

The Importance of Multi-level Theoretical Integration in Biopsychosocial Research

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Abstract

There is a growing interest in the unification of health research in a biopsychosocial framework. However, increasing specialization and advancement in instrumentation makes it more difficult to bridge understanding across areas. It would be very useful to ground biopsychosocial research in the most powerful explanatory framework in the life sciences, evolution by natural and sexual selection. This would require an explanation of the functional significance of the phenomena related to the area of study, in addition to descriptions of the mechanism. The application of an integrative evolutionary framework will be illustrated with the example of sex differences in human mortality rates, which are related to endocrine, psychological, and socio-environmental factors. The integrative evolutionary model will be contrasted with a theoretical model that acknowledges physiological and social influences, but artificially separates them.

Keywords: biopsychosocial, sex differences, evolution, theory, health, mortality

Specialization and theoretical integration

As scientific research on health and illness has progressed in the past few decades, the increasing complexity of research areas and growing sophistication of research methods has led researchers to adopt increasing degrees of specialization. This specialization may be necessary, given the many years of training necessary to master the understanding of advanced areas of biopsychosocial research. Of course, specialization may also lead to a narrowing of focus on those studies which are very similar in methodology and content to one's own. This poses the risk of fragmentation along the lines of topical areas and research techniques, especially when specialized and expensive equipment is needed for certain types of investigations.

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This situation poses a challenge to those promoting an integrative biopsychosocial research framework. It may not be possible to stay current with the details of findings in all areas of research, and learning the continually growing set of skills necessary for research techniques may require more post-doctoral fellowships than could fit into one lifetime. Fortunately, there is a solution which may bind together disparate areas of research and would also allow researchers to comprehend at least a basic outline of research outside their area of study. Although some projects may seem to have a tangential or distant relationship to one's specialization, the implications could be much more relevant than may seem at first glance because of the ultimate connections among any studies of living organisms.

An evolutionary framework for biopsychosocial research

The solution for the dilemma of research fragmentation is to ground biopsychosocial research in the most powerful explanatory framework in the life sciences, evolution by natural and sexual selection. There are a growing number of researchers who explicitly explore evolutionary influences and implications in their research on health and illness. One does not need to seek to advance evolutionary theory itself in order to ground biopsychosocial research in an evolutionary framework. It also would not necessarily require substantial modifications to research plans or programs. However, by explicitly describing how one's research area and findings are connected to living processes and roles in survival and reproduction, each study would find its place in understanding the web of life.

Although an understanding of mechanisms is certainly important, especially for medical and health intervention, an evolutionary biopsychosocial framework emphasizes function. There are two interrelated levels of function and causality: proximate causes are immediate influences that are responsible for "how" phenomenon happen. Proximate causes of health phenomena include biochemical properties, physiological features, psychological constructs, and social forces. Ultimate causes are evolutionary selection pressures which physiological and psychological adaptations have evolved to respond to (Buss, 1995). Understanding the connection between proximate and ultimate causes can be beneficial to understanding health and disease, as well as crafting interventions to improve health and prevent disease. For example, pharmaceuticals have been developed to relieve the symptoms of both colds and fevers. Whereas the sneeze may be a parasite organism's way of spreading itself to other hosts, the fever may have evolved as an adaptation to speed up metabolism in response to threats from invading organisms and viruses and thus would usually be a beneficial response (Kluger et al., 1998). Thus, one would best distinguish between the functions of these responses to promote recovery from illness and reduce its spread.

The evolutionary framework also addresses other challenges that have historically separated different levels of biopsychosocial research. It is becoming more difficult to ignore the multiple levels of factors influencing health and illness. These range, for example, from the microscopic biochemical mechanisms that form the basis of the immune system (e.g., Hughes & Yeager, 1997) to the macroscopic relationships between social status inequality and disease outcomes (e.g., Marmot, 2004). Without a unifying framework, these factors may become separated into biological, psychological, and social predictors which create contrasting depictions of the phenomena of study and may suggest different solutions for handling health issues.

An integrative biopsychosocial model of sex differences in human mortality rates

The separation of influences can be illustrated with contemporary research on human sex differences in mortality rates. For example, as part of a book documenting mortality patterns in the United States, three well respected researchers devoted a chapter to understanding sex differences in mortality rates (Rogers, Hummer & Nam, 2000). These researchers used the most comprehensive dataset available to predict differences in the mortality rates of men and women based on age, race, employment status, income equivalence, education, marital status, cigarette use, alcohol use, exercise, and body mass. Given this impressive range of predictors, the analysis was able to explain a considerable proportion of the variance, however the authors concluded that “a full understanding of the explanatory factors [for excess male mortality] remains elusive” (Rogers, Hummer & Nam, 2000, p. 49). The authors suggested that if it were possible to add additional predictors to the model, such as affiliation with street gangs, they would have a better explanation for sex differences in mortality rates.

Increasing the number of predictors might increase the amount of variance explained (however slightly), but it still would not explain how contributing factors relate to each other or why men are more likely to face greater risk from the majority of influences. It is as if the researchers have a handful of pieces of a puzzle and are trying to assemble them together. However, the surfaces of the puzzle pieces are uniform in color and thus they can only be joined by compatibility in shape. There are pieces that are obviously part of the same puzzle, but they do not fit with any of the other pieces. It would be very valuable to have a theoretical framework that can show the connections between the puzzle pieces by coloring the surface of each one and depicting an approximation of what the overall completed image should look like. This would indicate how the pieces “fit” together (relate to each other) in the general framework, even if they are not physically contiguous.

Analyses predicting sex differences in mortality rates based on a loose collection of likely influences provide only a descriptive explanation. To really understand why sex differences in mortality follow the pattern that they do, one requires a causal framework based on how sex differences were shaped by natural selection, and how those differences interact with environmental factors to result in the observed patterns and variations. In order to establish the evolutionary foundation for biopsychosocial understanding, it may be helpful to start with the most basic building blocks upon which the rest of the theory sits.

Life on earth is sustained through the continual reproduction of organisms. There are two methods of reproduction, sexual and asexual. Asexual reproduction was likely the original form of reproduction, as it involves breaking off some portion of the organism to create a genetic clone (Boyden, 1954). Sexual reproduction involves a combination of genetic material with another compatible organism. Although this reduces the proportion of an individual's genes represented in offspring, it likely was successful because sexual recombination of genes can purge harmful mutations (which may accumulate in a cloned lineage) and the increased genetic variability facilitates adaptation to challenges. These challenges include changes in environmental conditions (Williams, 1975), threats from predators and parasites (Williams, 1975), competition from other species (Bell, 1982), countering the adaptations of prey to predation, and starvation (Bell, 1982).

When organisms begin combining gametes (sex cells which combine their genetic materials with other sex cells) in sexual reproduction, there is disruptive selection for gamete size. This is because a greater somatic investment (a larger contribution of cytoplasm) to gametes increases the viability of the resulting zygote (combination of sex cells from two organisms). Smaller gametes are less physiologically costly to produce, but by themselves they are less viable than larger gametes. However, when large gametes with sufficient cytoplasm to produce a highly viable zygote are available, smaller gametes will out-compete medium sized gametes because they are sufficiently functional (in combination with the larger gametes) and less costly to produce than medium sized gametes (Bulmer & Parker, 2002). Thus, across sexually reproducing animals, an egg with an abundance of cytoplasm combines with sperm, which carries genetic material but very little cytoplasm. The depiction of reproductive strategies will be a reoccurring theme in studies related to sex differences.

The relative somatic contribution to gametes is what defines the sex of organisms, rather than chromosome structure or any other feature. Chromosome composition varies across species. For example, in birds males have two similar sex chromosomes and females have two dissimilar sex chromosomes (Smith & Sinclair, 2004). Thus, beginning with the most basic organisms, female parental investment is greater than male parental investment (Bateman, 1948). Because of the sex difference in parental investment, females are generally more selective in

choosing mating partners than males. Thus, males generally compete for reproductive access to females (Trivers, 1972). Sometimes this competition involves fighting other males for social rank or control of territories, sometimes it involves elaborate traits and displays that females prefer in their mates (Darwin, 1871). It is notable that in the handful of species where males make a greater parental contribution to females, such as in seahorses, the "Mormon cricket," and certain bird species, it is the females that are brightly colored and compete for males (see Berglund & Rosenqvist, 2003). This reinforces the notion that sex differences in parental investment are responsible for other sexually dimorphic characteristics.

In humans, males often provide considerable parental investment, relatively much more than in other primates (Buss & Schmitt, 1993; Geary & Flinn, 2001). Thus, women also evaluate prospective male partners on their potential for long-term resource investment. And so, men will compete with each other for resources and social status to attract and retain mates. In ancestral times, men who controlled more resources married younger women, married more women, and produced offspring earlier (Low, 1998). Among contemporary foraging societies, even ones which are relatively egalitarian have some degree of status hierarchy, and men with higher social status are able to attract more mates (Chagnon, 1992; Hill & Hurtado, 1996). The greater variation and skew in male reproductive success selected for higher investments in mating effort and competition relative to somatic effort (building and maintaining one's body) promoting longevity than for females.

In industrial societies, the prevalence of risky behaviors and sex differences in mortality rates from risky behaviors peak in young adulthood (Kruger & Nesse, 2004, 2006). This pattern occurs because of the importance of male social status and resource control for attracting and retaining mates, and risky behavioral strategies of young males were selected for because they tended to aid in mating competition (Wilson & Daly, 1992). The observed peak of risky behaviors in young adulthood corresponds with entrance into mating competition. Male mating effort may peak in young adulthood in part because young men may not yet have partners or offspring to invest in, and also they may be more attractive to females because they have not committed their resources (Hill & Kaplan, 1999). Among Ache foragers, offspring from extra-pair sexual affairs were mainly fathered by younger men. Older men tended to produce most of their offspring within long-term relationships (Hill & Hurtado, 1996). Young males who do not have substantial resources or status may be unable to establish enduring partnerships.

Our theoretical framework suggests that male social status and economic power may be related to mortality patterns in modern industrial societies. Within a society, men that need to compete more vigorously for social status and resources may show higher mortality rates, as a reflection of riskier behavioral strategies and physiological susceptibility to the stress of competition. This notion is supported by data from population representative samples in the United States, where sex

differences in mortality rates are higher for those in lower income groups and those with lower educational attainment (Kruger & Nesse, 2006). Unmarried men also have higher mortality rates across the adult lifespan than married men (Kruger & Nesse, 2006), also suggesting hazards associated with a life history centered on mating effort.

Within societies across time, changes that increase economic uncertainty and variation and skew in social status and economic power may also lead to riskier behavioral strategies and physiological embodiment of stress. The economic transitions from state planned to market economies in Central and Eastern Europe in the 1990s provide a naturalistic experiment to test this hypothesis. During the socialist period, we expect lesser tendencies towards risky male strategies because of the relatively low payoffs for aggressive competition. During this time, social status and material wealth variations were relatively small for most of the population, and employment was guaranteed. During the rapid transition market economies, the variance and skew in social status and resources increased tremendously (United Nations Development Program, 1998). In fact, sex differences in mortality rates increased substantially for Eastern European nations during the years of economic transition, most prominently during early adulthood (Kruger & Nesse, 2007). This increase was due both to external causes, reflecting risky behavioral strategies, and internal causes, reflecting the impact of stress on physiological susceptibility. These trends contrasted with a minimal increase in Western European countries.

Hopefully this brief overview demonstrated how an evolutionary framework can provide an understanding of sex differences in human mortality patterns and lead to predictions for factors which would influence such patterns. The properties of sexual selection offer a well-developed framework for explaining both the basic sex differences and why these differences are likely to be influenced by certain environmental factors and not others (Andersson, 1994; Cronin, 1991). Age and sex-specific mortality patterns reflect life history characteristics and the ecological factors that influence reproductive success for any species (Low, 1998; Stearns, 1992). The evolutionary framework may also be the only theoretical structure that could possibly integrate related research findings that range from behavioral endocrinology to large scale social trends.

Androgens, mating competition, and mortality

For example, we can examine the relationships between behavioral patterns related to mortality and male sex hormones. Male gonadal function is regulated by the hypothalamus, pituitary gland, and testes (the HPT axis), which comprise the male reproductive neuroendocrine system (Bribiescas, 2006). This system acts as a negative feedback loop, similar to a heating system regulated by a thermostat.

During childhood, the thermostat is set very low. If the hypothalamus detects testosterone or estradiol in the bloodstream, the hypothalamus shuts off production of Gonadotropic releasing hormone and testosterone and estradiol are no longer generated.

Around ages 12 and 13, the thermostat setting begins rising and the hypothalamus becomes more tolerant of male sex hormones (Bribiescas, 2006). The steady rise in adrenal androgens, adrenarche, initiates the physical transition to adulthood. Thus begins the life history transition from predominantly somatic effort, building and maintaining the body, to include reproductive effort. Testosterone and estradiol have crucial regulatory roles in the allocation of body tissue to energy storing fat and lean muscle tissue (Bribiescas, 1996, 2001). The shift towards a greater proportion of lean muscle tissue reflects the allocation of energy towards reproductive effort.

Among men in Western industrialized countries, testosterone peaks shortly after age 20 and begins declining somewhat more rapidly after age 40. Non-industrialized populations do not exhibit the same rate of decline in later adulthood (Ellison et al., 2002). This may reflect the different life history patterns occurring in industrialized and non-industrialized societies. In Western industrialized countries, the male testosterone peak coincides with peaks in male mortality from behavioral causes, including intentional violence and accidents (Kruger & Nesse, 2004). Sex differences in mortality from behavioral causes peak in early adulthood and decline rapidly afterwards. This gradual decline continues in later adulthood, although sex differences in suicide rates rise dramatically after age 65 (Kruger & Nesse, 2004). In the forest-dwelling Ache of Paraguay, a flexible social system allowed for easy remarriage and mating effort remained high throughout adulthood. Among the Ache, sex differences in mortality from behavioral causes remained high throughout adulthood (Kruger & Nesse, 2006). In pre-contact Ache, homicide accounted for about half of all deaths. Cardiovascular disease, the leading cause of adult mortality in industrialized countries, was apparently absent (Hill & Hurtado, 1996).

Illness and disease (primarily gastrointestinal diseases) accounted for one quarter of all deaths and accidents accounted for one-eighth of deaths.

Testosterone levels appear to be related to male competition, they rise when males anticipate athletic competition and social status competition, possibly to prepare one's body and mind for engaging in competitive behaviors (e.g., Booth, Shelley, Mazur, Tharp & Kittok, 1989; Cohen, Nisbett, Bowdle & Schwarz, 1996; Gladue, Boechler & McCaul, 1989). Mortality patterns and mating systems also appear to be interrelated (Hill & Hurtado, 1996), and this relationship may be partially mediated by adrenal androgens such as testosterone. Men with high testosterone levels have increased rates of infidelity, violence, and divorce (Booth & Dabbs, 1993). Male testosterone levels decrease following marriage and increase following divorce (Mazur & Michalek, 1998), reflecting a life history shift in the

allocation of effort from mating to parenting, which could also partially account for observed mortality patterns (Kruger & Nesse, 2006).

In adolescent boys, testosterone levels are associated with social dominance (Schaal, Tremblay, Soussignan & Susman, 1996). Given that social status is related to male reproductive success, why hasn't evolution selected for increasingly higher testosterone levels? Production of testosterone is physiologically costly because of its impact on other somatic systems. For example, high testosterone levels interfere with proper immune system functioning (Folstad & Karter, 1992). Thus, there is a trade-off between reproductive and somatic effort in regulating testosterone levels. Male secondary sexual characteristics, including facial traits such as prominent brow ridges and large jaws, are dependent on testosterone levels. Because development of highly masculine features is physiologically costly and difficult to fake, these features signal a good match between the genotype and developmental environment, as well as a stable developmental trajectory free of debilitating injury or disease. Such costly signals are used by females to evaluate prospective mates (Zahavi's, 1975). Having these features is related to reproductive success across species (see Andersson, 1994).

The degree of male facial masculinity is directly related to perceptions of social dominance (Berry & Brownlow, 1989; McArthur & Apatow, 1983) and these perceptions are accurate reflections of actual social status (Mueller & Mazur, 1997). Facial masculinity of military cadets predicted their rank at graduation (Mazur, Mazur & Keating, 1984) and at the peak of their career (Mueller & Mazur, 1997). Higher degrees of male facial masculinity are related to earlier ages of first sexual intercourse (Mazur, Halpern & Udry, 1994). Both women and men associate highly masculine male faces with riskier and more competitive behavioral strategies, higher mating effort, and lower parenting effort in comparison with less masculine faces (Kruger, 2006). Although women prefer men with more masculine faces for sexual affairs (where genetic investment is predominant), they prefer men with more feminine faces for marriage (Kruger, 2006). Men who have higher mate value because of social dominance or physiological quality may have a higher return on mating effort, and thus may not allocate as much effort to parenting and long-term relationships.

Researchers lacking an evolutionary perspective provided here and by other researchers such as Daly and Wilson (1999) and Hill and Kaplan (1999) have difficulty accounting for why adolescents are so prone to morbidity and mortality from voluntary risky behaviors (e.g., Gardner, 1993). It is also more difficult to account for relationships between social conditions and health outcomes, aside from basic factors such as poverty and access to medical care. As was noted previously, social and environmental conditions intensifying male competition for resources and status lead to increased male mortality through riskier behavior patterns and the impact of stress on physiological susceptibility (Kruger & Nesse, 2007). The famous Whitehall studies of British government employees

demonstrated that in a population that was relatively affluent by global economic standards and had universal access to state supported health care, there was still a steep status gradient in health and mortality outcomes (Marmot, 2004). The impact of the status gradient was stronger for men than it was for women.

There are really no competing scientific accounts of human biology apart from the evolutionary framework. However, the evolutionary framework has only recently gained wider recognition in the social sciences. Considering that research in the social sciences comprise important components of the biopsychosocial framework, it would be useful to integrate social science research within a unifying evolutionary structure. Again, this does not require that social scientists need to abandon their research interests, or directly test evolutionary hypotheses. It would be helpful to at least explicitly detail how one's research area may relate to established evolutionary theory. Of course, there are multiple levels of evolutionary theory, ranging from the basic principles of natural and sexual selection (which have overwhelming empirical support), to mid-level theories such as parental investment theory, to more specific theories such as those relating to (partially) concealed human ovulation (e.g., Strassmann, 1981). There are often several competing explanations based on evolutionary principles for a particular phenomenon, and even more attempting to explain more complex topics such as consciousness and religion. The process of science will select from these theories those that best account for observed patterns.

A contrasting bio/social model

Some social scientists have taken note of the advancement of evolutionary explanations for human health and behavior and have generated hybridized models that claim to account for both evolutionary and social influences. Integration, of course, of evolutionary and social influences is the key to effective biopsychosocial models. However, sometimes this integration is incomplete. For example, Wood and Eagly (2002) have developed a "biosocial approach" which they contrast with social constructionism, where gender is arbitrarily defined by a particular society at a particular time, and (mainstream) evolutionary psychology, where evolved sex differences interact in complex ways with the social and ecological environment, including shaping the social environment. This model specifically challenges the framework described above, which connects male mortality patterns to competition and risky behavior (i.e. mating effort) in the service of reproductive success.

In Wood & Eagly's (2002) framework, men and women are placed in different social roles because of the physical specialization of the sexes, particularly female reproductive capacity. Because women bear offspring and breastfeed, they are expected to fill a motherly role. Men are physically larger, have a greater muscle-to-fat ratio, have greater oxygen-carrying capacity, and greater upper-body

strength. Thus, men are more likely to perform tasks, such as hunting, which are aided by these attributes (Wood & Eagly, 2002). Men and women's activities are constrained by their physiology, in industrial societies women are more likely to take the domestic roles and men are more likely to enter the workforce and be an economic provider. There are social expectations, or gender roles, for each sex to have psychological characteristics that are suited for these tasks. Thus, physical sex differences and social expectations result in roles that are more efficiently performed by one sex.

Of course, Eagly and Wood (2002) do not explain the origin of physical sex differences, instead they dismiss human sexual dimorphism as negligible. They cite Plavcan and van Schaik's (1997, p. 351) designation of human sexual dimorphism in body size as "low" among primates and the fact that humans also have minimal canine dimorphism. Of course, human females are still on average only 80% as large as males (Clutton-Brock, 1985), which is obvious in any random sample of sufficient size. Biologists note that not only is the degree of sexual dimorphism directly related to the level of male mating competition, it is also inversely related to the level of paternal investment (See Bribiescas, 2006), consistent with life history tradeoffs of effort. Minimal canine dimorphism in humans may be due to a combination of skeletal constraints stemming from the evolution of the very large human brain and fact that human ancestors have cooked their meat for at least the last 700,000 years (Goren-Inbar, et al., 2004) and have used stone knives since the beginning of the Oldowan period more than 2.5 million years ago. Thus, they would no longer require large canines to tear raw flesh with their teeth and somatic effort could be more efficiently allocated elsewhere.

Eagly and Wood (2002) also call into question the causal direction of the endocrine system and behavioral roles. They cite findings that fathers' anticipation and vicarious experience of childbirth leads to changes in hormone levels, including a drop in testosterone (Berg & Wynne-Edwards, 2001; Storey, Walsh, Quinton & Wynne-Edwards, 2000). They believe that changes in hormone levels work in concert with psychological processes to facilitate the performance of social roles. If so, one might expect men who father multiple offspring to gradually become more compassionate and motherly, due to the accumulated effects of proxy pregnancy and childbirth. However, in addition to the relationships noted above between male reproductive success and social dominance, historical examples of the men most prolific in leaving offspring contradict this notion. Moulay Ismail Ibn Sharif, the Sultan of Morocco from 1672 to 1727 has the highest number of documented children on record, 888 (Abum-Nasr, 1987). Moulay Ismail was nicknamed "The Bloodthirsty" and was known throughout his country as the "Warrior King." The person with the most known living descendants was named Genghis, rather than Gandhi. Genetic analyses indicate that 13th Century Mongolian warlord Genghis Khan has around 16 million direct male descendants currently living in the regions of his Medieval conquest (Zerjal, 2003).

This model also challenges the mate selection criteria observed cross-culturally by evolutionary psychologists (e.g. Buss, 1994), where men are differentially valued for their social status and resource potential. Eagly (2004) believes that women select men who have more economic resources because they are just utility maximizers and men happen to have the social role of providing resources. Eagly claims that these preferences would diminish if women had access to greater economic power. However, when women who are older, and/or more socially and economically powerful (such as Harvard Medical School students) are asked about their partner preferences, they still prefer older, more powerful males (Kenrick & Keefe, 1992; Townsend, 1987; Wiederman & Allgeier, 1992). If there is any difference, these women are actually more concerned about social standing and economic power than average women (Townsend, 1987).

Eagly and Wood's (2002) model would be more accurately referred to as a "bio/social" approach, because although they admit to both biological (at least in terms of general physical characteristics) and social influences, these influences have separate origins and social forces are independent of biological or evolutionary influences. Alfred Russell Wallace described a theory of evolution similar to that of Darwin's; however Wallace stopped short of explaining the human species. Wallace believed that humans were so complicated and sophisticated that they could not possibly be products of natural selection, so they must have been specially created by a divine power (Dugatkin, 2006). Like Wallace's theory, Eagly and Wood (2002) subscribe to an artificially limited version of evolution, one where sexual selection can only operate from the neck down. Just as it is extremely unlikely that *Homo sapiens* required special creation through supernatural forces, it is problematic to hold that the human brain (and therefore psychology and behavior) can be shaped in some vague way by selection independent of sex, but not by inter-sexual selection or intra-sexual competition.

Despite the protests above, Eagly and Wood's (2002) model was deconstructed not because it was particularly absurd, but because the authors have a more accurate understanding of evolutionary psychology than is typical for contemporary critics. It is probably more productive to respond to critics who do not fall for the typical fallacies when encountering evolutionary explanations. By engaging higher quality critiques, researchers can revise or clarify theory to address any shortcomings in the evolutionary framework. One must remember to adequately account for all aspects of the biopsychosocial work, including social influences.

CONCLUSION

This paper will hopefully promote the utility of an integrative evolutionary framework for understanding biopsychosocial research on health and illness. Fully integrative models will provide superior understanding and predictive power to models which unnecessarily separate levels of influence. In addition to promoting understanding, an evolutionary framework may also lead to novel insights because of similarities across systems of life. Convergent adaptations emerge in distantly related organisms in response to similar selection pressures. Solutions to theoretical challenges may appear when puzzles are considered in the light of proximate and ultimate functions of aspects of living systems.

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