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Keith Hayes' Experience-Producing Drives: *An Appreciation and Extension.*

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Abstract

We discuss the idea of experience-producing drives (EPDs) as introduced by Keith J. Hayes and elaborate on the intellectual context in which he developed it, namely behavior genetics, learning theory, motivation, intelligence and evolutionary theory. We then expand the range of application, from the construct of intelligence where it was developed, to the entire domain of individual differences: that is personality, vocational interests, values and attitudes. We argue, consistent with Hayes' perspective, that EPDs can be understood as facets of an emergent evolved agent designed by evolution to transact actively with the world in a manner conducive to survival and successful reproduction. We stress that "EPD theory" is best conceptualized as a set of ideas that expands the perspective of individual difference psychologists, a meta- rather than formal theory. It is, however, consistent with numerous other perspectives developed over the years in both biology and psychology and we note how. Hayes did not consider whether EPDs might be biologically distinguishable categories and it may not be a relevant question. But we believe numerous useful dimensions can be characterized rigorously, at various developmental 'stages', and we provide an example in adulthood that reflects many of Hayes' ideas.

196 words

Keith J. Hayes with Viki

1. Introduction

In 1962 Keith J. Hayes published an underappreciated classic in psychology. The monograph entitled “Genes, Drives and Intellect” presented a motivational-experiential-genetic theory of intelligence. It was not published in a mainstream journal and has not been widely cited. We might be inclined to believe that its obscurity was because it dealt, in part, with the genetics of behavior during a period when the idea of genetic influences on behavior was resisted, but in the same year Paul Meehl, in his presidential address to the American Psychological Association (APA) and published in the *American Psychologist*, argued that, “schizophrenia, while its content is learned, is fundamentally a neurological disease of genetic origin.” (Meehl, 1962, p. 837), and he was not run off the lectern. Hayes’ theory was considerably subtler than this about how genes are involved in intelligence: “(a) manifest intelligence is nothing more than an accumulation of learned facts and skills, and (b) innate intellectual potential consists of tendencies to engage in activities conducive to learning, rather than inherited intellectual capacities, as such. These tendencies are referred to here as *experience-producing drives* (EPDs).” (K. J. Hayes, 1962, p. 337). Perhaps Hayes published outside the mainstream because he dealt with the topic of “intelligence” which at that time had become all but taboo. McNemar in his APA presidential address – “Lost: Our intelligence? Why?” – (1964) tried to explain why, but also reported that, “By far the most provocative recent discussion that I have encountered is the closely reasoned 44-page paper by Keith Hayes.” (p. 881). He appreciated Hayes’ paper because it was an attempt at needed synthesis. As Hayes put it, "This review attempts to integrate the developments which have occurred recently—largely independently—in three areas of psychology: behavior genetics, motivation and the theory of intelligence." (K. J. Hayes, 1962, p. 301). He did not mention it there, but he also incorporated an evolutionary perspective. Hayes was the comparative psychologist who with his wife raised the chimpanzee Vicki in their home (C. Hayes, 1951; K. J. Hayes & Hayes, 1951). It is clear from reading their works that EPD theory had its roots in evolutionary thinking. He (1962) cited the works of Groos (1898, 1901), who certainly qualifies as an early evolutionary psychologist. He also cited literature on individual differences in non-human animals at a time when this was rare. This area has exploded recently as illustrated by work on the relations between personality and cognition in fish (e.g., (Lucon-Xiccato & Dadda, 2017).

While some parts are inevitably out of date, Hayes' (1962) "closely reasoned" paper is still well worth reading.

Our purpose is not to review relevant work since Hayes wrote, though we inevitably touch on it, but rather to expand his theory's scope by applying it to individual differences in general, adding some modern ideas from developmental genetics and evolutionary theory, and bringing it to the attention of wider audiences of psychologically-oriented scientists. In broad brush, these goals can be accomplished by modifying Hayes' original formulation of the theory only slightly. Items in italics have been added.

"The argument supporting the motivational-experiential theory involves four main points: (a) Differences in motivation *are evolved mechanisms*. (b) These motivational differences, along with differences in *learning*

> *abilities and differences in extents and nature of opportunities to learn*, cause differences in experience. (c) Differences in experience lead to differences in *psychological traits*. (d) The differences commonly referred to as *‘traits’ emerge through constantly accumulating, contemporaneously intertwined, motivated initiated behaviors and responses to experience*.” (K. J. Hayes, 1962, p. 303).

Experience-Producing Drive (EPD) Theory posits that a fundamental, ubiquitous outcome of evolution is the emergence of agency. Complex organisms are agents actively seeking circumstances in which they can optimally not just survive, but thrive: live in circumstances conducive to successful reproduction. As Hayes put it, this means that genes exert their influences on behavior not through any kind of fixed determination, but by influencing what in the environment attracts attention and how it is perceived and emotionally and cognitively interpreted, thus influencing motivations and preferences for future behavior and fostering development of behavioral patterns. Over time, consistencies in these attentional, perceptual, and interpretive predilections drive acquisition of experiences that result in pursuit and practice of skills, habitual activities, and response patterns. Together, these create environmental niches, which in turn reinforce the underlying drivers through gene–environment interactions and correlations.

Extension of Hayes’ idea to all psychological traits is consistent with his perspective, as he cited a wide array of studies, both human and non-human, of genetic influences on individual differences (vocational interests, emotionality, aggressiveness, exploratory behavior, hoarding, activity, etc.). Hayes did not try to enumerate EPDs, and doing this may be neither necessary nor possible. He did suggest that a statistic, today called ‘genetic correlation’ (standardized genetic covariance), might be relevant to whether and how they might aggregate into distinguishable population-level ‘traits’. He also put manifestation of EPDs in an ontogenetic context, positing that many are expressed and influence learning at opportune life stages and fade in intensity once the relevant learning is in place. Mechanisms underlying such scheduled gene expression are slowly being unraveled (Blundon et al., 2017) and many are now well-established scientific facts. Ronald Wilson (1983) documented their observable trajectories for IQ nicely.

2. **Theory or Meta-Theory?**

EPD theory should perhaps be viewed not as a theory but as a metatheory, a set of concepts from multiple intellectual domains, in this case genetics, evolution, development, motivation theory, ethology, comparative psychology, etc.; from which theories and testing methods and practical applications emerge (Bouchard & Loehlin, 2001, p. 250-251). The underlying idea that humans create their own environments (’niche construction’) has been proposed in various forms many times before and since Hayes’ work was published. Two widely cited examples since are (Bell, 1968) and Scarr (1996; 1983). Baldwin (1896), Waddington (1942) and (Schmalhausen, 1949) are important examples preceding Hayes. Bell argued for reinterpretation of socialization effects, arguing that often children elicit responses from their parents rather than cause always flowing from parent to child. Like Hayes, Bell cited both human and non-human behavior genetics literature supporting his ideas. Scarr drew on behavior genetics, evolutionary, and developmental psychological literature, arguing strongly that people largely make their own environments. She called hers "a theory of genotype->environment effect", explicitly drawing on the work of Plomin, DeFries and Loehlin (1977) that outlined the roles of genotype-environment interaction and correlation in behavior genetics. Neither article cited Hayes, although Scarr did cite him in later work.

The Baldwin (1896) 'effect', an evolutionary process through which culturally developed and learned habits become established genetically within species through natural selection, is now widely accepted, in part due to Waddington's (1942) experimental demonstrations in *drosophila melanogaster.* Schmalhausen's (1949) 'law' articulated a role in evolution of what is now the often-assumed stress-diathesis model of psycho- and other pathologies. These works have all been widely cited; Bell's (1968) article was a citation classic in 1981. The tightly entwined gene-environment interplay implied by pervasive niche construction has moved into 'mainstream' research on individual differences and is starting to be acknowledged even in developmental psychology.

The roles of gene-environment interplay in the development of motivations and in traits as well as niche construction have rarely been addressed. Quite recently, in a comprehensive discussion of the personality trait conscientiousness, Roberts, et al. (2014) pointed to current lack of integration between motivation and trait theories: "Some serious thinking is due on the front of reconciling traits and motives" (p. 132). Dweck (2017) is an exception at least at the phenotypic level, but it is very incomplete at the level of gene-environment interplay (which she explicitly noted). As Bouchard (2016) pointed out, EPD theory addresses the motivation question directly. To Hayes active niche construction involves not just autonomic temperamental responses within contemporaneous (though usually not permanently fixed) capacity constraints but also, at least in humans, interests, preferences, values, and social attitudes that contribute to multi-step goals. It also often involves considerable self-aware planning, 'deliberate practice' (Ericsson, 2004), trade-offs with other goals, willingness to resist impulses, and re-evaluation commonly deemed 'conscious'. It thus seems worthwhile to develop Hayes' ideas in more up-to-date contexts. Because all these activities involve learning and he focused on intelligence as an accumulation of learning, we first address his views on intelligence and learning.

3. Intelligence and Learning

Hayes wrote his monograph at a time when the idea of a general factor of intelligence had been "lost". He concluded that, "there appears to be very little evidence to support the intuitively attractive notion that the higher levels of intellectual activity depend on special kinds of innate activity…It seems, in short, that higher mental functions are pure concepts, which have no counterparts in the real world of behaving organisms." (p. 312-313). This led him to the view that intelligence, at least in any way that can currently be assessed, consists entirely of learned skills. In this, at some level, he has to have been correct at least for humans. Human infants can do nothing recognizable as intelligent – newborn lizards are veritable geniuses by comparison. Hayes went further, however, and assumed (admitting this assumption was both bold and difficult if not impossible to test) that humans and other organisms do not differ in learning capacity (p. 313-314). On this there is much more room for debate.

That intelligence is based on learning was the foundation of EPD Theory. Under it, EPDs influence the kinds of stimuli sought and attended to and the ways they are interpreted and acted upon, given available environmental options. This combination of what is experienced and how, determines what is learned, and thus what contributes to subsequent experience. Learning goes on in all environments, but the ranges of available options of what to learn vary. Every organism has some choice among what is available, but no organism has complete freedom of choice. There are always at least some physical constraints, and, especially among humans, social constraints. Hayes was explicit that neither learning nor choice need have much to do with experiencing pleasure or anticipating reward.

Hayes lacked a meaningful (theoretically relevant and empirically-based) definition of intelligence on which considerable consensus rested. We now have such a definition, though considerable disagreement persists over our success in measuring it.

> *'Intelligence is a very general mental capability that, among other things, involves the ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience. It is not merely book learning, a narrow academic skill, or test-taking smarts. Rather, it reflects a broader and deeper capability for comprehending our surroundings-"catching on," "making sense" of things.* (Gottfredson, 1997, p. 13)

In summary, intelligence is the ability to learn from experience and *do* something with it. Under this definition it is necessary to administer a wide variety of mental tasks to assess intelligence adequately; any single format (e.g., Raven's Matrices) is inadequate (Gignac, 2015; Major, Johnson, & Bouchard, 2011). While not explicitly stated, it implies (correctly) that all mental abilities are positively correlated and can be characterized by a general factor, commonly termed the '*g* factor'. The generality of this *g* factor was once widely debated; this is no longer the case (Ángeles et al., 2015; Kaufman, Reynolds, Liu, Kaufman, & McGrew, 2012; Warne & Burningham, 2019). The statistical regularity of the *g* factor is now well established in the human literature and has also been observed in virtually every species with a brain that has been examined with adequate instruments (Bouchard, 2014). At the statistical level, the *g* factor can represent the intuitively attractive notion of 'higher mental functioning', but at the functional, behavioral, and biological levels, just what constitutes and goes into developing 'higher mental functioning' is far less clear.

Hayes was correct that organisms learn and consequently acquire skills and patterns of behaviors that are often termed 'traits' through transactions with their environments. His premise, however, that there are no individual differences within and across species in learning capacity is much more questionable. There is now considerable evidence in support of genetic influences on tasks assessing learning ability at least within species. Human fear conditioning is genetically influenced (Hettema, Annas, Neale, Kendler, & Fredrikson, 2003) as is psychomotor learning (Fox, Hershberger, & Bouchard, 1996) and eyelid conditioning (Merrill, Steinmetz, Viken, & Rose, 1999). All measured forms of learning show such influences and they can be genetically selected even in fruit flies (Kawecki, 2009). Every animal learns, but just what and how quickly and readily varies within and among species. There may even be multiplicative interactions between EPDs and learning capacities. Such interactions would help explain the enormously skewed distributions of intellectual and creative productivity of all forms – where those falling at the extreme high ends are termed 'geniuses', (Johnson, 2013;

Johnson & Bouchard, 2014).

The importance of learned content is illustrated by the Flynn effect, the secular rise in mean IQ throughout the world (Rindermann, Becker, & Coyle, 2017). Reasons for the Flynn effect remain unclear but it is unlikely that it has but one or just a few causes (Lynn, 2007; Williams, 2013). Flynn and Rossi-Cassé (2012) argued that, "Even in developed nations, the notion that the Flynn effect will have identical causes should be banished from the literature" (p. 148). In different times, places, and cultures, humans develop – learn – different mental habits, algorithms, strategies, knowledge content, mnemonics, etc. These are the tools we use in day-to-day life to 'figure things out' and decide what to do. Cognitive ability assessments always draw on these tools to different degrees in people with different backgrounds. This can have large effects that have little or nothing to do with whatever constitutes intellectual *capacity* on performance levels on these always 'drop in from the sky' (Hunt, 2011, p. 12) tasks. Nevertheless, within populations sharing similar culture, time, and place, measures of cognitive abilities continue to correlate highly, and they do similarly for all non-human animals that have been studied (Bouchard, 2014). Stephen Wolfram (2017) has put this in a form consistent with the abstract definition of intelligence as *g*: "human intelligence as we experience it is deeply entangled with human civilization, human culture and ultimately within human physiology-even though none of those details are [sic] presumably relevant in the abstract definition of intelligence".

This entanglement suggests that humans have evolved species-consistent physiological predispositions to develop particular adaptive responses to typically encountered cultural as well as physical environmental experiences that, over time, become firmly enough engrained to be labelled 'mechanisms' by some (e.g., Tooby & Cosmides, 2015). But these vary genetically like all biological features that have been studied (Bouchard, 2004), implying that either ability to learn or willingness to adapt to the relevant experiences varies. Either way, intelligence seems to be involved.

A relevant theoretical debate arises at this point. Intelligence has been defined as a "very general mental capacity" and is often referred to as a "general problem solver" or "domain-general unspecialized mechanism". Some evolutionary psychologists argue that evolved mechanisms arise to solve highly specific problems and that "there is no such thing as a 'general problem solver' because there is no such thing as a general problem" (Symons, 1992, p. 142). But, as Dennett has noted, how general any cognitive mechanism may be is an empirical question (1995, p. 491). The *g* factor appears to be quite general and has emerged in many species. Perhaps any organism with more than a rudimentary nervous system evolving in a complex environment will manifest a *g* factor.

4. Causation in the Context of Experience-Producing Drives

Psychology seeks explanations at multiple levels. These range from species evolution to cultural accumulation to individual development of behavioral 'traits' to typical state-only responses to specific stimuli. Atypical behavioral regularities that surrounding social-group members consider worrisome also demand explanation. Figure 1 outlines commonly articulated causal levels, running roughly from distal to proximal. EPD theory provides ideas to address each of them. In doing so, it implicitly recognizes that similar processes operate simultaneously at all levels, generating both distal and proximal causation.

The Phenonena	The Focus	The Science
Species Evolution	Human Evolution	Evolutionary Biology
DNA (The Genome)	Allelic Structure	Genomics
Genetic Predispositions	Genome Function	Developmental Genetics
Social Development	Socialization Processes	Developmental/Social Psychology
Psychological Traits	Gene-Environment Interplay	Differential Psychology
Situational Impact	Cognitive and Emotional Responses	Experimental Psychology
Phenomenological Experience	Perceptions, Interpretations, etc.	Clinical Psychology
	Behavior/Outcomes	

Figure 1. Levels of behavioral causation and associated scientific disciplines

Hayes discussed the roles of species evolution, the individual genome and the dispositions and traits to which it contributes, environmental factors, situational impacts, perceptions, and cognitive and emotional processing in producing behavior, treating them as separate ‘causes’. Today it seems much clearer that these processes occur simultaneously and reciprocally, so that behavior emerges from all of them. Yet in most cases, new information elaborates on his ideas rather than undermining them (Johnson, 2014). We summarize his ideas of these roles, and note how later developments have furthered them in ways that extend his theory.

Level 1: Species Evolution: As noted, Hayes wrote from the perspective of evolutionary psychology before it had a name. Our reframing of EPD theory simply states that over long periods of time "environments of evolutionary adaptation" shape all human traits. A major issue for scientists is how to characterize and study the emergence of particular adaptations (Lewis, Al-Shawaf, Conroy-Beam, Asao, & Buss, 2017). Interestingly a construct very similar to EPDs, *"behavioral drive"*, was developed independently by the evolutionary biologist Alan Wilson (1985) to explain the evolution of large brains in mammals and birds. According to Wilson "pressure to evolve arises not only from external factors such, as environmental change but also from the brain of mammals and birds: from the power to innovate" (p. 164). This is the investigation of what causes evolution to take the directions it does.

Level 2. DNA (The Genome): Hayes recognized that if genes cause differences among species they could also cause differences among individuals within species. The idea that traits considered socially valuable/'adaptive' might show considerable genetic variance, while controversial and even actively denied well after Hayes wrote, is widely accepted today. Kinship studies in humans and selection studies in animals have long indicated this clearly, but many questioned their validity.

Until recently human work in this domain was largely restricted to kinship studies (Boomsma, Busjahn, & Peltonen, 2002). Scientific advances now allow us to calculate “polygenic scores” (roughly counts of individual genetic variants with observed associations with particular traits) and correlate these scores with these and other traits (Khera et al., 2018; Richardson, Harrison, Hemani, & Davey Smith, 2019). Each genetic variant has such a tiny association that extremely large sample sizes and numbers of involved genetic variants are required. Consequently, the best available data are on widely measured morphological traits such as Stature and Body Mass Index. Nevertheless considerable data are available for Educational Attainment (Lee et al., 2018; Rustichini, 2019) and some data are available for intelligence (Savage et al., 2018; Sniekers et al., 2017). Despite generally small proportions of variance these scores account for and the possibility of alternative explanations beyond direct genetic cause for the observed associations, development of these scores has basically demolished opposition to the idea of genetic influences on within-species traits in a way kinship studies never could. It has not, however, done much to articulate just how these genetic influences are manifested. Hayes’ theory may, in this area, have been most prescient, as the means he proposed suggest reasons for it.

Level 3: Genetic predispositions. The term ‘predispositions’ is central in describing this level. Predispositions are not traits or characteristics. All traits have to be elicited, and not all are. A physical example is callouses. Not everyone has callouses, but everyone could have them: they are a species-typical skin adaptation to repeated pressure and rubbing in the same spot. A psychological example is sociality. Evolution predisposed us to become highly affiliative but we can only become so in the context of other people, and we tend to do it rather awkwardly, thus less ‘adaptively’, when our infant caregivers do not offer secure attachment relationships. Unless an organism transacts with relevant environmental stimuli, predispositions do not become fully developed. This idea lies at the core of EPD theory. While not stated quite so explicitly, Hayes' argument is that organisms evolve and develop to do things but just what things depends on their evolutionary history. He also places this 'doing' in the context of individual lifespan development, with expression of some drives being functions of age, sex, previous environmental exposures, and current environmental opportunities and constraints, with balance among drives being of considerable importance.

This idea has common currency today. For example, Schmidt (2011) postulated "that sex differences in technical aptitude (TA) stem from differences in experience in technical areas, which is in turn based on sex differences in technical interests." (p. 560). Even such a genetic determinist as Rushton (1988) offered examples of how age and sex moderated expression of altruism and aggression, manifestations of EPDs in our view. Tucker-Drob and Briley (2014) described these processes as "embedded dynamism". Culture is clearly implicated as one reason people develop the particular interests and skills they do. For example, an EPD to arrange materials spatially could be expressed by becoming a dressmaker or landscape architect or city planner, and, historically at least, cultural traditions may have offered women much more opportunity and encouragement for the former than the latter, and men the opposite.

In a prescient discussion of the "synthetic brain", (now called 'artificial' or 'machine intelligence'), Hayes noted the limitations resulting from machines' lack of EPD's, a feature that still clearly distinguishes them from living organisms. As he pointed out, "This restricts its [a machine's] range of exploratory behavior rather severely, of course; but it could still choose to read some tapes thoroughly and skim others, *if* such an experience-selecting, motivational characteristic were *designed* into it" (K. J. Hayes, 1962, p. 323), a point commonly noted these days as a major limitation in artificial intelligence. The philosopher of science Richard Braithwaite raised this same point long ago in a BBC program that included the brain surgeon Sir Geoffrey Jefferson and Alan Turing discussing Turing test. Braithwaite asserted, "A human's interests are determined, by and large, by his appetites, desires, drives, instincts.…It would seem to be necessary to equip the machine with something corresponding to a set of appetites" (Isaacson, 2014, p. 128).

Hayes used the term 'drive' to describe "the neural mechanism responsible for an organism's tendency to engage in certain behavior, independently of deficit states" (K. J. Hayes, 1962, p. 306). To rephrase, organisms have evolved to **do** something, and to be **doing** it for its own sake even in the absence of or counter to Skinnerian expectations of reinforcement theory. This agency can, and is, expressed at different levels among, but also within, species – and individuals. The evolutionary philosopher Daniel Dennett (2017) refers to *'Darwinian creatures'*, who have only hard-wired predispositions; *'Skinnerian creatures'*, who in addition to hard-wired predispositions also have dispositions to try out new behaviors randomly just to see what happens and act accordingly in the future; and finally, *'Popperian creatures'*, who in addition to the other dispositions, also have dispositions to track what goes on around them, whether it matters to them at the time or not, and store it for future reference in testing hypothetical possible actions – abstract concepts and principles such as arithmetic, democracy, double-blind studies, and computers. According to Dennett, only the last level actually requires what we call ‘consciousness’. It is certainly possible that only humans are ‘Popperian creatures’, but we too execute many, even the majority, of our behaviors at the lower levels (Dennett, 2017).

Organisms are thus actively agentic (Canestrelli, Bisconti, & Carere, 2016). The scientific problem is to describe the what, why and how of their agency, especially as implemented in humans (Carere & Maestripieri, 2013). As Hayes noted, an evolved agent is endowed with a variety of drives that work in synchrony with each other. Trying to understand how these emerge biologically is the study of causation at the level of neurobiology (Gee et al., 2016). Artificial intelligence is working towards agency in the sense that organisms have it. Organisms develop their own goals as they go along. How to operationalize this process is a major goal in the domain of ‘artificial life’ (Stanley & Lehman, 2015).

A major step is recently developed ‘software agents’. A software agent is a “persistent, goal-oriented computer program that reacts to environment and runs without continuous direct supervision to perform specified functions for end users or other programs” (<http://whatis.techtarget.com/definition/software-agent>). Robots destined for distant planets are now being fitted with such agents (Chien & Wagstaff, 2017). These programs are still far short of ‘doing’ in the sense that organisms do, however, as the sorts of explorations they carry out are designed into them by their programmers in service of particular goals.

Level 4: Social development. As emphasized by Bell (1968) and Scarr (1985), correlations between parental behavior and offspring outcomes are difficult to interpret without appropriate control groups. Hayes recognized this problem implicitly and argued strongly that differences in environmental exposures alone do not cause differences in *experience* and the relevant learning; motivational differences in what captures attention and the kinds of experiences sought also contribute.

Confusion on this matter abounds. Consider the still widely cited study by Hart and Risley (1995). Put simply, only observing association, they proposed exposure to a rich vocabulary early in childhood as the major *cause* of later high verbal ability. This correlation by itself is un-interpretable as children share genes and thus predispositions to EPDs similar to those of their parents, and parents often do at least as much to respond to their children's EPD expressions as to try to shape their behavior. A huge body of data speaks to this (Bouchard, 2001, 2009). The well-replicated observation that unrelated individuals reared together, assessed as adults, have a near-zero correlation for IQ alone calls into question the theory of mere exposure as a causal influence on IQ development as such pairs of individuals have quite similar early exposures. Other sorts of data are also relevant. Moffitt, et. al (1993), in a rigorous and large scale longitudinal study, found that naturalistic change in IQs, "[was] not systematically associated with environmental changes" (p.499). There were many measures and, as they argued, "To dismiss the findings on the grounds that our assessment of the environment was simply too crude is tantamount to arguing that being hit by a hammer is less consequential than being tapped by a pencil." (p. 494). These and other results led them to draw on Scarr's genotype->environment theory rather than environment alone as the most plausible explanation. Determining that any particular environmental factor is actually causal is very difficult. The environment can be shaped in ways that produce higher IQ or *g* (Protzko, 2016).

The difficulty is that very often unless the interventions persist, fadeout results; that is, effects of interventions that are not ongoing are not maintained and no further gains occur. Rather, the effects disappear (Protzko, 2015).

All these results are consistent with Hayes' theory that development and maintenance of IQ are driven by EPDs and are not some kind of fixed-trait manifestation. Protzko (2015) suggested a notion quite similar to EPD theory, arguing that, "It is therefore possible that people select more cognitively demanding environments for reasons other than their intelligence and that intelligence is not a causal factor in those decisions" (Protzko, 2015, p. 208). Stated otherwise, intelligence is not itself an EPD but rather an emergent manifestation of the accumulation of learning arising from the experiences EPDs have fostered (Johnson & Bouchard, 2014, pp. 279-281). Pervasive fade-out is inconsistent with the Dickens and Flynn (2001, p. 347) transactional model that specifies IQ as a driving force; ''Higher IQ leads one into better environments, causing still higher IQ, and so on.'' It is also inconsistent with Cattell's theory of fluid-crystalized intelligence and the alternative models proposed by Kan, et al. (2013) and Schmidt (2014). These authors proposed, in one sense or another, that intelligence, as usually conceptualized, drives the acquisition of additional intelligence. EPD theory postulates that numerous EPD-by-environment correlations contribute to the growth and maintenance of *g*. This view is highly consistent with the evolving network model of intelligence proposed by Savi, et. al. (2019) designed to unify the fields of human ability and human learning.

Level 5: Psychological traits. Hayes left open the question of whether EPDs could/should be enumerated. He clearly meant personality traits and psychological interests to be considered reflections of EPDs, but his perspective was much more comprehensive, ranging from "overt activity" to "manipulation of the contents of awareness". He also specified that EDPs could be avoidance- as well as approach-oriented, with accumulated experience restricted when avoidance EPDs are strong. This led him to consider the question of EPD 'balance'. He suggested that the most adaptive situation was relatively moderate drives in both directions over broad ranges of content/activity area. He thought unbalanced EPDs – combinations of strong approach EPDs in very specific areas and strong avoidance EPDs in most of the rest – could result in unusual phenomena such as idiot-savants. Such imbalance also appears to be characteristic of the autism spectrum and may well underlie the distinction between the Analytic and Cultured EPDs discussed below.

Bouchard (2016) may have conducted the only study that has attempted explicitly to operationalize Hayes' ideas in the individual differences domain. Specifically, he factor analyzed (Principal Axis factoring with oblique rotation) a very broad array of traits; personality (21 scales), psychological interests (23 scales), attitudes (2 scales), work motivations (7 scales), and values (5 scales), to begin to understand their interrelations more comprehensively. He found 12 factors and Table 2 in Bouchard (2016) compared them to a variety of descriptive/explanatory schemes from the individual differences literature. Suffice it to say, none of these schemes encompass all 12 factors. Here we briefly summarize the results from an EPD point of view. Excluding the General Psychopathology factor ('p-factor'), which has now been widely replicated

(Kotov et al., 2017; Lahey, Krueger, Rathouz, Waldman, & Zald, 2017), the remaining 11 factors all meet the requirement that EPDs foster taking things on and seeking to master them. That is, they capture Allport's (1937) assertion that, "personality is something and personality does something" (p. 49). Each trait name is given in bold type and followed with a label consistent with David Campbell's (2002) interest orientation nomenclature that characterizes the underlying goal. This is followed by a hypothesized EPD drive term borrowed from existing literature.

Consequently we have:

Persuasive > *Influencing* > Power,
Traditional > *Conforming* > Obedience,
Cultured > *Creating/Appreciating* > Openness,
Analytical > *Analyzing* > Rationality,
Realistic > *Producing* > Practicality/"Hands On",
Empathetic > *Helping* > Altruism,
Aggressive > *Attacking* > Hostility,
Affiliative > *Socializing* > Belongingness,
Sensation-Seeking > *Adventuring* > Need for Stimulation,
Self-Reliant > *Achieving* > Independence,
Entrepreneurial > *Organizing* > Acquisitiveness.

We make no claim that this scheme is complete or correct. It is a work in progress and requires replication and refinement, and could vary in cultures other than the one from which these data came. We do claim that it is more encompassing than other schemes and makes some useful distinctions, in particular one between Analytic and Cultural, rather than the single trait of Openness. This distinction captures the important interest dichotomy between the sciences and the humanities (B. C. Campbell & Wang, 2012; Snow, 1963), and illustrates the productivity of Hayes' ideas.

The '*p* factor' is obviously related, in some manner, to so-called "mental disorders". We agree with (Cuijperes, 2019, p. 274) that, "It is …. still not clear what these disorders exactly are. There are no objective tests or measures to establish the presence of a mental disorder, nor are there clear thresholds for when a patient has a disorder and when not". Essentially, the idea that mental disorders represent taxonomic categories remains unproven (Bouchard, Johnson, & Gottesman, 2019). Nevertheless, some of the *p* factor's underlying facets may well be evolutionary adaptations (Nesse, 2019). And some of its manifestations may be situational adaptations.

Level 6: Situational impacts. "An organism's experience is considered to be a joint function of its experience-producing drives, and the environment in which these drives operate" (K. J. Hayes, 1962, p. 307). Hayes clearly distinguished between "experience" and "exposure". Exposure to situations offering relevant stimuli is necessary to trigger EPDs, but EPDs are flexible and many different situations can trigger them. At the same time, the specific behavioral patterns arising from them may look very different to observers. For example, someone driven to construct things may end up a carpenter, an engineer, a fashion designer, a sculptor, a chef or baker, among many other outcomes. In many social milieus, it is easy to picture how girls and boys with very similar levels of this particular EPD would have been socially 'siloed' into experiences leading to marked differences in their distributions among these outcomes. At the same time, if a situation has no relevance to an individual's drive system (interests, motives, values), EPDs will not be elicited and other considerations (e.g., social norms, etc.) will influence behavior. Herbert Simon articulated this long ago;

> "the term *environment* is ambiguous. We are not interested in describing some physically objective world in its totality, but only those aspects of the totality that have relevance as the "life space" of the organism considered. Hence, what we call the "environment" will depend upon the "needs," "drives," or "goals" of the organism, and upon its perceptual apparatus". (Simon, 1956, p. 130).

Experimental science addresses this level of causation, subject to the limitations imposed by the inevitable artificiality of lab environments – their lack of ecological validity (Winograd, Fivush, & Hirst, 1999).

Level 7: Phenomenological experience. Hayes was clear that "the concept of EPDs does not imply either enjoyment of the activity or anticipation of its results". Reported experiences are common outcomes assessed in psychological studies and proper sampling of those aspects of behavior is an informative enterprise. Whether predispositions to interpret experiences in various ways can be considered causal is complex, but experiences in doing so accumulate in ways that reinforce those predispositions. The next step in understanding this process will be development of measurement instruments and observational methods sensitive to the individual's role in constructing experience (McGue, Bouchard, Lykken, & Finkel, 1991, p. 401).

Level 8: Behavior/Accomplishments. Any prediction or explanation of behavior or behavioral outcomes (i.e., educational accomplishment) based on one or more levels implies the influence of underlying levels unless they can be excluded (e.g., mental retardation due to brain damage at birth does not involve evolution or DNA, etc.). It is clear, for example, that there are evolutionary reasons for two sexes, so observations that many sex-related traits do not follow the same life trajectories in the two sexes should come as no surprise. Changes in traits over the life course do nothing to undermine the presence of genetic influences, and may even help to articulate how they actually arise (Del Giudice, Gangestad, & Kaplan, 2015). At the same time, we cannot use observations of behavioral patterns to infer specific causal explanations at lower levels. For example, the Wilson Effect, the increase in heritability of IQ with age and consequent decline in the relative influences of other factors, most noticeably common/shared family environmental influence, could contradict the emphasis on learning espoused by Hayes. Direct genetic influence could be minor initially and grow with age while shared environmental influences erode with movement toward adult independence. But the same observation could support Hayes' emphasis. Babies are not born with what we measure as intelligence, so every aspect of its later manifestation has been at some level learned. The changes in apparent relative genetic influence may be nothing more than artifacts of distortions in estimates of the various sources of influences created by violations of the assumptions underlying the estimation processes.

5. Transactions, not Interactions

Psychologists often speak loosely about organisms "interacting" with their environments when they actually mean "transacting with their environments". The term "interaction" is best restricted to its statistical meaning of non-additive association between two variables, direction of influence unclear. The distinction between "transactions" and "interactions" is fundamental to understanding genetic influences on traits. Without an environment to transact with genes cannot do anything. In this sense both environments and genes are equally *essential* in genesis of any behavior or trait. This fact, however, does not preclude one being more *important* than the other. The argument that both genes and environment are important and therefore logically inseparable is often illustrated with a rectangle: since both height and width are necessary, they are said to be equally important. The confusion is between *essential* and *important*. Both are essential. For a long flat rectangle, length is more important than height. For a square, height and width are equally important. Their extents can easily be quantified (Tredoux, 2019).

EPDs can be best understood as influencing the choices and intensities of the environments with which an individual transacts. There are many transactions between organisms and their environments over very important developmental periods. To the extents they are driven by various perceptual-cognitive-emotional biases influenced by the genotype, they result in particular phenotypes (personality, interests, values, etc.). It is critical to distinguish between mere environmental exposure and organisms' transactions with the environment. An example of failure to do so can be found in a Brookings Institution report from a series called, "Evidence Speaks" (Loeb & York, 2016). The report begins with the following paragraph, citing the Hart and Risley (1995) study discussed earlier; "Many young children grow up without supportive home learning environments. One often cited study found that by the age of four, poor children hear about 30 million fewer words than wealthy children. This fissure manifests in great differences in children's motor, social, emotional, literacy, and numeracy skills when they first start kindergarten, gaps that persist through school and into the labor market." (Loeb & York, 2016). As noted earlier, this study's observations were confounded with genetic influences. As the quote shows, this confounding is still often overlooked (Rohrer, 2018; Schmidt, 2017).

Hayes recognized that IQ tests sample a large universe of test items that measure a variety of abilities. His theory specified that a potentially very bright individual's EPDs cause that person to transact with a broader range of stimuli with more intensity and a higher frequency than one less potentially bright. He stated, "the intellectual potential of children may be measured more effectively with a test of motivation than with a test of childish achievement" (K. J. Hayes, 1962, p.336). He cited examples from relevant studies and characterized the measures as reflecting "innate activity preferences".

This is a difficult idea to test, and examples remain rare. The most rigorous relatively recent replication of these general findings is a prospective longitudinal study (ages 3-11) of the relation between Stimulation Seeking (SS) and Intelligence (Raine, Reynolds, Venables, & Mednick, 2002). The participants were members of the large Mauritius Child Health and Development Project. The correlation between SS and *g* at age 11 was .25 and replicated across sex and ethnic groups. The component of their measure of SS that was most highly associated was physical exploration: .24, compared to verbalizations .15, gregariousness .19 and active social play .15. Numerous potential confounds were tested and rejected. Apparently, no measure of SS was obtained at age 11. The correlation of total IQ over time was .30. Given the high likelihood that the IQ measures were more reliable than the SS measures, corrections for attenuation would probably show that SS at age 3 correlated about equally with IQ at age 11. The hypothesis that "young children who physically explore their environment, engage socially with other children, and verbally interact with adults create for themselves an enriched, stimulating, varied and challenging environment" was supported (Raine et al., 2002, p. 669). We proposed a process similar to this as an explanation of the similarity in IQ of adult monozygotic twins reared apart and credited Hayes for the idea; "It is a plausible conjecture that a key mechanism by which the genes affect the mind is indirect, and that genetic differences have an important role in determining the effective psychological environment of the developing child (K. J. Hayes, 1962)." (Bouchard, Lykken, McGue, Segal, & Tellegen, 1990, p. 227).

This raises several questions that need to be addressed in future research. It is possible that the 'potentially bright' vary in degree to which their capacity for 'brightness' depends not just on intensity of their EPDs, but also breadth, as Hayes noted with his concept of EPD 'balance'. The degree to which brightness potential would end up being expressed would thus depend on a match between the variety of available environmental stimuli and a child's particular EPDs, and the degree to which socialization processes allowed and/or fostered particular expressions consistent with what is assessed as 'brightness'.

6. In Conclusion

The EPD approach to understanding human individual differences has many important implications for both research and practice. As we have argued elsewhere; “if the genome impresses itself on the psyche largely by influencing the character, selection, and impact of experiences during development – if the correct formula is nature via nurture – then intervention is not precluded even for highly heritable traits, but should be more effective when tailored to each specific child's talents and inclinations” (Bouchard et al., 1990, p. 228). Krapohl, et. al. (2014) have recently made the same argument in the context of a behavior genetic analysis of educational achievement. They argued, correctly in our view, that education should have the twin goals of teaching (building in knowledge) and eliciting (bringing out talents and inclinations).

The EPD idea also leads to a stronger incorporation of ideas from the world of work into personality assessment. That there is a “world of work” is a very modern distinction; the environment of early humans was almost solely a ‘world of work’ (Judge & Hogan, 2015). From an EPD perspective, most personality theories are impoverished because they do not incorporate what underlies goal-directed behavior, namely values and attitudes. Perhaps that is because specific attitudes and values are so often controversial. Most importantly, EPD Theory views humans as dynamic exploring organisms — Popperian creatures with an evolutionary history — who create their own unique environmental niches.

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