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A Five-Factor Theory Perspective on Causal Analysis

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Abstract

Five-Factor Theory (FFT) provides a broad but largely blank template for causal personality research. Within FFT, there are three major categories of questions: (1) How do biological structures and functions lead to trait levels? (2) how do traits and the environment give rise to acquired psychological institutions? and (3) how do personality characteristics interact with specific situations to determine behaviors and reactions? Both practical and ethical issues complicate the search for the causes of trait change. Causal explanations of the development of characteristic adaptations are likely to be incomplete, because there are many different ways in which the same adaptation may be acquired. Studies of the determinants of behavior are usually left to social, educational, or clinical psychologists—although personality psychologists may make distinctive contributions by emphasizing the role of the individual in selecting and creating situations. A causal understanding of the functioning of the personality system is possible through the integration of many lines of evidence, but it is likely to take a very long time. In the meanwhile, personality psychologists may fruitfully pursue the identification of practical causes by which individuals with a given set of traits can optimize their adaptation.

> If we require truth in any strict sense, we must confine ourselves to one entire state of the world. This will be the cause, and the next entire state will be the effect. There is much truth in this conclusion, but it remains indefensible.
>
> F. H. Bradley, 1893/1966, p. 48

Psychologists concerned with causality ought perhaps to be required to read the brief chapter on "Causation" in Bradley's *Appearance and reality* to get some appreciation of the complexities of the topic when approached rigorously. Even in that simpler time, before the advent of relativity and quantum mechanics, causality posed serious issues of continuity and change, infinite regress, and the role of what Bradley called "background," and we would call context.[1]

Psychologists, and most other empirical scientists, have a more pragmatic view of causation. Basically, they recognize two kinds of causes: We will call them *explanatory* if they provide a conceptual account of why a phenomenon occurs, and *practical* if one can use them to

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[1]For a more contemporary example of the complexities of causal analysis, readers might consider the discussion of functional explanation in the Internet Encyclopedia of Philosophy; http://www.iep.utm.edu/func-exp/#H2.

make the phenomenon happen. These two are essentially independent. Five-Factor Theory (FFT; McCrae & Costa, 2008) proposes an explanatory cause of lifespan trait development —intrinsic maturation—but says nothing about how development can be accelerated or modified. Electroconvulsive therapy (ECT) is widely used because it is often an effective treatment for serious and refractory psychiatric conditions, and thus qualifies as a practical cause of improved mental health. But, as Prudic and Duan (2017) euphemistically noted, "the mechanism of action of ECT remains an active area of hypothesis and research" (p. 3280)—that is, we have basically no idea how it works.

Ideally, of course, the two kinds of causes are closely intertwined: Explanatory causes should guide us to practical interventions, and (in the hypothetico-deductive method) the success of a practical cause (the experimental treatment) is taken as evidence for the validity of the explanation. It is perhaps less widely appreciated that the relation between explanation and practice can be and often is extremely loose, especially in the early stages of a science. We could, for example, provide a causal explanation for the efficacy of ECT: "Psychiatric disorders are dysfunctions of the brain; ECT affects the brain, and somehow improves the situation." Readers who think such an explanation is completely meaningless and empty should recall that in ECT the electric current is directed through the brain, not the liver. Trait explanations of behavior are often loose as well as distal, but this does not disqualify traits as real causes (McCrae & Costa, 1995).

Statisticians have provided psychologists with sophisticated tools for the quantitative evaluation of causal models (Pearl, 2009), but the value of these models depends entirely on the causal assumptions built into them. These assumptions should "derive from prior studies, research design, scientific judgment, or other justifying sources" (Bollen & Pearl, 2013, p. 307). Theories like FFT can be used as a justifying source of causal assumptions if, in the judgment of the scientist, the theories are plausible.

Traits in Five-Factor Theory

FFT offers a framework for causal explanations in personality psychology, but does so in very general terms. Biology causes basic tendencies (BTs—including personality traits at all levels of the trait hierarchy); BTs in interaction with external influences (EIs) cause characteristic adaptations (CAs—including habits, skills, and beliefs); CAs in interaction with EIs cause behaviors and reactions. These assertions are so broad that they may at first seem trivial. What merit FFT has depends on the conceptual value of the distinction between BTs and CAs, and the heuristic value of emphasizing certain causal pathways to the exclusion of others. We first consider the conceptual distinction; in later sections we will focus on the causal pathways allowed by FFT.

Traits as Basic Tendencies

BTs are abstract potentials, hypothetical psychological features of the individual that, over time and in specific situations, come to be manifested in concrete realizations, CAs. BTs include more than personality traits, and the notion is perhaps more easily grasped in other areas. All healthy infants, for example, have a capacity for language (BT); over time, they develop fluency in their native tongue (CA). Intelligence (BT) is a hypothetical aptitude for

learning that can only be discerned when education leads to acquired knowledge (CA). Musical genius (BT) must be inferred from the prodigious rate at which a child masters an instrument (CA). The central premise of FFT is that personality traits are BTs: People low in Agreeableness (BT) develop skeptical attitudes (CAs); those low in Conscientiousness learn tricks to get by with minimal effort.

There are many other ways of defining "trait" (McCrae, in press). Some theorists see traits as observable patterns of behavior (Pervin, 1994); some as neuropsychic structures that are shaped by experience (Cloninger, Przybeck, Svrakic, & Wetzel, 1994); some as distributions of personality states (Fleeson, 2001). FFT views traits as BTs because that premise allows causal explanations for a number of well-replicated observations that are not easily accommodated by other definitions. If traits were simply patterns of behavior, we would expect them to vary widely across cultures (where behaviors surely vary), yet traits are universal (McCrae, Terracciano, & 78 Members, 2005). Experience encoded in the brain may lead to new habits, interests, or relationships, but traits endure over decades (Ferguson, 2010) despite changing life circumstances. Distributions of personality states are statistical summaries of behavior, and it is not immediately clear why they would be similar in monozygotic twins—yet traits are heritable (Jang, McCrae, Angleitner, Riemann, & Livesley, 1998). We can explain the universality, stability, and heritability of traits by assuming that they—like height and blood type and eye color—are innate and relatively enduring human potentials that vary quantitatively across individuals, but are qualitatively universal.[2]

The distinction between BTs and CAs is easier to articulate than to operationalize. There can be no direct measurement of an abstract potential; traits and other BTs can only be inferred from their consequences. The consequences of traits are CAs, and, indirectly, the behaviors and experiences that are generated by CAs. Extraversion, for example, might show the following manifestations:

- Smiles at strangers
- Vacations at popular beaches
- Leads groups
- Acts energetically
- Listens to loud music
- Laughs often

One could assess such characteristics in several ways: By direct surveillance, daily diary entries of the target, self-reports, observer ratings. Personality questionnaires employing self-reports or informant ratings are the default method in contemporary research, and although they are far from perfect, they both offer serviceable tools for trait assessment. Such instruments essentially ask the respondent to estimate the frequency or intensity with

[2]A study of a preliterate culture in Bolivia (Gurven, Von Rueden, Massenkoff, Kaplan, & Lero Vie, 2013) may suggest limits to the claim of universality of personality structure, or it may simply suggest limits to the use of self-report personality questionnaires as a means of assessing personality.

which the target engages in the behavior, relative to some implicit norm. Despite the vagueness of a statement such as "I [strongly agree that, compared to other people, I] often lead groups," scales composed of such items form reasonably valid trait measures (Funder, 1989).

Note that such scales are implicitly adopted by FFT as operationalizations of traits. One essential rationale for FFT is the universality, stability, and heritability of traits, and the empirical basis for asserting those properties is research conducted with self-reports and observer ratings on personality scales. If BTs could not be operationalized by personality scales, FFT would collapse. But they can: If there is a trait (or a certain degree of a trait), then it would likely be manifest in particular CAs or behaviors that function as what Tellegen (1991) called *trait indicators*. By inductive reasoning, people who exhibit such trait indicators are likely to have the trait.

The difficulty—there are always difficulties with inductive reasoning—is that trait indicators are inherently ambiguous. The questions in a personality scale do not ask directly about underlying dispositions, but about beliefs, values, behaviors, and so on, and these may have many different causes. Why might one smile at strangers if one is not an extravert? It might be the disarming defensive strategy of a timid person; or a Boy Scout's conscientious attempt to be friendly, as the Scout Law requires; or a politician's ploy to win votes. Beyond the fact that a particular CA may reflect different traits (e.g., Extraversion, or timidity, or Conscientiousness, or ambition), it may also be chiefly the product of the environment. Smiling at strangers may be a general cultural norm, or a form of courtesy instilled by one's mother.

Good personality items—the kinds that survive rigorous item analyses (see Clark & Watson, 1995)—have a high likelihood of actually indicating the intended trait, and a lower likelihood of indicating something else. But items are never perfect.

The Duality Principle

Conceptually, there is another issue. Personality items inevitably have a dual nature: They are simultaneously instantiations of both BTs and CAs, something that FFT calls the *duality principle* (Costa & McCrae, 2017). A fondness for heavy metal music is at once an acquired taste and (perhaps) a manifestation of Excitement Seeking. Psychologists are familiar with this notion of duality in studies of intelligence. Each of the items on a vocabulary test assesses specific knowledge that must have been acquired through formal education or informal exposure, yet scores on the test are excellent indicators of general (and heritable) intellectual ability. Is a vocabulary test an aptitude test or an achievement test? Clearly, it is both; FFT asserts that something similar is true of personality scales.

Some readers might imagine that the problem of duality can be avoided by items that ask about tendencies rather than their manifestations. Isn't the item "I am very extraverted" a pure measure of an underlying disposition? On the surface it is, but in fact it is only duality once removed. If we asked a respondent what she meant by "I am very extraverted," she might say, "Oh, you know, I have lots of friends, and I'm fun-loving, and I like to keep active, and I talk a lot, and …" (she *does* talk a lot). As this example illustrates, people learn

the meaning of trait terms, including their indicators, as part of basic language acquisition; and they learn which terms apply to them by reflecting on their own patterns of thinking, feeling, and behaving. They incorporate their conclusions into their self-concept (an important CA), and draw on it when asked to describe themselves. At least according to FFT, people have no direct, intuitive apprehension of their inner nature; they discover it only through experience.

There is, however, one way in which one can approximate a pure measure of BTs: By aggregating over a wide range of trait indicators. Each item in a scale may be about some particular habit or value or belief; but if many different items are summed, the conceptual interpretation of the sum must become more general. Just as statistical error variance tends to cancel out when items are summed to form a scale, leaving a higher proportion of true score variance, so specific CA meanings cancel each other, leaving a purer indicator of the underlying trait.

One might argue that global trait assessments (e.g., “I am very extraverted”) implicitly aggregate over a range of specific indicators (e.g., number of friends, enjoyment of fun, activity, talkativeness) and thus offer purer trait assessments than more behavioral items. However, from a psychometric perspective, the disadvantages of global ratings in comparison to multi-item scales are twofold: First, even if they are conceptually purer, single global items are prone to considerable random error of measurement in comparison to multi-item scales; and second, the implicit “items” that underlie a global trait rating are unknown and likely to vary widely across different respondents. (It is, of course, an empirical question whether and to what degree these disadvantages limit the criterion-related validity of global trait assessments.)

The Structure Postulate of FFT states that “Traits are organized hierarchically from narrow and specific to broad and general dispositions” (McCrae & Costa, 1996, p. 72). When that postulate was first formulated, a two-level hierarchy of domains and facets was the focus of attention; now there are levels between these two (DeYoung, Quilty, & Peterson, 2007), above domains (Digman, 1997), and below facets (McCrae, 2015). At the lowest level are nuances, which correspond roughly to single items. Mõttus, Kandler, Bleidorn, and McCrae (2017) showed that most of the items of the NEO Inventories function as traits: They are consensually valid, longitudinally stable, and substantially heritable. This is true not only of the items themselves (which is unsurprising, because they must have those properties to serve as valid indicators of facets and domains), but also of the residual variance specific to each item when variance due to facets and domains has been statistically removed. There is some meaning peculiar to each individual item that corresponds to a specific BT; the biological basis of traits must be exquisitely complex.

It is clear that the problem of duality is most acute for nuances. At this level of the hierarchy, the trait is essentially isomorphic with its manifestation, and this poses special problems for causal analysis. Suppose, for example, there is a nuance of the Angry Hostility facet assessed by the item, “I lose my temper a lot.” If we identified a set of individuals who scored high on this item and trained them to count to ten before responding to a provocation, we might find that they subsequently scored lower on that item. If we wished to know if we

had altered the Angry Hostility trait, we should examine their responses to *other* items in the facet scale (cf. Nicholls, Licht, & Pearl, 1982), dealing perhaps with bitterness or with disgust at incompetent people. If these other items also showed a reduction (and if it endured for months or years, and if it was corroborated by independent observers), we could argue that our intervention had successfully caused the facet to change (c.f. Mõttus, 2016). But suppose the other items did not change; could we sustain the narrower claim that we had at least changed the BT corresponding to the quick temper nuance? Or had we merely changed the CA used to assess the nuance by instilling a new habitual response to provocation?

Nuances, like facets and domains, are transcontextual traits (McCrae & Costa, 1984), so it should in principle be possible to identify different forms in which they are manifested. Perhaps the item "I get really frustrated when things don't work" taps the same nuance as "I lose my temper a lot." If so, it could be used as a test of the hypothesis that our intervention had altered the quick temper nuance. Of course, identifying a set of alternative items to assess a nuance to allow such causal tests would require a program of scale development and validation as for any other trait. Fortunately, most personality psychologists are more concerned with broader traits.

The conceptual distinction between BTs and CAs is fundamental for FFT. It provides a basis for asserting that manifestations that change over time, or vary across situations, can be indicators of enduring and transcontextual traits. The value of this distinction has been implicitly acknowledged by other theorists (e.g., Church, 2017; McAdams & Pals, 2006), who have adopted the term *characteristic adaptations* to refer to acquired features that express the individual's personality.

Causal Pathways in FFT

The Personality System in Operation

Figure 1 provides a simplified version of the personality system as portrayed by FFT. The present article focuses on the solid arrows, which represent *dynamic processes* and indicate the causal pathways specified by the theory. Several points need to be made about these processes.

- The most important pathways (there are other pathways not discussed here) fall into three categories: Developmental, accommodative, and assimilative (see Figure 1). Developmental processes give rise to BTs; accommodative processes to CAs; and assimilative processes to behavior and experience, and, over time, to the cumulative objective biography.
- These three operate on different time scales. Developmental processes often require years; accommodative processes may take days or months; and assimilative processes occur in the moment.
- Accommodative and assimilative processes are inherently interactive. That is, both traits and the environment jointly lead to the emergence of CAs, and both CAs and the environment jointly lead to behaviors. All high school students might be required to take the same courses, but what and how much they learn,

and whether they develop new interests, will be (in part) a reflection of their abilities and traits. Without exposure to, say, Byzantine history, few students would ever develop an interest in the topic; but without a native curiosity, even students exposed to the topic would probably remain indifferent. The development of CAs requires both traits and experiences—both motive and opportunity, as it were. The relative importance of these two contributing causes may vary. Every child learns the times tables by rote and willy-nilly; elementary education is a strong situation. Conversely, mathematically gifted children (like Gauss) may teach themselves even when opportunities for formal education are limited.

- According to FFT, the major personality processes are unidirectional, with a clear distinction between causes and effects. Behaviors do not create CAs, and CAs do not modify traits. One apparent exception to this is indicated by the curved arrow in Figure 1, pointing from CAs to CAs, and identified as an accommodative process. This arrow refers to the obvious fact that CAs build on previously established CAs. A new exercise is added to an established routine; the role of assistant professor segues into associate; knowledge of trigonometry is a prerequisite for learning the calculus. But the causal ordering is still basically linear, provided one distinguishes between CA_1 (the cause) and CA_2 (the effect).
- Crucially, the arrows in Figure 1 refer collectively to *all* the processes that operate on a given pathway, of which there are presumably a very large number (McCrae, 2016). In part, this is because there are many quite different sorts of CAs. The processes needed to learn knitting are clearly different from those involved in bonding with a new pet or forming an opinion about legalizing marijuana. Further, for any given CA, there are often a wide variety of different causal routes: One may learn knitting by observing one's grandmother, or reading a book, or attending a class at the Senior Center; the physicist P. A. M. Dirac is alleged to have "invented" knitting by topological analysis.
- Note that these alternative routes are themselves likely to express personality. For example, introverts will likely prefer to learn knitting by reading a book rather than by attending a class; closed people may focus on mastery of basic stitches, whereas open people may try to skip ahead to more elaborate and interesting patterns. FFT expresses this in the Differential Dynamics Postulate, which claims that "Some dynamic processes are differentially affected by basic tendencies of the individual" (McCrae & Costa, 1996, p. 75).

It is the ubiquitous equifinality of accommodative processes that constrains causal explanation within FFT. We cannot specify how one learns to act agreeably or conscientiously, because there are many different and equally possible routes, some or all of which, on different occasions, may have contributed to the establishment of CAs that express those traits. This does not mean that research into specific processes is impossible or unimportant; indeed, that remains a major task for personality psychology (McCrae, 2016). But one can understand how personality will be expressed without considering the causal mechanisms in detail.

Correspondence and Emergence

Baumert and colleagues (in press) have outlined a research agenda intended to integrate personality structure, process, and development. Briefly, they argued that observed traits (behavior patterns) are caused by personality processes, and point out that there are two different ways in which the organization of processes (the causal structure) can be related to the organization of traits (the phenotypic structure). If distinct sets of processes are implicated in the creation of each distinct set of related traits (e.g., Agreeableness-generating processes produce facets of Agreeableness), then there will be *correspondence* between the causal structure and the phenotypic structure. If, however, the same processes contribute in various ways to the development of a wide range of possibly unrelated traits, then the causal structure will bear no necessary resemblance to the phenotypic structure, which can be ascribed to *emergence*.

It is possible to draw some rough parallels between Baumert and colleagues' (in press) model of the personality system and FFT's. Their traits ("relatively stable inter-individual differences in the degree/extent/level of coherent behaviors, thoughts, feelings;" p. xxx) seem to refer to CAs and the behaviors they give rise to; their personality processes appear to parallel FFT's dynamic processes. However, their model does not seem to have a direct equivalent to BTs. In their model, processes are the basic causal units, whereas in FFT, processes are intermediaries between BTs and CAs (or CAs and behavior). The study of personality processes is fundamental for Baumert and colleagues' agenda, whereas it is incidental for FFT.

To the extent that BTs are underlying causes of CAs, FFT must be described as a correspondence model; the observed covariance of trait indicators is considered to be a direct (if imperfect) reflection of the structure of the traits themselves. But, as noted above, the processes involved in translating a BT into a CA are variable across persons and occasions. Further, the same processes (e.g., habit formation, rational choice) might contribute to the development of many unrelated CAs. It is not immediately clear to what the "structure of dynamic processes" would refer in FFT, but it seem likely that the relation between such a structure and the structure of trait indicators would be one of emergence.

Traits as Effects: Developmental Processes

"Development" usually refers to normative changes after birth that lead to a mature, fully-functioning organism. In the case of non-human animals, development is assumed to have been shaped by natural and sexual selection to increase the animal's fitness. We will use *development* in a broader sense here, to refer to anything that leads to enduring changes in trait levels. Such development need not be evolved, need not stop with the attainment of adulthood, and need not be functional. Alzheimer's disease, for example, leads to late-life changes in Conscientiousness (Siegler et al., 1991) that are neither normative nor functional, but it can be understood as trait development in the broad sense of trait change.

As Figure 1 illustrates, the Origin and Development Postulates of FFT assert that traits are endogenous BTs that change (largely in adolescence and early adulthood) through processes of intrinsic maturation. Genetics plays a role, but any biological process that affects the

brain, from intrauterine environment to traumatic brain injury, can also shape personality traits.

Although FFT's *biological bases* includes much more than genetics, it is reasonable to expect that traits should be substantially heritable, and there is currently some controversy about just how heritable traits are. In particular, recent genomic studies of personality traits have suggested only modest heritability. Lo and colleagues (2016) reported significant heritability for all five factors, but with all $h^2 \leq .18$. Hill and colleagues (2017), using a sample of related individuals and a different analytic approach, found heritabilities of .30 and .13 for Neuroticism and Extraversion, respectively. A meta-analysis of behavior genetic studies (Vukasović & Bratko, 2015) found considerably larger values, with a mean value of .40. However, that figure combined results from family and adoption studies (where mean $h^2 = .22$) and twin studies (where mean $h^2 = .47$). Vukosović and Bratko attributed this dramatic difference to the presence of non-additive genetic effects that are detectable only in twin designs. That might account for the relatively low heritabilities in some genomic studies.

Further, all these studies rely on self-reports, and thus refer to the heritability of observed scores. All personality assessments include substantial error, both random and systematic, so these are necessarily lower limits of the heritability of true scores. Multi-method studies, that allow estimates of true score heritability, typically find heritabilities of .5 to .7 (Mõttus et al., 2017; Riemann, Angleitner, & Strelau, 1997).

Conspicuously absent from Figure 1 is an arrow from EIs to BTs: Traits are relatively immune to effects from the psychological environment. This is the most radical and unpopular tenet of FFT, and it is almost certain that there will be exceptional circumstances in which it is wrong. But, as argued elsewhere (McCrae, De Bolle, Löckenhoff, & Terracciano, in press), a purely biological basis for traits is consistent with a wide range of findings[3] from comparative (King, Weiss, & Sisco, 2008), cross-cultural (McCrae, Terracciano, & 78 Members), longitudinal (Costa, McCrae, & Arenberg, 1980), and behavior genetic (Jang et al., 1998) studies, whereas evidence for important effects on personality traits from the psychological environment is not yet compelling.

FFT's claim that the environment does not affect trait development could easily be misunderstood by psychologists and developmentalists (e.g., Gottlieb, 2007). In fact, no one imagines that the human brain develops in a vacuum; cognitive and personality development presuppose a rich social environment with which the organism interacts. An embryo raised to maturity in a sensory deprivation tank—if it survived at all—would not be a human being. Developmentalists are naturally interested in the details of the organism/environment transactions that allow development to unfold, but these need not concern the personality psychologist, because the psychological environment—at least Hartmann's (1939) average expectable environment—has no *differential* effect on trait development. According to FFT, any psychological environment will lead, in the long run, to the same levels of personality

[3]Other, non-biological explanations are also possible, although they are unlikely to be as parsimonious. Stability of the environment might account for stability of traits, but it could not explain the similarity of personality structure across cultures.

traits. This phenomenon was most famously illustrated in the Minnesota studies of twins raised apart (Tellegen et al., 1988).

Biological Influences on Development

If the psychological environment has no distinctive effect on trait development, it makes sense to focus on the causal analysis of biological influences on personality. Because most psychologists agree that biology has some effect on traits, this approach ought to be uncontroversial … as far as it goes.

There are several possible approaches to understanding the biological underpinnings of trait development across the lifespan, ranging from correlational to experimental. Where analogous developmental processes are seen in other species (e.g., King et al., 2008), even animal models might be exploited. Each approach is informative in contributing a piece of evidence on the biological origins of personality development, yet each also has limitations that prohibit strong claims about causality.

Correlational studies have been useful for identifying associations of traits with a range of biological factors, including brain structures (DeYoung et al., 2010), inflammatory and other physiological markers of health (Luchetti, Barkley, Stephan, Terracciano, & Sutin, 2014; Sutin et al., 2010), and chronic diseases (Chapman, Lyness, & Duberstein, 2007). These studies, however, are limited in the way that all correlational studies are limited: They provide information about an association but no indication of which variable is cause and which consequence.

Longitudinal studies are more informative than cross-sectional studies because they can sometimes help tease apart the temporal ordering of the variables. For example, van Sheppingen and colleagues (2016) reported that participants who became parents during the course of a longitudinal study did not change any more than a matched set of participants who did not become parents on any of the Five-Factor Model domains. Thus, having children—which is a profound biological as well as psychological event—does not appear to be a cause of personality change. However, van Sheppingen and colleagues did find that closed extraverts were more likely to become parents, suggesting a possible causal role of personality in the decision to have children.

Several longitudinal studies have found that biological factors are associated with change in personality traits, but two-point data often provide insufficient information for strong causal inferences. For example, physiological dysregulation, as indexed by cardiovascular, metabolic, and immune markers of allostatic load (or stress), is associated with subsequent declines in Extraversion and Conscientiousness four years later (Stephan, Sutin, Luchetti, & Terracciano, 2016), and may be a contributing cause to personality change. However, without serial data on personality traits prior to the baseline measure of allostatic load, one cannot rule out the alternative possibility that the physiological dysregulation was itself a consequence of an ongoing decline in Extraversion and Conscientiousness. Likewise, young adults who quit smoking decline in Neuroticism and impulsivity (Littlefield & Sher, 2012). Nicotine is a powerful drug with well-established pharmacological effects on the brain, so these findings are plausible from the perspective of FFT. But even though smoking cessation

occurred before the change in Neuroticism was measured, it is not possible to know whether cessation caused the decline in Neuroticism or whether naturally occurring declines in Neuroticism led the individual to quit smoking.

Evidence for a causal role of biology on personality also comes from the change in personality traits that occurs with the onset of Alzheimer's disease (AD). Numerous studies have found that individuals with dementia have dramatic increases in Neuroticism and decreases in Conscientiousness compared with their premorbid personality (Robins Wahlin & Byrne, 2011). There are profound changes in the brain due to AD, and the changes in personality that occur with AD are likely a result of these changes in biology. How these alterations in the brain directly lead to the observed changes in personality are not yet known. Still, change in personality with the onset of dementia is so common that it is enshrined in the clinical criteria for AD (McKhann et al., 2011).

Because AD patients may not be able to complete self-report measures, research on the personality changes that occurs with AD relies primarily on retrospective reports from knowledgeable loved ones. Such reports are presumably biased to some extent because the informant may exaggerate the difference between pre- and post-morbid personality and may rely on stereotypes of dementia when rating their loved one's personality. There is some evidence, however, that supports these findings even in the presence of bias. First, the stability of self-reported traits is much lower among individuals with cognitive impairment (Terracciano, Stephan, Luchetti, & Sutin, 2017). Over a four-year follow-up, for example, the mean stability coefficient for individuals with dementia was .43 compared to .70 for individuals of similar age without dementia. By contrast, the internal consistency of the scales was similar across individuals with and without dementia, which suggests that lower stability coefficients were not merely a reflection of lower reliability in the self-reports of those with dementia. Second, there is little relation between baseline personality and AD neuropathology. Terracciano and colleagues (2013) reported an association between Neuroticism and the Braak stage of neurofibrillary tangles in the brain at autopsy, but not neuritic plaques; others haves found no relation between either tangles or plaques and personality (Wilson, Schneider, Arnold, Bienias, & Bennett, 2007). Premorbid personality thus does not predict the amount of neuropathology that accumulates in the brain. Instead, the brain changes associated with AD presumably account for the significant changes that occur in personality with the disease. The mechanisms through which AD leads to changes in personality traits, however, have yet to be identified.

Natural experiments provide a quasi-experimental approach to identifying factors that have causal effects on personality traits. Natural experiments occur when an intervention happens in the "real world," not under the control of the investigator. In psychology, natural experiments often examine the effect of environmental stressors on psychological outcomes, including traits. A recent example comes from the 2011 earthquake in Christchurch, New Zealand. This massive 6.3 magnitude earthquake killed nearly 200 people and destroyed much of the city's infrastructure. Milojev and colleagues (2014) used this occasion to test whether personality changed as a result of a major natural disaster. With data collected a year before and after the earthquake, the researchers found that participants in Christchurch increased slightly in Neuroticism from before to after the quake, whereas participants from

similar areas of New Zealand that were not affected by the earthquake had a slight decline in Neuroticism over the same time period; there were no changes in any of the other traits for either group, and there were no differences in pre-quake personality between the two groups. The random selection of the inhabitants of Christchurch subjected to a major earthquake suggests—contra FFT—that exposure to a significant natural disaster increases Neuroticism. It is not yet known for how long this difference will persist, and this design cannot identify underlying mechanisms, including perhaps biological processes, that may account for the observed change.

Researchers guided by FFT might choose to study natural experiments that focus on potential biological processes, comparing populations that do or do not experience famine, epidemics, or climate change. One problem with all such designs is that the independent variable (earthquake, famine, etc.) typically consists of an entire complex of biological, psychosocial, and political influences, and it will rarely be possible to single out the effective cause of any observed changes.

In medicine, randomized controlled trials (RCTs) are the gold standard for establishing causality. Such studies are difficult in the context of personality research for both practical and ethical reasons. Still, some RCTs suggest that biological interventions can change personality. Experimental studies with psilocybin, a common hallucinogen, for example, indicate that Openness increases with exposure to this drug: Individuals who received high doses increased in Openness following administration and maintained this higher Openness at least one year later (MacLean, Johnson, & Griffiths, 2011). A short-term (two week) follow-up study replicated this effect with LSD (Carhart-Harris et al., 2016). In both cases, this effect was specific to Openness. Further evidence suggested that changes in brain function accounted for this effect: LSD may increase Openness through greater entropy in the brain (i.e., changes in brain signal that are related negatively to predictability of a time series; Lebedev et al., 2016). RCTs, however, still face limitations that compromise the ability to draw conclusions about causality. For example, there is significant selection bias both in who chooses to participate and who completes the study. In the above examples, hallucinogens increased Openness among participants who were willing to accept the possibility of being given a hallucinogen as part of a study; whether the same effect would occur in individuals unwilling to take a hallucinogen in the first place is unknown.

Even with evidence from RCTs, it is difficult to evaluate whether the intervention changed the underlying BT or the CA that measures it. As discussed in the example of angry hostility above, if all or at least many items within the trait or facet changed in response to the intervention, then there would be some evidence for change in the BT. If, however, only one or just a few items showed change in response to the intervention, it would be more difficult to differentiate whether the change reflected a change in the BT or the CA used to assess it.

The methodology of RCTs provides a rigorous test of how a biological intervention may or may not change personality. Such approaches, however, may be less useful for identifying the pure biological determinants of traits. If administration of a drug known to effect a specific structure or function of the brain also leads to change in personality, compared to controls, then one can infer that the structure or function effected by the drug is also

implicated in personality. As such, it would provide support for the biological processes responsible for personality but not necessarily its entire biological basis. There are other limitations of RCTs that limit their usefulness (Deaton & Cartwright, 2016), and, for any biological process that may contribute to personality development, no one methodology is likely to lead to conclusions about causality. Rather, it will take converging evidence from diverse approaches to identify plausible explanatory causes.

Neither diseases nor drugs nor earthquakes are likely to be able to account for personality trait development in the narrow sense, such as the gradual normative decrease in Neuroticism and increases in Agreeableness and Conscientiousness that have been called *personality maturation* (e.g., Roberts & Mroczek, 2008), or the gradual erosion of rank-order stability over decades of life (Conley, 1984). FFT ascribes such developmental pathways to intrinsic maturation, due presumably to genetically-controlled processes of aging and to accumulated random changes in brain structure. Because aging cannot be manipulated, direct tests of these hypotheses are probably impossible. Twin studies speak to the heritability of differential rates of trait change, but not to the possible genetic basis of universal trait changes. Indeed, the best evidence for the intrinsic maturation hypothesis comes from ruling out alternatives (van Sheppingen et al., 2016; McCrae, De Bolle, Löckenhoff, & Terracciano, in press).

Traits as Causes: Assimilative Processes

Many psychologists would claim that the chief task of psychology is to understand, predict, and control behaviors. Cognitive psychologists focus on how behaviors are learned and how actions are planned or chosen. Social psychologists emphasize situational determinants of behavior, although sometimes in conjunction with individual differences in goals and needs (Cacioppo, Petty, Reinstein, & Jarvis, 1996). Personality psychologists also predict specific behaviors (e.g., Kolar, Funder, & Colvin, 1996), although they have learned that traits are better predictors of aggregated than of single behaviors (Epstein, 1979).

Social psychological explanations of behavior are usually tested with experimental designs in which participants are randomly assigned to conditions. Personality psychologists understand that situations do not occur randomly in real life; instead, people select situations (Buss, 1987), often on the basis of their personality traits. Personality psychologists may be able to provide more naturalistic accounts of behavior because they acknowledge the contribution of the person (as well as the situation; Funder, 2016).

To justify the imperialistic claim that personality psychology is the study of the whole person, one might note that CAs, a central part of the personality system, are involved in the generation of all behaviors—except perhaps unconditioned responses—and thus that personality provides part of the causal explanation of virtually all psychological phenomena. In practice, personality psychologists are concerned with a more limited range of behaviors and experiences that are tied, at least conceptually, to traits, or to CAs (such as values, interests, or the self-concept) that are substantially related to traits. Knowledge of basic English grammar is a CA, but writing a grammatical sentence would not generally be considered a personality-related behavior.

FFT asserts that traits, as BTs, are distal causes of behavior, their effects mediated by CAs. For example, extraverts are better group leaders (Judge, Bono, J., Ilies, & Gerhardt, 2002), and extraversion is associated with social skills (Riggio, 1986); it is plausible to argue that social skills are a proximal cause of good leadership, and Extraversion a distal cause. Similarly, investigative vocational interests might be a proximal cause of career choices, and Openness the distal cause (Costa, McCrae, & Holland, 1984); a nicotine addiction the proximal cause of smoking behavior, and Neuroticism a distal cause (Terracciano & Costa, 2004). Personality psychologists can extend the causal chains of educational, industrial/organizational, and health psychologists back—in part—to enduring dispositions.

The causal mediation between traits and behaviors posited by FFT does not translate directly into simple statistical mediation. One might, for example, assess Extraversion, social skills, and leadership behavior, and find that, statistically, social skills partially mediate the effect of Extraversion on leadership[4]—leaving, in the usual interpretation of the data, an additional *direct* effect of Extraversion that FFT would not predict. FFT would explain this anomaly by arguing that other mediating CAs related to Extraversion (e.g., social network size) account for the remaining variance. A full model, in which all relevant CAs were included, would be expected to show no direct effect of traits on behaviors.

Conversely, empirical studies might show that particular CAs offer stronger causal accounts of outcomes than do the traits that underlie them. For example, social skills might be much better predictors of leadership than Extraversion itself is. Such a result might be due to the indirect influence of other, unmeasured BTs such as intelligence (Riggio, 1986), or to EIs such as formal education or life coaching that increase social skills and thus leadership ability.

FFT insists that the effects of traits on behavior must be mediated by CAs, but for practical purposes it may suffice to know that traits predict an outcome of interest, without any consideration or assessment of CAs. Some links in the causal chain will be missing, but some links in any causal chain are inevitably missing. It is useful to know that conscientious job applicants will outperform others, even if one does not know whether to attribute this to their perfectionist attitudes, their habits of punctuality, or their methodical working styles. Of course, if one knew which specific CAs were relevant to the outcome, for practical purposes it might make sense to assess them and ignore the underlying traits. But a small number of domain- and facet-level personality traits are associated with a myriad of CAs, so systematic exploration of potential predictors of some outcome is probably easier at the trait level.

Traits as Causes: Accommodative Processes

Most of the vast literature on personality correlates consists of studies linking traits to CAs: health habits, values, prejudices, personality disorders, relationships, parenting styles, virtues, music preferences, and so on. Although these are correlational studies, the usual

[4]In any such design, care should be taken to assess the BT with indicators that are not confounded with the CAs of interest. For example, the Extraversion scale in this example should probably omit items related to assertiveness.

(and reasonable) assumption is that traits are the cause and their correlates the effect. Such studies are valuable in charting the causes of behavior and cataloging the consequences of personality traits, and they have been greatly facilitated by the widespread adoption of the Five-Factor Model, which provides a framework for organizing systematic research and meta-analyses.

FFT claims that in these cases, an association is found because traits respond to the demands and opportunities of the environment to create new intrapsychic structures that can become relatively enduring features of the individual—CAs. People are not born with a distrust of foreigners, but some are born with (or develop over time) a disposition to be wary and skeptical. The specific objects of mistrust are learned—through personal experience, modeling one's peers, or formal indoctrination. As noted above, many different mechanisms may be involved, including self-selection into like-minded groups.

FFT expects that the end result of a lifetime of experience is more-or-less fixed by the traits the individual brings to it; the stability of individual differences over periods of up to 40 years (Terracciano, Costa, & McCrae, 2006) is consistent with the idea that BTs provide a kind of set-point around which CAs hover. A prediction that follows from this is that effects produced by one set of experiences (including deliberate interventions) may stimulate compensating effects elsewhere. This phenomenon was made famous in the psychoanalytic notion of symptom substitution: Cure one problem in an individual high in Neuroticism, and another will pop up (c.f. Ellis, 1987). It is also the basis of the therapeutic strategy of channeling aggression in socially acceptable ways, rather than trying to reduce it. FFT would anticipate similar effects for all traits: For example, natural introverts who are required by their profession to interact extensively with others may seek out new opportunities for solitude (Long & Averill, 2003). Psychologists evaluating interventions intended to modify trait-related CAs should perhaps also enquire about unintended compensatory consequences that might be considered side-effects of the intervention.

CAs develop over time, in the context of enduring dispositions. One implication is that experimental research on modifying CAs may be misleading. Swann (1983) provided a nice illustration of this fact. He showed that fairly simple false feedback could alter a person's self-concept, as assessed by a post-intervention self-report. But a follow-up assessment collected a few days later showed that the original self-concept had been restored. Psychotherapists are well aware that the progress made in one session may have evaporated by the next.

Core and Surface Characteristics

Kandler, Zimmermann, and McAdams (2014) have discussed a distinction found in the personality literature between core and surface characteristics—a distinction they liken to that between BTs and CAs. Core characteristics (roughly, traits) are thought to be stable, heritable, and causally prior to surface characteristics. The latter, including self-related schema, attitudes and beliefs, and personal strivings, would generally be classified by FFT as CAs. Kandler and colleagues argued that if they are really distinct from core characteristics, surface characteristics should be substantially less stable and less heritable.

FFT does not make specific predictions about the stability of CAs. Some of them are quite time-limited (e.g, the goal of finishing a term paper), whereas others endure for decades (e.g., knowledge of one's native tongue). Some CAs are malleable (the route one takes to work), whereas others resist change (cigarette smoking). Thus, stability is generally expected for BTs, but it is not contraindicative for CAs.

Kandler and colleagues (2014) reviewed a series of studies on the heritability of general interests, attitudes, and life goals in conjunction with personality traits. The most straightforward interpretation of FFT would predict that interests, attitudes, and goals ought to be heritable only insofar as they are related to heritable traits. In fact, Kandler and colleagues typically found that these CAs were sensibly related to traits, and that part of their heritability could be accounted for by the heritability of traits—but that some could not. Interests, attitudes, and goals appear to have some unique biological basis beyond that captured by the traits assessed by the Revised NEO Personality Inventory (Ostendorf & Angleitner, 2004). Kandler and colleagues (2014) argued that this means that the conceptual distinction between traits and other attributes (e.g., interests) offered by FFT (and some other personality theories) needs revision.

However, it is possible to reconcile the findings of Kandler and colleagues with standard FFT (Costa & McCrae, 2017). FFT insists on the distinction between BTs and CAs, and it claims that the personality sphere is essentially exhausted by the five factors and their definers. From this perspective, Kandler and colleagues have documented (1) that the duality principle applies to attitudes, interest, and goals as well as to NEO Inventory traits; and (2) that many attitudes, interests, and goals may be regarded as facets or nuances of one or more of the five factors. This is not a radical innovation: The NEO Inventories already include facets that tap attitudes (Openness to Values; Tender-Mindedness), interests (Openness to Aesthetics and Ideas), and goals (Excitement Seeking, Achievement Striving).

Kandler and colleagues (2014) argued that the catalogue of core characteristics should be broadened beyond "stylistic and regulatory patterns of thoughts, feelings, and actions" to include "interests, motives, attitudes and values" (p. 240). At least in theory, current views of the Five-Factor Model already do. Costa and McCrae (2017) discussed the fact that all broad traits are expressed in a variety of ways; the items in personality questionnaires tend to be a mix of emotional, behavioral, and cognitive indicators of the trait (Pytlik Zillig, Hemenover, & Dienstbier, 2002). One of the early demonstrations of the comprehensiveness of the Five-Factor Model showed that its factors could be found in an inventory of Murray's needs (Costa & McCrae, 1988), and the NEO Inventories have been described as assessing "emotional, interpersonal, experiential, attitudinal, and motivational characteristics" (Costa & McCrae, 2014, p. 231).

From the perspective of FFT, the issue is not whether attitudes, values, and interests are core characteristics, but whether they are BTs or CAs, and the answer to that depends entirely on how one looks at them. If one focuses on the concrete content of a need or interest or value, it is a CA; if one focuses on the general tendency underlying the specific instantiation, it is likely a BT. Aspiring to be President is a CA that would have been meaningless in most

cultures throughout most of history. Having a predisposition to seek social dominance is a BT that is presumably universal.

A Lesson from Discordant MZ Twins

Turkheimer, Pettersson, and Horn (2014) present an interesting approach to causal analysis exploiting differences between monozygotic twins. In their example, drug use is hypothetically associated with Extraversion, which would normally be interpreted as evidence of an accommodative process: Extraversion, a BT, leads to the development of drug addiction, a CA. Turkheimer and colleagues suggest another possibility: Perhaps some of the same genes affect both Extraversion and drug use, so the cause of drug addiction is not Extraversion, but a shared set of genes. Discordant twins provide a way of testing this hypothesis. Because twins are never identical, we can expect that one MZ twin in each pair will be more extraverted than the other,[5] and we can compare the rate of drug addiction in the more extraverted twins with the rate in the more introverted twins. If Extraversion per se is the causal factor, then the former group should have a higher rate of abuse. If, however, there is no difference, Turkheimer and colleagues would conclude that Extraversion is not a cause of drug abuse; instead, Extraversion and drug use are common effects of shared genes. That might appear to imply that biological bases are direct causes of CAs—a conclusion that is not consistent with FFT.

A proponent of FFT would argue that drug use is a suite of attitudes and behaviors that might include finding a dealer, buying the drug and paraphernalia, smoking, snorting, or injecting the drug, concealing the stash, and so on. Surely Turkheimer and colleagues (2014) do not believe that genes dictate these attitudes and behaviors in the way that instinct guides a squirrel to conceal a stash of acorns. Drug use per se is heritable in the statistical sense that if one twin uses drugs, the other has a greater probability of doing so. In a mechanistic sense, genes must affect the brain in such a way as to create a *disposition* to acquire drug-use attitudes and behaviors—CAs that are developed through life experience in a particular social context. FFT would interpret this heritable disposition as a trait we might call *drug-use proneness*. It might turn out that drug-use proneness is merely another name for Extraversion; if so, the more extraverted group in a discordant twin study should show higher rates of drug use. What if the study showed that (true score) Extraversion and drug use were not completely yoked? Because drug-use proneness is a trait associated with, but not equivalent to, Extraversion, FFT would interpret it as a facet of Extraversion—perhaps Excitement Seeking, or perhaps some new and distinct facet. Extraversion would then be one of the contributing causes of drug-use proneness (in the “factorial” sense; see below), and a distal cause of drug use.

The same argument, of course, can be applied to any other CAs—like Kandler and colleagues’ (2014) interests, motives, and values—that are statistically heritable and substantially related to one or more of the five factors: They must correspond to (and be indicators of) BTs somewhere in the personality trait hierarchy. That a CA is a personality

[5]Note that such differences might reflect the influence of the non-shared environment on the trait, as Turkheimer and colleagues assume, but they might also result in part or in whole from random and systematic measurement error. Fruitful implementation of this design would probably require multi-method trait assessment and large samples.

correlate, that it is statistically heritable, that some portion of its heritability is not shared with Five-Factor Model factors—these are empirical findings. That a personality-related CA has some corresponding BT is merely a logical deduction from the premises of FFT, but it facilitates a whole series of hypotheses on the characteristic's stability, universality, and development.

Traits as Causes: "Factorial" Processes

Statistical purists argue for a sharp distinction between factor analysis and component analysis: Principal component analysis is said merely to describe the correlational structure of variables, whereas factor analysis explains it by revealing the causal connection between underlying factors and their manifestation in observed variables. In fact, however, causal inferences are not made by statistical manipulations, but by scientists who consider a pattern of evidence (including, on occasion, factor or component loadings).

With this understanding, it is appropriate to ask whether the broader traits identified by factor or component analysis can be considered causes of the narrower traits that define them. This is the default view in personality psychology; we tend to assume that warmth and cheerfulness and activity covary because they share some common cause that we call Extraversion. Similarly, items about laughing, feeling joy, and being optimistic covary because they share a facet-level cause called Positive Emotions.

We might imagine that there is an Agreeableness center in the brain, with neural connections to centers controlling Trust, Straightforwardness, Altruism, Compliance, Modesty, and Tender-mindedness. If the Agreeableness center is highly active, it will cause activity in all the related centers; in a population with varying levels of activity in the Agreebleness center, the facets of Trust, Straightforwardness, and so on will covary to define the phenotypic factor. Or perhaps Agreeableness reflects the operation of a set of genes, and some or all of the same genes contribute to each of its facets (McCrae, 2015). In these scenarios, the biological basis of the factor contributes to the biological bases of the facets, and in this sense, the factor causes the facets.

An alternative view has recently been promoted (e.g., Cramer et al., 2012): In network models, traits covary because they are functionally linked to each other; facets essentially cause each other. Some aspects of this account are plausible. For example, we might suppose that people who are cheerful make more friends, and people with many friends learn good social skills, and people with social skills become leaders, and leaders enjoy the prerogatives of leadership and become cheerful. Thus Positive Emotions, Gregariousness, and Assertiveness will tend to co-occur, and we label that syndrome Extraversion. In this network model the factor emerges from the facets; it is effect, not cause. Throughout this article we will discuss a simplified, pure network model in contrast to a pure factorial model; it is, however, clearly possible that both contribute to the observed covariance of traits.

Normally if there is a question about which of two related phenomena is cause and which effect, researchers may try to manipulate each and see if the other responds. If we could increase the level of Neuroticism, we could see if all its facets increased, too. In our present

state of ignorance, this approach (even if it were ethical) is not feasible; we have not identified practical causes of trait change.

There are, however, manipulations that may provide some hints. When administered antidepressant medications, many patients improve (although others do not). For those who respond to the drug, there are significance changes in trait profiles. Costa, Bagby, Herbst, and McCrae (2005) showed that recovered patients decreased on total Neuroticism and four of its facets: Anxiety, Depression, Self-Consciousness, and Vulnerability; the declines in Angry Hostility and Impulsiveness did not reach significance. One might reasonably conclude from these findings that antidepressants lower Neuroticism and thereby its facets. However, trait levels also changed for Extraversion, Openness, and Conscientiousness, and 7 of their facets. Antidepressant medications (nine different drugs were used in this clinical study, at the discretion of the treating psychiatrist) do not seem to provide a clear and selective way to manipulate Neuroticism.

A more specific manipulation may have been found for Openness. As noted earlier, MacLean, Johnson, and Griffiths (2011) administered the “magic mushroom” drug, psilocybin, in a controlled setting, and found significant increases in Openness, but none of the other factors. A subgroup of 30 (of 52 total) participants had mystical experiences during the drug session; these could be considered “responders.” Within this subgroup, increases in Openness of about 1/2 standard deviation were seen, and were sustained after a one-year follow-up. As the causal interpretation of factors would predict, significant effects were also found for five of the six Openness facets.

Although these results are generally consistent with the hypothesis of a factorial cause, they unfortunately do not rule out a network explanation. Antidepressant medications, for example, may alter the level of the Depression facet, and its network connections may then create changes in Anxiety, Self-Consciousness, and Vulnerability facets. In principle it might be possible to decide between the two alternatives by assessing trait levels repeatedly: If all trait changes are simultaneous, then a factorial explanation is favored; if changes in one facet regularly precede changes in other facets, it would suggest the unfolding of network processes. At present we know almost nothing about the time scale on which network processes work (if they do in fact work), so a good deal of exploratory research would need to precede a convincing test.

It is also possible to consider natural experiments, of which the most convenient is aging (Mõttus, 2016; Mõttus, Realo, Allik, Esko, Metspalu, & Johnson, 2015). With age, adults show regular, though very gradual, changes in all personality factors. In general, from age 30 to age 70, Neuroticism and all of its facets decline, whereas Agreeableness and Conscientiousness and their facets increase (McCrae, Martin, & Costa, 2005; Terracciano, McCrae, Brandt, & Costa, 2005), consistent with the notion of a unitary and unifying factor. But the developmental courses of the facets of Extraversion are not consistent. In both self-reports (Terracciano et al., 2005) and observer ratings (McCrae et al., 2005), Warmth increased slightly with age, whereas Excitement Seeking declined dramatically. Part of the explanation for this difference is that these two facets of Extraversion have secondary loadings on Agreeableness; the positive loading of Warmth on Agreeableness may explain

its increase (because Agreeableness increases); the negative loading of Excitement Seeking on Agreeableness helps explain its rapid decline.

But even if the influence of all five factors is statistically removed from each of the facets, there are developmental trends in the remaining specific variance that are consistent across cultures (McCrae et al., 1999). We cannot easily tease apart the causal influence of factors on facets through a study of aging, because age has effects on both: Any deviation from the pattern predicted by the factor-as-cause model could be due to developmental effects on the specific portion of the facet.

Researchers might have more luck testing predictions from the network approach. Here traits must be malleable; otherwise, they would not be able to coalesce into a network. Manipulation of any single facet should have ramifications for all the other facets in the network.

We might, for example, assign individuals low in Gregariousness to jobs that require extensive human contact. According to a network analysis, increased social interaction ought to promote increased social skills, cheerfulness, assertiveness, and so on—the entire network of Extraversion-related traits. Placed in a new social environment, these individuals would achieve a new network equilibrium that elevates all facets of Extraversion.

Note that such predictions from network models are exactly the opposite of those made by FFT for CAs. According to FFT, assigning introverts to jobs requiring extensive socialization should lead them to seek more solitary free-time activities—what Little (1996) has called a *restorative niche*—in compensation. It might be possible to conduct experiments—or find natural ones—that allow one to determine whether changes to one facet (or its CAs) lead to proportional or, on the contrary, to compensatory changes in others.

Similar ideas have been proffered by Little (2008) in his concept of *free traits*. Individuals need not be forced to act in unaccustomed ways by therapeutic interventions or experimental manipulations; they may themselves freely choose to enact a trait that runs counter to their own natural disposition. These free traits are patterns of behavior to chosen to advance one's personal projects. An introvert might take a position in sales because this is the best job available; to keep it, he or she would adopt an outgoing manner. Although free traits can advance one's agenda, they require effort and, without restorative resources, can lead to lowered well-being (Little, 2008). Presumably free traits are discarded as soon as they cease to be useful.

The Heritability of Facets and Factors

Evidence on the heritability of facets and factors can shed some light on the causal status of factors. We know that both broad and narrow traits are heritable (e.g., Mõttus et al., 2017), so traits at some level of the hierarchy must have some genetic basis. But network and factorial models have quantitatively different implications about the heritability of higher-order factors. Consider a simplified example of a factor with two facets, X and Y. From a network perspective, we might identify three sources of variance that contribute to an individual's score: Genetic components specific to each trait that accounts for their

heritability (G_X and G_Y); a network component (N) that accounts for the observed covariation of X and Y; and error (E_X and E_Y). If we assume that these are combined in the proportion of a:b:c (where $a^2 + b^2 + c^2 = 1$), and that the proportions are identical in both traits, we can say that

$$X = aG_X + bN + cEx$$
$$Y = aG_Y + bN + cE_Y$$

The correlation between traits, r_{XY}, is entirely due to the shared component, N, and is equal to b^2. The heritability of X (or Y) is entirely due to G_X (or G_Y), and is equal to a^2. To choose illustrative values, let $r_{XY} = b^2 = .3$, and $h^2 = a^2 = .4$. Then c^2 must equal $1 - .3 - .4 = .3$.

Now consider the factor formed by summing X and Y. Clearly,

$$(X + Y) = aG_X + aG_Y + 2bN + cE_X + cE_Y$$

The heritability of (X+Y) is due entirely to G_X and G_Y, and is given by

$$h^2(X + Y) = (a^2 + a^2)/(a^2 + a^2 + 4b^2 + c^2 + c^2) = (.4 + .4)/(.4 + .4 + 1.2 + .3 + .3) = .31 < .4.$$

The factor is less heritable than its component facets.

Now consider the factor-as-cause model. Here we assume the components of variance are the heritable specific variance, the heritable common variance, G, (i.e., the causative underlying factor), and error:

$$X = aG_X + bG + cE_X$$
$$Y = aG_Y + bG + cE_Y$$

The correlation between traits, r_{XY}, is entirely due to G, and is equal to $b^2 = .3$. The heritability of X (or Y) is due to both G_X (or G_Y) and G, and is equal to $a^2 + b^2 = .4$. Thus, a^2 must equal $.4 - .3 = .1$, and $c^2 = .6$. The factor score is given by

$$(X + Y) = aG_X + aG_Y + 2bG + cE_X + cE_Y,$$

and the heritability of the domain is due to all heritable components:

$$h^2(X + Y) = (a^2 + a^2 + 4b^2)/(a^2 + a^2 + 4b^2 + c^2 + c^2)$$
$$= (.1 + .1 + 1.2)/(.1 + .1 + 1.2 + .6 + .6) = .54 > .4.$$

Here, the factor is considerably *more* heritable than the facets.

Both these models are greatly simplified, omitting, for example, method variance that itself may or may not be heritable. But they illustrate the general point that if facets share a common genetic influence, that influence will be compounded when they are added together and tend to produce higher heritability estimates for factors than for facets. Conversely, if there is no common genetic influence—as pure network models assume—then the sum of the facets, although still heritable, will show a diluted genetic effect, because the compounded network influence, *N*, increases as a proportion of the variance in the sum.

Which model better fits the data? Jang and colleagues (1998) reported that the mean heritability of NEO Inventory facets was .39, whereas the mean heritability of the five factors was .48. Those data support the underlying-factor-as-cause model.

It might be argued that the simplified network model we have discussed is a straw man. In their Figure 7, Cramer and colleagues (2012) described a possible network model in which a set of genes affect more than one indicator of Neuroticism, as well as some of the connections between the indicators. Certainly this is a possible scenario, but such a set of genes would necessarily contribute to the covariation of items that define a Neuroticism factor, and FFT would argue that the set of genes is in fact a (partial) biological basis of Neuroticism itself. In that sense, Neuroticism is a factorial cause of its facets. If we must choose between a pure network and a pure factorial model, the data on heritability favor the latter, but they do not rule out a mixed model.

Conclusions

Personality psychologists are concerned with discovering both explanatory and practical causes for the phenomena with which they are concerned. The discovery of explanatory causes is particularly challenging for personality psychologists, because personality traits are not easily manipulated. With our still-limited understanding of the brain, specifying the developmental processes through which biology shapes basic tendencies is likely to require decades—if, indeed, it can ever be done at all: Biological structures and personality dispositions occupy different conceptual levels, and seeking the mechanisms by which the brain produces thoughts, feelings, or enduring dispositions is like asking for the mechanisms by which a printing press creates poetry.

Causal explanations for assimilative processes—to allow the prediction of behaviors—are more tractable, but we normally leave the problem of discovering how attitudes lead to votes, or learning styles to test scores, or irrational thoughts to suicide attempts to specialists in social, educational, or clinical psychology. Personality psychologists are more likely to be concerned with providing causal explanations for the accommodative processes that create characteristic adaptations. But here equifinality complicates the task: There are many very different routes by which the antagonistic person may acquire skeptical attitudes, inflated self-regard, and hostile relationships.

In the near future, personality psychologists may be better advised to concentrate on seeking practical causes. There equifinality is not a problem. *Any* intervention they find that can reliably rechannel anger, or promote better dietary habits, or increase teamwork is useful.

The search for interventions to modify CAs can, of course, be guided by knowledge of personality traits and their typical expression (McCrae, 2011). And personality psychologists should take every opportunity to see if people with different traits respond differently to particular interventions, using the classic Trait × Treatment design (McCrae & Sutin, 2007).

Traits are plausible explanatory causes of many psychological characteristics and behavior patterns, but because traits are not easily modified, these causal explanations do not offer a direct path for intervention. Instead, trait psychology is perhaps most widely used in the contexts of selection and diagnosis, where personality assessment can be used to predict many desirable occupational and marital outcomes and many forms of maladjustment. The I/O psychologist often has the luxury of choosing the candidate with an optimal set of personality traits (Costa, McCrae, & Kay, 1995). The clinical psychologist must deal with clients' traits as given, but being able to anticipate their strengths and weaknesses can facilitate the process of therapy (Miller, 1991).

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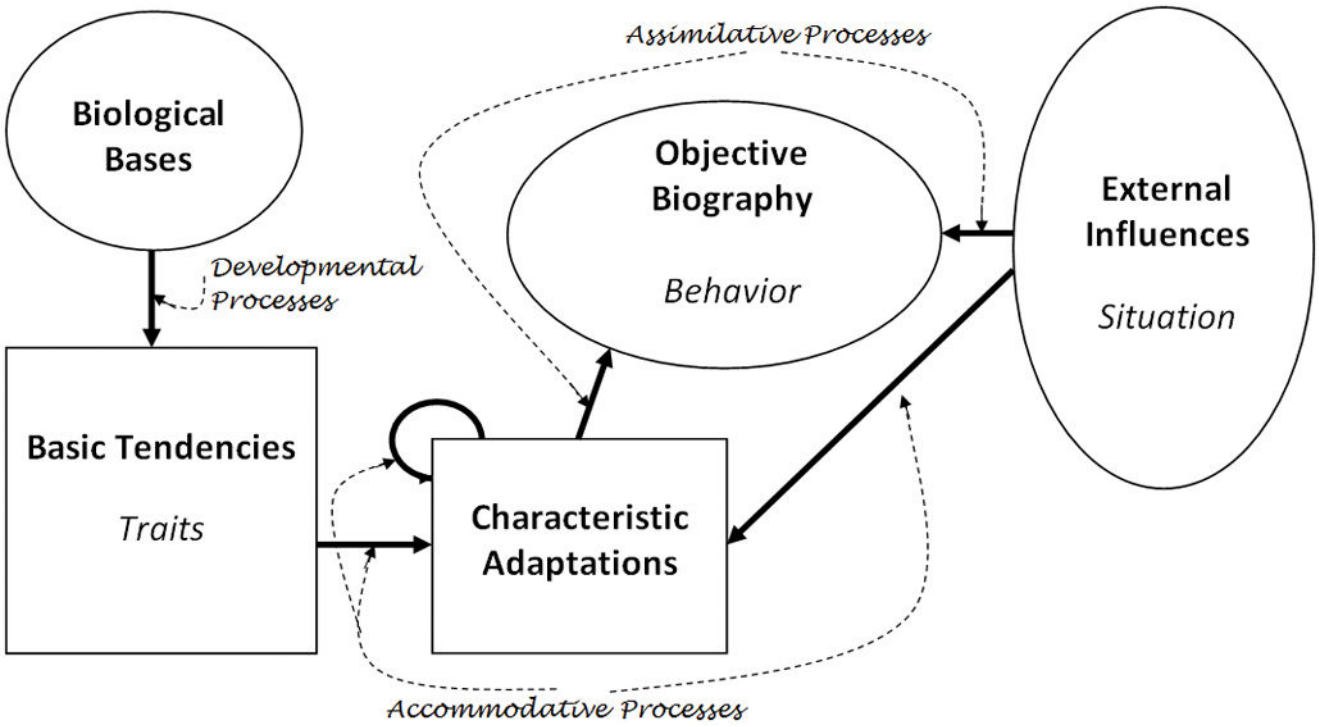

Figure 1.

A simplified representation of the Five-Factor Theory personality system. Core components are in rectangles; interfacing components are in ellipses; solid arrows represent causal pathways on which dynamic processes operate. Adapted from McCrae & Costa, 1996.