. In that case, one pragmatically chooses to study relations between sub-networks without assuming them to be fundamental, just as one can study interactions between sub-systems in the brain without phrenological assumptions. However, grouping multiple items would only work when the assumption of local independence is warranted as in the case of multiple thermometers. For example, sleep problems might be assessed by asking the individual, asking his/her spouse and by administering a polysomnography. As such, a measurement temperature model applies, and in that case, a personality component might be a latent variable. This approach would also effectively deal with the problem of incorporating measurement error into the network model (**Asendorpf**).

EAT THE PUDDING!

In our target paper and in this rejoinder, we have articulated a network perspective on personality in which traits result from the mutual interactions between personality components. Additionally, particularly in this rejoinder, we have articulated many reasons why the currently dominant latent trait view is in trouble: traits are probably not latent entities nor do they appear to have explanatory power, rendering the status of the latent trait view as the grand unifying theory of personality problematic. Naturally, criticising existing theories and suggesting new ones necessarily generates critical responses. However, the *concern* that **Schimmack and Gere** expressed over our '. . .suggestion that network analysis provides an alternative account of classic personality constructs. . .' does not make sense in our view, for science cannot progress without regularly questioning the basic assumptions upon which research traditions are founded. That is, in a healthy scientific field, no doors should be closed; indeed, alternative theories should be welcomed, formalised and tested adequately. Regardless of which theory will in the end paint the best picture of how human beings develop unique and yet, in some ways, similar personalities, one should not prematurely throw away the pudding without eating from it first.

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REFERENCES

Albert, R., Jeong, H., & Barabási, A. L. (1999). The diameter of the world wide web. *Nature*, *401*, 130–131.

Allport, G. W. (1937). *Personality A psychological interpretation*. New York: Henry Holt & Co.

Allport, G. W. (1946). Personalistic psychology as science: A reply. *Psychological Review*, *53*, 132–135.

Allport, G. A. (1968). The historical background of modern social psychology. In G. Lindzey, & E. Aronson (Eds.), *The handbook of social psychology* (Vol. *1*). Reading: Addison-Wesley.

Almlund, M., Duckworth, A., Heckman, J. J., & Kautz, T. (2010). *Personality psychology and economics*. IZA Discussion Paper No. 5500. Available at SSRN: http://ssrn.com/abstract=1765666

Ashton, M. C., & Lee, K. (2005). A defence of the lexical approach to the study of personality structure. *European Journal of Personality*, *19*, 5–24.

Ashton, M. C., & Lee, K. (2007). Empirical, theoretical, and practical advantages of the HEXACO model of personality structure. *Personality and Social Psychology Review*, *11*, 150–166.

Ashton, M. C., & Lee, K. (2010). Trait and source factors in HEXACO-PI-R self- and observer reports. *European Journal of Personality*, *24*, 278–289.

Back, M. D., Baumert, A., Denissen, J. J. A., Hartung, F.-M., Penke, L., Schmukle, S. C., . . .Wrzus, C. (2011). PERSOC: A unified framework for understanding the dynamic interplay of personality and social relationships. *European Journal of Personality*, *25*, 90–107.

Bartholomew, D. J. (2004). *Measuring intelligence: Facts and fallacies*. Cambridge, UK: Cambridge University Press.

Baumeister, R. F., Vohs, K. D., & Funder, D. C. (2007). Psychology as the science of self-reports and finger movements. Whatever happened to actual behavior? *Perspectives on Psychological Science*, *2*, 396–403.

Baumert, A., Gollwitzer, M., Staubach, M., Schmitt, M. (2011). Justice sensitivity and the processing of justice-related information. *European Journal of Personality*, *25*, 386–397.

Blum, G. S., & Miller, D. R. (1952). Exploring the psychoanalytic theory of the "oral character." *Journal of Personality*, *20*, 287–304.

Borsboom, D. (2008). Psychometric perspectives on diagnostic systems. *Journal of Clinical Psychology*, *64*, 1089–1108.

DOI: 10.1002/per

Carver, C. S., & Scheier, M. F. (1998). *On the self-regulation of behavior*. New York, NY US: Cambridge University Press.
Cassidy, J., & Shaver, P. R. (2008). *Handbook of attachment: Theory, research and clinical applications* (2nd edn). New York: Guilford Press.
Cattell, R. B. (1950). *Personality: A systematic theoretical and factual study*. New York: McGraw-Hill.
Cattell, R. B. (1973). *Personality and mood by questionnaire*. San Francisco: Jossey-Bass.
Chen, C., Chen, C., Moyzis, R., Stern, H., He, Q., Li, H., . . .Dong, Q. (2011). Contributions of dopamine-related genes and environmental factors to highly sensitive personality: A multi-step neuronal system-level approach. *PLoS One*, *6*(7), 1–9. e21636
Clark, L. A., & Watson, D. (2008). Temperament: An organizing paradigm for trait psychology. In O. P. John, R. W. Robins, & L. A. Pervin (Eds.), *Handbook of personality: Theory and research* (3rd edn, pp. 265–286). New York: Guilford Press.
Cramer, A. O. J. (2012). Why the item "23 + 1" is not in a depression questionnaire: Validity from a network perspective. *Measurement: Interdisciplinary Research & Perspective*, *10*, 50–54.
Cramer, A. O. J., van der Sluis, S., Noordhof, A., Wichers, M., Geschwind, N., Aggen, S. H., . . .Borsboom, D. (2012). Dimensions of normal personality as networks in search for equilibrium: You can't like parties if you don't like people. *European Journal of Personality*, *26*, 414–431.
Cramer, A. O. J., Waldorp, L. J., van der Maas, H. L. J., & Borsboom, D. (2010). Comorbidity: A network perspective. *The Behavioral and Brain Sciences*, *33*, 137–193.
Denissen, J. J. A., & Penke, L. (2008). Motivational individual reaction norms underlying the five-factor model of personality: First steps towards a theory-based conceptual framework. *Journal of Research in Personality*, *42*, 1285–1302.
Denissen, J. J. A., & Penke, L. (2012). *Personality maturation as improved emotion regulation*. Manuscript submitted for review.
Ellis, A. (1987). The impossibility of achieving consistently good mental health. *American Psychologist*, *42*, 364–375.
Epskamp, S., Cramer, A. O. J., Waldorp, L. J., Schmittmann, V. D., & Borsboom, D. (2012). *Qgraph: Network representations of relationships in data*. R package version 1.0.0.
Eysenck, H. J. (1967). *The biological basis of personality*. Springfield: Thomas.
Fleeson, W. (2001). Towards a structure- and process-integrated view of personality: Traits as density distributions of states. *Journal of Personality and Social Psychology*, *80*, 1011–1027.
Fleeson, W. (2004). Moving personality beyond the person-situation debate: The challenge and the opportunity of within-person variability. *Current Directions in Psychological Science*, *13*, 83–87.
Fleeson, W. (2012). Perspectives on the person: Rapid growth and opportunities for integration. In K. Deaux, & M. Snyder (Eds.), *The Oxford handbook of personality and social psychology* (pp. 33–63). New York: Oxford University Press.
Fleeson, W., & Jolley, S. (2006). A proposed theory of the adult development of intraindividual variability in trait-manifesting behavior. In D. Mroczek, & T. D. Little (Eds.), *Handbook of personality development* (pp. 41–59). Mahwah, NJ: LEA.
Foster, E. M. (2010). Causal influence and developmental psychology. *Developmental Psychology*, *46*, 1454–1480.
Freeman, L. C. (1978). Centrality in social networks: Conceptual clarification. *Social Networks*, *1*, 215–239.
Friedman, H. S. (2011). *The longevity project: Surprising discoveries for health and long life from the landmark eight-decade study*. New York: Penguin.
Fruchterman, T. M. J., & Reingold, E. M. (1991). Graph drawing by force-directed placement. *Software: Practice and Experience*, *21*, 1129–1164.
Funder, D. C. (1991). Global traits: A Neo-Allportian approach to personality. *Psychological Science*, *2*, 31–39.
Furr, R. M. (2009a). The study of behaviour in personality psychology: Meaning, importance, and measurement. *European Journal of Personality*, *23*, 437–453.
Furr, R. M. (2009b). Profile analysis in person-situation integration. *Journal of Research in Personality*, *43*, 196–207.
Gere, J., & Schimmack, U. (2011). A multi-occasion multi-rater model of affective dispositions and affective well-being. *Journal of Happiness Studies*, *12*, 931–945.
Grafton, B., Ang, C., & MacLeod, C. (2012). Always look on the bright side of life: The attentional basis of positive affectivity. *European Journal of Personality*, *26*, 133–144.
Gray, J. A., & McNaughton, N. (2000). *The neuropsychology of anxiety: An enquiry into the functions of the septo-hippocampal system* (2nd edn). New York, NY: Oxford University Press.
Greenberg, A. S., & Bailey, J. M. (1993). Do biological explanations of homosexuality have moral, legal, or policy implications? *Journal of Sex Research*, *30*, 245–251.
Guttman, L., & Levy, S. (1991). Two structural laws for intelligence tests. *Intelligence*, *15*, 79–103.
Hartman, C., & Benes, B. (2006). Autonomous boids. *Computer Animation and Virtual Worlds*, *17*, 199–206.
Hofstee, W. K. B., De Raad, B., & Goldberg, L. R. (1992). Integration of the Big Five and circumplex approaches to trait structure. *Journal of Personality and Social Psychology*, *63*, 146–163.
Hogan, R., Hogan, J., & Roberts, B. W. (1996). Personality measurement and employment decisions: Questions and answers. *American Psychologist*, *51*, 469–477. DOI: 10.1037/0003-066x.51.5.469
Holland, P. W., & Rosenbaum, P. R. (1986). Conditional association and unidimensionality in monotone latent variable models. *Annals of Statistics*, *14*, 1523–1543.
Jang, K. L., McCrae, R. R., Angleitner, A., Riemann, R., & Livesley, W. J. (1998). Heritability of facet-level traits in a cross-cultural twin sample: Support for a hierarchical model of personality. *Journal of Personality and Social Psychology*, *74*, 1556–1565.
Kendler, K. S. (2005). Toward a philosophical structure for psychiatry. *The American Journal of Psychiatry*, *162*, 433–440.
Kenny, D. A., & Zautra, A. (1995). The trait-state-error model for multiwave data. *Journal of Consulting and Clinical Psychology*, *63*, 52–59.
Kievit, R. A., Romeijn, J.-W., Waldorp, L. J., Wicherts, J. M., Scholte, S., & Borsboom, D. (2011). Modeling mind and matter: Reductionism and psychological measurement in cognitive neuroscience. *Psychological Inquiry*, *22*, 139–157.
Lee, J. J. (2012). Correlation and causation in the study of personality. *European Journal of Personality*, *26*, 372–390.
Lord, F. M. (1953). The relation of test score to the trait underlying the test. *Educational and Psychological Measurement*, *13*, 517–549.
Lord, F. M., & Novick, M. R. (1968). *Statistical theories of mental test scores*. Reading, MA: Addison-Wesley.
van der Maas, H. L. J., Dolan, C., Grasman, R. P. P. P., Wicherts, J. M., Huizenga, H. M., & Raijmakers, M. E. J. (2006). A dynamical model of general intelligence: The positive manifold of intelligence by mutualism. *Psychological Review*, *113*, 842–861.
Marshalek, B., Lohman, D. F., & Snow, R. E. (1983). The complexity continuum in the radex and hierarchical models of intelligence. *Intelligence*, *7*, 107–127.
Mathews, A. (2012). Personality and information processing: We are what we encode. *European Journal of Personality*, *26*, 158–163.
Matthews, G., Deary, I. J., & Whiteman, M. C. (2009). *Personality traits* (3rd edn). Cambridge: Cambridge University Press.
McArdle, J. J. (2009). Latent variable modeling of differences and changes with longitudinal data. *Annual Review of Psychology*, *60*, 577–605.
McCrae, R. R., & Costa, P. T., Jr. (1984). *Emerging lives, enduring dispositions: Personality in adulthood*. Boston: Little, Brown.
McCrae, R. R., & Costa, P. T., Jr. (1992). Discriminant validity of NEO-PI-R facets. *Educational and Psychological Measurement*, *52*, 229–237.
McCrae, R. R., & Costa, P. T., Jr. (1995). Trait explanations in personality psychology. *European Journal of Personality*, *9*, 231–252.
McCrae, R. R., & Costa, P. T. (1997). Personality trait structure as a human universal. *American Psychologist*, *52*, 509–516.

McCrae, R. R., & Costa, P. T., Jr. (2008a). Empirical and theoretical status of the Five-Factor Model of personality traits. In G. Boyle, G. Matthews, & D. Saklofske (Eds.), *Sage handbook of personality theory and assessment* (Vol. *1*, pp. 273–294). Los Angeles: Sage.

McCrae, R. R., & Costa, P. T., Jr. (2008b). The Five-Factor theory of personality. In O. P. John, R. W. Robins, & L. A. Pervin (Eds.), *Handbook of personality: Theory and research* (3rd edn, pp. 159–181). New York: Guilford.

McDonald, R. P. (1981). The dimensionality of tests and items. *British Journal of Mathematical and Statistical Psychology*, *34*, 100–117.

McDonald, R. P. (1999). *Test theory: A unified treatment*. Mahwah, NJ: Erlbaum.

McDonald, R. P. (2003). Behavior domains in theory and in practice. *Alberta Journal of Educational Research*, *49*, 212–230.

McNiel, J. M., & Fleeson, W. (2006). The causal effects of extraversion on positive affect and neuroticism on negative affect: Manipulating state extraversion and state neuroticism in an experimental approach. *Journal of Research in Personality*, *40*, 529–550.

Meehl, P. E. (1945). The dynamics of "structured" personalitytests. *Journal of ClinicalPsychology*, *1*, 296–303.

Meehl, P. E. (1978). Theoretical risks and tabular asterisks: Sir Karl, Sir Ronald, and the slow progress of soft psychology. *Journal of Consulting and Clinical Psychology*, *46*, 806–834.

Messick, S. (1989). Validity. In R. L. Linn (Ed.), *Educational measurement* (pp. 13–103). New York, NY: Macmillan.

Mischel, W. (1973). Toward a cognitive social learning reconceptualization of personality. *Psychological Review*, *80*, 252–283.

Mischel, W. (2004). Toward an integrative science of the person. *Annual Review of Psychology*, *55*, 1–22.

Mischel, W., & Shoda, Y. (1994). Personality Psychology Has Two Goals: Must It Be Two Fields? *Psychological Inquiry: An International Journal for the Advancement of Psychological Theory*, *5*, 156–158.

Mischel, W., & Shoda, Y. (1995). A cognitive-affective system theory of personality: Reconceptualizing situations, dispositions, dynamics, and invariance in personality structure. *Psychological Review*, *102*, 246–268.

Molenaar, P. C. M. (2004). A manifesto on psychology as idiographic science: Bringing the person back into scientific psychology, this time forever. *Measurement: Interdisciplinary Research and Perspectives*, *2*, 201–218.

de Moor, M. H., Costa, P. T., Terracciano, A., Krueger, R. F., de Geus, E. J., Toshiko, T., et al. (in press). Meta-analysis of genome-wide association studies for personality. *Molecular Psychiatry*.

Nave, C. S., Sherman, R. A., Funder, D. C., Hampson, S. E., & Goldberg, L. R. (2010). On the contextual independence of personality: Teachers' assessments predict directly observed behavior after four decades. *Social Psychological and Personality Science*, *1*, 327–334.

Opsahl, T., Agneessens, F., & Skvoretz, J. (2010). Node centrality in weighted networks: Generalizing degree and shortest paths. *Social Networks*, *32*, 245–251.

Ozer, D. J. (1986). *Consistency in personality: A methodological framework*. New York.

Paunonen, S. V., Haddock, G., Forsterling, F., & Keinonen, M. (2003). Broad versus narrow personality measures and the prediction of behaviour across cultures. *European Journal of Personality*, *17*, 413–433.

Pearl, J. (2000). *Causality: Models, reasoning, and inference*. Cambridge: Cambridge University Press.

Perugini, M., Conner, M., & O'Gorman, R. (2011). Automatic activation of individual differences: A test of the gatekeeper model in the domain of spontaneous helping. *European Journal of Personality*, *25*, 465–476.

Pervin, L. A. (1994). A critical analysis of current trait theory. *Psychological Inquiry*, *5*, 103–113.

Pinker, S. (1997). *How the mind works*. New York: Norton & Co.

Quek, M., & Moskowitz, D. S. (2007). Testing neural network models of personality. *Journal of Research in Personality*, *41*, 700–706.

Read, S. J., Monroe, B. M., Brownstein, A. L., Yang, Y., Chopra, G., & Miller, L. C. (2010). A neural network model of the structure and dynamics of human personality. *Psychological Review*, *117*, 61–92.

Robins, R. W., John, O. P., & Caspi, A. (1994). Major dimensions of personality in early adolescence: The Big Five and beyond. In C. F. Halverson, G. A. Kohnstamm, & R. P. Martin (Eds.), *The developing structure of temperament and personality from infancy to adulthood* (pp. 267–291). Hillsdale, NJ England: Lawrence Erlbaum Associates, Inc.

Rothbart, M. K., & Bates, J. E. (1998). Temperament. In W. Damon (Series Ed.), & N. Eisenberg (Vol. Ed.), *Handbook of child psychology: Vol. 3. Social, emotional, and personality development* (5th edn, pp. 105–176). New York: Wiley.

Rusting, C. L. (1998). Personality, mood, and cognitive processing of emotional information: Three conceptual frameworks. *Psychological Bulletin*, *124*, 165–196.

Schimmack, U. (2010). What multi-method data tell us about construct validity. *European Journal of Personality*, *24*, 241–257.

Schimmack, U., & Lucas, R. E. (2010). Environmental influences on well-being: A dyadic latent panel analysis of spousal similarity. *Social Indicators Research*, *98*, 1–21.

Shevlin, M., Dorahy, M., Adamson, G., & Murphy, J. (2007). Subtypes of borderline personality disorder, associated clinical disorders and stressful life-events: A latent class analysis based on the British Psychiatric Morbidity Survey. *British Journal of Clinical Psychology*, *46*, 273–281.

Skodol, A. E., Gunderson, J. G., Pfohl, B., Widiger, T. A., Livesley, W. J., & Siever, L. (2002). The borderline diagnosis: I. Psychopathology, comorbidity, and personality structures. *Biological Psychiatry*, *51*, 936–950.

Steyer, R., Ferring, D., & Schmitt, M. J. (1992). States and traits in psychological assessment. *European Journal of Psychological Assessment*, *8*, 79–98.

Steyer, R., Geiser, C., & Fiege, C. (in press). Latent state-trait models. In H. Coooer (Ed.), *APA handbook of research methods in psychology*. American Psychological Association.

Steyer, R., Schmitt, M., & Eid, M. (1999). Latent state-trait theory and research in personality and individual differences. *European Journal of Personality*, *13*, 389–408.

Stout, W. F. (1990). A new item response theory modeling approach with applications to unidimensionalityassessment and ability estimation. *Psychometrika*, *55*, 293–325.

Sutin, A. R., Costa, P. T., Jr., Uda, M., Ferrucci, L., Schlessinger, D., & Terracciano, A. (2010). Personality and metabolic syndrome. *Age (Dordrecht, Netherlands)*, *32*, 513–519.

Tellegen, A. (1991). Personality traits: Issues of definition, evidence and assessment. In D. Cicchetti, & W. Grove (Eds.), *Thinking clearly about psychology: Essays in honor of Paul Everett Meehl* (pp. 10–35). Minneapolis: University of Minnesota Press.

Tellegen, A., Lykken, D. T., Bouchard, T. J., Jr., Wilcox, K. J., Segal, N. L., & Rich, S. (1988). Personality similarity in twins reared apart and together. *Journal of Personality and Social Psychology*, *54*, 1031–1039.

Terracciano, A., Costa, P. T., & McCrae, R. R. (2006). Personality plasticity after age 30. *Personality and Social Psychology Bulletin*, *32*, 999–1009.

Terracciano, A., Esko, T., Sutin, A. R., De Moor, M. H. M., Meirelles, O., Zhu, G., et al. (2011). Meta-analysis of genome-wide association studies identifies common variants in CTNNA2 associated with excitement-seeking. *TranslationalPsychiatry*, *1*, e49.

Terracciano, A., Sanna, S., Uda, M., Deiana, B., Usala, G., Busonero, F., et al. (2010a). Genome-wide association scan for five major dimensions of personality. *MolecularPsychiatry*, *15*, 647–656.

Terracciano, A., Sutin, A. R., McCrae, R. R., Deiana, B., Ferrucci, L., Schlessinger, D., et al. (2009). Facets of personality linked to underweight and overweight. *Psychosomatic Medicine*, *71*, 682–689.

Terracciano, A., Tanaka, T., Sutin, A. R., Sanna, S., Deiana, B., Lai, S., et al. (2010b). Genome-wide association scan of trait depression. *Biological Psychiatry*, *68*, 811–817.

Travers, J., & Milgram, S. (1969). An experimental study of the small world problem. *Sociometry*, *32*, 425–443.

DOI: 10.1002/per

Turkheimer, E. (1998). Heritability and biological explanation. *Psychological Review*, *105*, 782–791.

Vassend, O., & Skrondal, A. (1997). Validation of the NEO Personality Inventory and the five-factor model: Can findings from exploratory and confirmatory factor analysis be reconciled? *European Journal of Personality*, *11*, 147–166.

Vazquez, A., Flammini, A., Maritan, A., & Vespignani, A. (2003). Modeling of protein interaction networks. *Complexus*, *1*, 38–44.

Wagner, G. P. (2001). *The character concept in evolutionary biology*. San Diego, CA: Academic Press.

Wiggins, J. S. (1984). Cattell's system from the perspective of mainstream personality theory. *Multivariate Behavioral Research*, *19*, 176–190.

Wilkowski, B. M., & Robinson, M. D. (2008). The cognitive basis of trait anger and reactive aggression: An integrative analysis. *Personality and Social Psychology Review*, *12*, 3–21.

Wood, D., & Hensler, M. (2011). *How a functionalist understanding of behavior can explain trait variation and covariation without the use of latent factors*. Retrieved from http://hdl.handle.net/10339/36461

DOI: 10.1002/per