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Review

Cardiovascular functioning, personality, and the social world: The domain of hierarchical power

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ABSTRACT

The present paper considers connections between cardiovascular functioning (i.e., disease status and acute stress responses) and social dominance, and its counterpart, social submissiveness, both of which are part of the broader domain of "hierarchical power" [Bugental, D.B., 2000. Acquisition of the algorithms of social life: a domain-based approach. Psychological Bulletin 126, 187–219]. Empirical research on connections between dominance/submissiveness and cardiovascular morbidity and mortality in humans is reviewed, as is research on dominance/submissiveness and cardiovascular reactivity to, and recovery from, acute stressors. Three general conclusions are established. First, in both cross-sectional and longitudinal investigations, trait and behavioral indicators of dominance have been positively associated with cardiovascular disease severity, incidence, and progression, whereas preliminary evidence from two studies suggests that trait submissiveness may protect against poorer disease outcomes. Second, among men and women, trait dominance is associated with reactivity to and recovery from acute stressors, particularly social challenges. Third, linkages between dominance/submissiveness and cardiovascular functioning, especially cardiovascular reactivity, are characterized by gender-specific patterning, and this patterning emerges as a function of social context. Implications for the next generation of research concerning social dominance, gender, and cardiovascular functioning are discussed.

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The human cardiovascular system is dynamic, enabling individuals to swiftly adapt to changing circumstances, such as shifts in posture and activity, and changes in states of arousal such as sleep versus wakefulness (Pickering and Kario, 2001; Sterling and Eyer, 1988). Maintenance of this dynamic system is complex, involving regulation by multiple biological mechanisms at molecular, cellular, and organ levels (Rushmer, 1989).

The human cardiovascular system is, in addition, subject to "socioemotional" regulation. That is, it has the capacity to dynamically respond to emotional qualities of the social environment, and to be influenced by psychological traits, particularly traits that pertain to how individuals perceive and function in the social world (Seeman and McEwen, 1996). For example, individuals show greater blood pressure reactivity when they face an acute stressor in an emotionally cold and potentially punitive social context, compared with a low social threat context (Kamarck et al., 1995). And hostile individuals who are cynical and mistrusting of others show exaggerated blood pressure reactions (Brondolo et al., 2003; Powch and Houston, 1996) and sluggish blood pressure recovery (Neumann et al., 2004) in response to brief socioemotional stressors.

Presumably, the socioemotional regulation illustrated by these examples supports an organism's ability to respond to actual or perceived social challenges. That is, cardiovascular activation during social challenge may be an adaptive response that subserves action tendencies and behavioral strategies associated with emotions provoked by clear and present social threats (Lovallo, 2005). Over the long-term, however, physiological costs may accrue (McEwen, 1998). For example, although causality has not been established, cardiovascular reactivity to acute stressors is associated with future development of adverse cardiovascular profiles (i.e., normotensive blood pressure elevations and essential hypertension) and subclinical cardiovascular disease (i.e., carotid atherosclerosis and increased left ventricular mass, Treiber et al., 2003). Within this context, the present article considers connections between cardiovascular disease status, cardiovascular stress responses, and two interpersonal stances that are part of a fundamental domain of social life: dominance and submissiveness.

1. Dominance and submissiveness

One of the most influential and longstanding models of interpersonal life is the interpersonal circumplex. Fig. 1 illustrates a version of the circumplex that is based on the Interpersonal Adjective Scale (IAS), a well-validated and widely used measure of interpersonal traits (Wiggins et al., 1988). As with all versions of the interpersonal circumplex, this one posits two orthogonal dimensions: the vertical dimension, ranging from dominant to submissive, and the horizontal dimension, ranging from hostile to warm. The underlying premise of the interpersonal circumplex is that most interpersonally relevant personality traits, behaviors (including verbal and nonverbal behaviors), and motives can be represented within this two-dimensional space.

The vertical dimension, the focus of the present review, has been described using various terms, including status, agency, and instrumentality (Wiggins, 1992; Wiggins et al., 1988). Regardless of which term is used, there is general agreement that the vertical dimension pertains to a mode of relating to the social world by striving for power, influence, and control (Wiggins, 1992). In contrast, the horizontal dimension has been termed love, warmth, or communion (Wiggins, 1992) and pertains to a social stance characterized by striving for closeness, intimacy, and union with others.

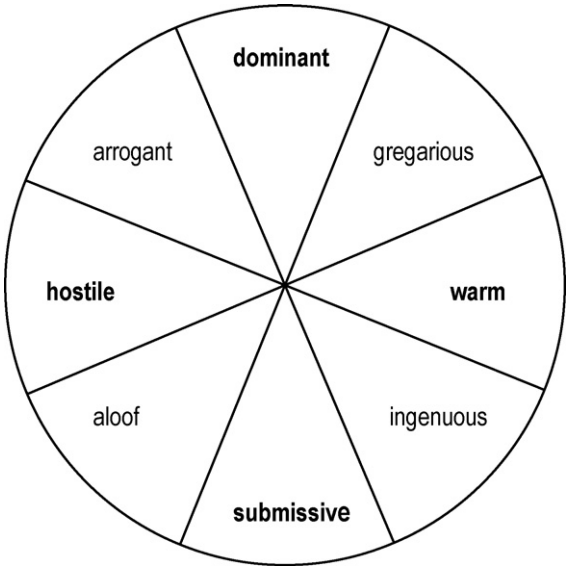


Fig. 1. This figure shows a version of the interpersonal circumplex that is based on the Interpersonal Adjective Scale (IAS) (Wiggins et al., 1988). According to interpersonal theory, status, agency, or instrumentality (i.e., the vertical dimension) and love, warmth, or communion (i.e., the horizontal dimension), are the two primary dimensions that underlie ways of relating to the social world. These two dimensions, represented in boldface, are anchored by the IAS subscales dominance and submission, and by hostility and warmth, respectively. The remaining subscales are blends of the two primary dimensions.

1.1. Measurement

With regard to the vertical dimension specifically, individuals high in trait dominance endorse items such as "I like to give orders and get things moving" (Gough, 1987) and describe themselves as "active" and "competitive" (Spence and Helmreich, 1978). Individuals high in trait submissiveness, in contrast, describe themselves as "forceless" and "timid" (Wiggins et al., 1988). As opposite ends of a single dimension, it is expected that measures of dominance and submissiveness will be negatively correlated. Low dominance, however, is not necessarily equivalent to high submissiveness, nor is low submissiveness necessarily equivalent to high dominance. Rather, both conceptually and empirically (Kiesler et al., 1991; Wiggins et al., 1988), dominance and submissiveness are each associated with a unique and circumscribed domain of characteristics.

Trait measures of dominance and submissiveness capture relational stances that are relatively stable across time and situation. Each of these stances can, in addition, be assessed through behaviors, or verbal and nonverbal expressions used in response to specific social situations or social challenges. Dominant behaviors include actions such as quickly taking charge of a discussion, or expressing firm preferences and standing up for one's opinions, whereas submissive behaviors include actions such as following the lead of others and backing down when questioned (Kiesler et al., 1991). For both dominance and submissiveness, trait and behavioral measures often diverge because, by definition, trait measures do not take into account situational factors that influence behavioral strategies. Depending upon the specific social challenge, trait dominant individuals may employ submissive behavioral strategies and, conversely, trait submissive individuals may employ dominant behavioral strategies. Thus, trait and behavioral measures provide unique, non-redundant information about individuals.

In addition to being measured as traits or behaviors, the two poles of the interpersonal circumplex's vertical dimension can also

be construed as relative social rankings. Within a given social domain, individuals can be hierarchically ordered with regard to their relative level of resources (e.g., occupational status, educational attainment, income level, or social resources such as prestige or potential to influence others), with those having a greater accumulation of resources characterized as higher in status, or more dominant. In addition to such relatively stable social rankings, other social rankings may emerge as a consequence of acute alterations in the social hierarchy, or in response to social conflicts. Thus, an individual may win or lose a specific social conflict and thereby emerge as dominant or subordinate with regard to a specific situation. Just as trait and behavioral measures of dominance and submissiveness will sometimes diverge, social rankings may also diverge from both trait and behavioral indicators. Trait dominant individuals, or individuals who employ dominant behavioral strategies, will sometimes lose, whereas trait submissive individuals, or those who employ submissive behavioral strategies, will sometimes prevail. Consequently, the most comprehensive assessment of dominance and submissiveness will include independent measures of traits, behaviors, and relative social rankings.

Whether measured as traits or behaviors, dominance and submissiveness may occur in different "forms." This is implied by the two orthogonal dimensions of the interpersonal circumplex. That is, dominance and submissiveness may occur as pure representations of the vertical dimension, or they may occur as blends of the vertical and horizontal dimensions. For example, as Fig. 1 makes apparent, arrogance is a blend of dominance and hostility, whereas gregariousness is a blend of dominance and warmth. Behavioral manifestations of these two different blends of dominance include challenging, disputing, or putting down another individual and avoiding sharing credit (i.e., arrogant) versus acknowledging, expressing interest in, and being responsive and attentive to another individual (i.e., gregarious). Overall, the implication is that there are multiple ways of striving for power and influence and, analogously, of yielding and submitting to others. This proposition is echoed in otherwise disparate literatures that have distinguished aggressive and sociable forms of dominance (Kalma et al., 1993) and that have emphasized the roles of both social attraction and intimidation in the complex process of attaining rank and status in human social groups (Allan and Gilbert, 1997). Thus, the interpersonal circumplex has utility for revealing the precise interpersonal nature of a variety of individual difference measures, including the degree to which they assess pure, hostile (i.e., aggressive), or warm (i.e., sociable) forms of dominance and submissiveness (Gallo and Smith, 1997; Gurtman, 1992; Lippa, 1995).

1.2. Function

The interpersonal circumplex provides a conceptually clear, empirically testable, and replicable framework for understanding some of the fundamental aspects of social life. Complementary perspectives are helpful, however, to address the origins and functions of interpersonal stances. With regard to dominance and submissiveness, it has been posited that these interpersonal stances are part of the "hierarchical power domain," one of the basic domains of social life (Bugental, 2000, p. 187). According to this perspective, basic domains represent bodies of social knowledge, or "social algorithms," that have been developed and preserved in order to manage "recurrent problems of social life across evolutionary history" (Bugental, 2000, p. 187). In the case of the hierarchical power domain, the recurrent problem pertains to management of unequal control, unequal resources, or unequal access to resources between or among individuals in a relationship. The associated social algorithm includes processes such as rapidly and automatically sizing up others with regard to their dominance status, dominance capability, and control of resources; judging the relative dominance of others vis-à-vis one's self; and judging when and whether dominant or submissive behavioral strategies will be most adaptive (Bugental, 2000; Kalma, 1991).

In this perspective, the personality traits of dominance and submissiveness represent individual differences in interpersonal motives that are activated in the service of navigating the social domain of hierarchical power. Thus, in the context of unequal control or unequal access to resources within relationships, high trait dominance identifies individuals who, in general, are motivated to compete for access to resources and who tend to adopt actively competitive strategies. High trait submissiveness, in contrast, identifies individuals who, in general, are motivated to avoid competition for resources and who tend to adopt strategies such as appeasement or suppression of anger. These submissive strategies presumably function to de-escalate potential social conflict, a strategy that may have emerged to facilitate survival and that may be particularly important for lower ranking individuals within social groups, given that threats and aggression are often expressed downward in hierarchies (Allan and Gilbert, 2002; Gilbert, 2000).

Successful operation of these interpersonal strategies and, hence, successful navigation of social terrain, requires mechanisms that can accurately attune individuals to social context, such as relative social ranking or winning or losing in social conflicts, and that can re-calibrate in response to a fluctuating social environment (Boyce and Ellis, 2005; Gilbert and Allan, 1998). Several perspectives suggest that these mechanisms are, fundamentally, psychobiological, and include a variety of peripheral response systems, including the cardiovascular system (Boyce and Ellis, 2005; Bugental, 2000; Gilbert and Allan, 1998). In this sense, dominance and submissiveness may each be considered individual differences in "biological sensitivity to context" – especially aspects of the social context that pertain to hierarchical power – that are differentiated with respect to predominant social motive and behavioral strategy (Boyce and Ellis, 2005, p. 271).

1.3. Gender

Some have noted that the two axes of the interpersonal circumplex are reminiscent of social behaviors and motives differentially attributed to men and women (Wiggins, 1992). In this view, the vertical axis, with its focus on power, influence, and control, is considered reminiscent of characteristics traditionally attributed to men. In contrast, the horizontal axis, with its focus on warmth and communion, is considered reminiscent of characteristics traditionally attributed to women. Indeed, self-report measures developed over three decades ago to assess the constructs "masculinity" and "femininity" are now widely recognized to measure the interpersonal constructs of dominance and warmth, respectively (Lippa, 1995). This perspective implies that traits and stressful situations that pertain to dominance will be more activating for the stress responses of men versus women.

In contrast, some empirical data suggest that this gender differentiation may be more apparent than real, especially with regard to the vertical axis of the interpersonal circumplex, and with regard to dominance, specifically. Over the course of approximately 20 years from 1973 to 1995, women's scores on measures that tap this aspect of the circumplex have increased steadily, and have done so at a rate greater than that of men's scores, culminating in a situation in which average gender differences in this interpersonal trait are either significantly diminished, or absent, in undergraduate samples (Twenge, 1997).

Thus, at least within the United States, it is no longer clear that traits related to dominance should be considered gender-linked, or inherently differentially relevant for activating the stress responses of men and women. This may be particularly true for individuals who participate in the paid labor force, because both objective and subjective career success are associated with increases in men's and women's dominance-related traits (Abele, 2003). Notably, women's scores on measures that tap warmth and communion, stereotypically feminine traits, have neither significantly increased nor decreased over 20 years. The non-significant decrease in *average* sex differences on such measures is likely attributable to small increases in men's reports of warmth (Twenge, 1997). Overall, this perspective implies that traits and stressful situations that pertain to dominance will be equally activating for the stress responses of men and women.

2. Dominance, submissiveness and cardiovascular morbidity and mortality

In animal research, there is a long tradition of utilizing social hierarchies, and behavioral indicators of dominance and submissiveness, as models for assessing social stress and physical diseases, including cardiovascular diseases (Sapolsky, 2005). For example, with regard to coronary artery atherosclerosis, research on male and female cynomolgus monkeys has documented associations with individual behavior patterns of dominance and submissiveness. Furthermore, for male animals, understanding the social context, specifically the stability or instability of the immediate social hierarchy, is key to clearly revealing these associations. Male cynomolgus monkeys that consistently achieve dominance over other animals exhibit significantly more advanced coronary artery atherosclerosis than do subordinate animals, but only when their social groups are intermittently reorganized to create unstable social status hierarchies (Kaplan et al., 1982). In contrast, subordinate female monkeys (i.e., those that are consistently unable to achieve dominant status over other animals) exhibit more extensive coronary artery atherosclerosis than their dominant counterparts regardless of the stability of the immediate social hierarchy (Kaplan et al., 1984). Among humans, research on dominance/submissiveness and cardiovascular disease is relatively limited and, with one exception, has been confined to either static trait or behavioral indicators without regard to the nature of the social context. Nonetheless, the overall pattern of results highlights the relevance of this domain of social life for cardiovascular disease status.

2.1. Trait dominance and submissiveness

Seven studies have examined relationships between trait dominance or trait submissiveness and cardiovascular disease status in humans. Two assessed trait dominance of male and female survivors of myocardial infarction (MI) a few days prior to discharge from post-MI hospitalization. Gender differences were not evaluated due to the small number of females in the study. In cross-sectional analyses, trait dominance was significantly and positively associated with a prognostic indicator of elevated post-MI morbidity and mortality after controlling for traditional risk factors (Helgeson, 1990). The trait dominance measure used in this analysis (i.e., the unmitigated agency subscale of the Personality Attributes Questionnaire, Spence et al., 1979) maps onto the hostile-dominant quadrant of the interpersonal circumplex, with a somewhat closer alignment to the hostile axis, suggesting that it taps aggressive dominance (Ghaed and Gallo, 2006). In longitudinal analyses of 1-year follow-up data from this same sample, trait dominance was significantly and positively associated with severity of post-MI chest pain, but not with rehospitalization (Helgeson, 1991). The trait dominance measure used in this analysis (i.e., the masculinity/agency subscale of the Personality Attributes Questionnaire, Spence et al., 1979) maps onto the hostile-dominant quadrant of the interpersonal circumplex for men, and both the hostile-dominant and friendly-dominant quadrants for women, but for both genders is very closely aligned with the dominant axis, suggesting that it taps a relatively pure form of social dominance (Ghaed and Gallo, 2006; Lippa, 1995).

Three empirical reports from the Edinburgh Artery Study sample, a general population sample of men and women 55–74 years of age, assessed associations between trait measures of dominance and submissiveness and various cardiovascular disease outcomes. One evaluated cross-sectional associations between dominance and the presence of peripheral arterial disease (PAD) classified as self-reported intermittent claudication, symptomatic PAD, or asymptomatic PAD, where PAD was operationalized by ankle-brachial pressure index and/or a reactive hyperemia test of ankle pressure (Deary et al., 1994). Domineering social attitude was associated with significantly increased odds of *asymptomatic* PAD (i.e., PAD in the absence of both intermittent claudication and angina); gender differences were not reported. Notably, the broader dominance construct, of which the attitudinal subscale is a part, was additionally comprised of a "hostile acts" subscale, suggesting that this measure of domineering attitude may tap aggressive dominance.

Two subsequent longitudinal studies from this sample employed a factor-analytically derived trait measure of submissiveness/low-self-confidence that loads on the submissive pole of a factor reminiscent of the vertical dimension of the interpersonal circumplex, ranging from dominance to submissiveness (Whiteman et al., 2001). In the first longitudinal study, submissiveness/low-self-confidence was evaluated as a predictor of PAD progression over 5 years (Whiteman et al., 2000). In men only, lower submissiveness was significantly associated with progression of PAD after adjusting for cigarette smoking and alcohol use. In the second longitudinal study, trait submissiveness/low-self-confidence assessed at baseline was evaluated as a predictor of first-onset adverse cardiovascular events (i.e., fatal MI, non-fatal MI and angina pectoris) in men and women over the course of 5 years of follow-up (Whiteman et al., 1997). Among women only, higher levels of trait submissiveness were significantly associated with reduced odds of both non-fatal and total (i.e., combined fatal and non-fatal) MI, after controlling for standard biomedical risk factors. Overall, across these three studies, higher levels of trait dominance are cross-sectionally related to poorer peripheral arterial disease status, whereas higher levels of trait submissiveness are associated with slower progression of peripheral arterial disease in men and reduced likelihood of first-onset adverse cardiovascular events in women.

Another longitudinal study examined associations between trait dominance assessed at baseline and the occurrence of adverse cardiovascular events (i.e., angina pectoris, non-fatal MI, and cardiovascular mortality) over the course of an average of 8 years of follow-up (Siegman et al., 2000a). All study participants were men an average of 61 years of age who were free of coronary heart disease (CHD) at baseline. Trait dominance was assessed using an MMPI-2-derived measure that was developed specifically for this study using a combination of expert ratings and factor analysis. After controlling for standard biomedical risks factors and a measure of anger, trait dominance was significantly and positively associated with increased odds of combined fatal and non-fatal cardiovascular events; there were no significant associations with angina pectoris. This is the only study of trait dominance and cardiovascular disease status that evaluated the incremental validity of trait dominance relative to other socioemotional

constructs (i.e., anger). Results support the incremental validity of trait dominance, indicating that it was not predictive of adverse cardiovascular events simply because of an underlying association with anger. Although there are no known evaluations of this measure with regard to sociable versus aggressive forms of dominance, inspection of individual items reveals at least two that are also part of the Cook-Medley Hostility Scale, an MMPI-derived measure of trait hostility (Cook and Medley, 1954), raising the possibility that a relatively more aggressive form of dominance may have been assessed in this study.

A final, novel study provides indirect evidence for the importance of socioemotional context and cardiovascular disease status. This study of husbands and wives employed a case–control design comprised of 54 Type A husbands, 24 with verified CHD, and 70 Type B husbands, 30 with verified CHD (Carmelli et al., 1985). Compared to the wives of Type A husbands without verified CHD, wives of Type A husbands with verified CHD reported significantly higher levels of activity and dominance on a self-report measure of temperament. Because wives' temperament was not associated with CHD among Type B men, the authors speculate that the *interaction* between the spouses' personality and behavior patterns (i.e., a Type A husband in the context of an active, dominant wife) and the ensuing marital dynamics may be of significance for husbands' cardiovascular disease status. Wives' cardiovascular disease status was not assessed.

2.2. Behavioral dominance

Four studies have examined relationships between behavioral indicators of dominance and cardiovascular disease status. In a cross-sectional study of men and women referred for coronary arteriography, two interview-derived stylistic speech indicators associated with dominance – loudness and simultaneous speech (i.e., talking at the same time as the interviewer) – were positively and significantly associated with coronary occlusion severity among individuals 60 years of age and younger (Siegman et al., 1987). These associations did not vary by gender and they held after adjusting for age, diastolic blood pressure (DBP), and weight. In another cross-sectional study, men and women who were referred for thallium stress testing were categorized as either free of cardiovascular disease indicators or positive for documented CHD. Interview-derived stylistic speech indicators consisted of behavioral dominance (i.e., interruptions and simultaneous talk) and behavioral hostility. Controlling for traditional biomedical risk factors and behavioral hostility, behavioral dominance was significantly and positively associated with CHD status; there were no significant interactions with gender (Siegman et al., 2000b).

Two other studies provide additional evidence for the unique association between behavioral dominance and cardiovascular disease status, above and beyond the effects of behavioral hostility. Participants in both studies were 250 men who developed CHD (i.e., coronary death, non-fatal MI and angina pectoris) during an average of 8.5 years of follow-up, along with 500 disease-free age-matched controls. Interview-derived stylistic speech indicators and ratings of emotional characteristics (e.g., hostility and self-aggrandizement) assessed at baseline were subjected to cluster analysis, which yielded six clusters. In the first study, these clusters were evaluated with regard to their ability to predict CHD status during the 8.5 years of follow-up (Houston et al., 1992). After controlling for traditional risk factors (i.e., serum cholesterol, DBP, and cigarettes smoked per day) and for hostile behavior, a behavioral cluster characterized by quick responses, interruptions, and verbal competitiveness, and interpreted as controlling and socially dominant behavior, was significantly and positively associated with CHD incidence. In the second study, a 22-year follow-up of the survival of these men, the controlling and socially dominant behavioral cluster was significantly and positively associated with all-cause mortality; these associations held after controlling for total cholesterol, DBP, cigarettes smoked per day, and the hostile behavior cluster (Houston et al., 1997).

2.3. Summary and conclusions

The empirical literature on dominance/submissiveness and cardiovascular disease reveals cross-sectional correlations between this interpersonal domain and both prevalence and severity of cardiovascular diseases, with higher levels of trait or behavioral dominance-associated with poorer cardiovascular disease status. In addition, several longitudinal studies, some of which were prospective, show that dominance and submissiveness are related to cardiovascular disease progression, incidence, and also to total mortality. Dominance is associated with poorer outcomes, whereas some preliminary evidence suggests that submissiveness may be protective.

Three of the trait studies employed trait dominance measures that either definitely, or possibly, included elements of hostility, suggesting that associations with poorer cardiovascular outcomes may pertain to aggressive dominance. Because there were no studies that included unambiguous measures of sociable dominance, the link between this construct and cardiovascular disease remains an open question. Among studies that employed measures of trait submissiveness, it is unclear the extent to which the trait measures tap relatively pure versus blended forms of submissiveness. With regard to the studies of behavioral dominance, three of the four studies established associations with cardiovascular disease outcomes after specifically controlling for an index of behavioral hostility, suggesting that the element of aggression is not a necessary component of these associations, and thus helping to establish the incremental validity of dominance.

A uniform conclusion regarding gender does not emerge, in part because of the limited database from which to draw. Seven studies did not evaluate gender differences. Of the remaining four studies, two reported significant gender differences (studies of trait submissiveness) whereas two did not (studies of behavioral dominance). Thus, a tentative conclusion may be that gender moderates associations between cardiovascular disease status and trait submissiveness, but not behavioral dominance. For these two studies of trait submissiveness, however, the disease outcomes were very different from one another (i.e., PAD progression versus first-onset cardiovascular events) making it premature to draw conclusions (Whiteman et al., 1997, 2000). Finally, although dominance and submissiveness are relational constructs, most studies of health outcomes in humans have measured them as static traits or behaviors, divorced from social context. One notable exception is the study by Carmelli et al. (1985) that yielded indirect evidence of the importance of dominance-related marital context for men's cardiovascular health.

Regarding submissiveness, at first glance it may seem surprising that this trait not only was not associated with poorer cardiovascular disease status, but also appeared to protect against poorer outcomes. Indeed, numerous studies of non-human primates underscore subordinate animals' stressful lives and greater susceptibility to acute and chronic illness (Cohen et al., 1997; Hamm et al., 1983; Kaplan et al., 1984). Moreover, trait submissiveness in humans and subordinate social rank in non-human primates have both been associated with signs and symptoms of depression (Allan and Gilbert, 1997; Shively et al., 1997). Depression, in turn, has been associated with increased risk for adverse cardiovascular events among individuals with and without pre-existing disease. For example, in longitudinal studies

of individuals who were apparently healthy at study initiation, depression in or above the mild clinical range was associated with significantly increased risk of coronary disease occurrence during the follow-up period, after controlling for relevant demographics and standard biomedical risk factors (Wulsin and Singal, 2003). Moreover, although not all results are consistent, depression has also been associated with progression of existing coronary artery disease (Lett et al., 2004). Why, then, does available research suggest that submissiveness is associated with decreased, rather than increased, risk for poorer cardiovascular outcomes?

One possibility is because moderators have not been examined. For example, the availability of social alliances moderates associations between subordinate social status and basal concentrations of the endocrine stress hormone cortisol in non-human primates; subordinate animals with fewer alliances have significantly higher cortisol concentrations compared to subordinate animals with more social alliances (Abbott et al., 2003). Extrapolating from this research, inclusion of social environment measures in human studies might reveal more nuanced relationships between submissiveness and cardiovascular disease outcomes, the direction of which may hinge upon the quality, or cumulative lifetime quality, of one's social environment.

Omission of a moderator such as social support availability might obscure an underlying negative relationship between trait submissiveness and cardiovascular disease status that hinges upon the absence of support availability. It does not, however, explain why submissiveness would appear to protect against the occurrence or progression of disease. Other unexamined moderators may, however, be operating. For example, a distinction has been made between "voluntary" versus "involuntary" submissiveness (Allan and Gilbert, 1997, p. 471). An individual who voluntarily adopts a submissive coping stance may perceive this approach and the ultimate outcome as a success if it prevents or curtails social conflict and attacks, particularly if minimal costs to the individual are involved. In contrast, in circumstances where submissiveness involves involuntarily yielding highly valued resources, or when social conflict and attacks continue despite the adoption of a submissive interpersonal stance, a submissive orientation may be more likely to lead to perceptions of defeat, and therefore, depression (Gilbert and Allan, 1998; Gilbert et al., 2002). Thus, a fuller understanding of the social context may clarify circumstances under which a submissive interpersonal stance confers risk for, or protection against, poor physical health outcomes.

Analogous processes may be operating in research on dominance and cardiovascular disease outcomes. That is, non-human primate studies indicate that social hierarchy stability moderates relationships between dominance and disease outcomes (Kaplan et al., 1982), yet research on humans has not incorporated measures of the social environment or of social status/rank attainment. Inclusion of such measures might similarly reveal more nuanced relationships between dominance and disease status, such that perhaps only dominant individuals with a consistent history of exposure to dominance challenges or social instability, or those who endorse low social status/rank attainment, will show elevated risk of cardiovascular diseases. Contrariwise, dominant individuals who have not faced these social challenges to the same extent may, instead, benefit from their social dominance, and this benefit might conceivably be reflected in more favorable health outcomes.

3. Dominance, submissiveness and cardiovascular stress responses

Potential pathways connecting personality with the development or progression of long-term chronic health conditions, such as the cardiovascular conditions reviewed above, include behaviors that damage or promote health (Weiss and Costa, 2005) along with more direct connections to physiological stress responses (Contrada et al., 1990). Although direct evidence is limited, it is at least plausible that patterns of cardiovascular responses that accompany personality traits and that occur in response to real and perceived social challenges may, if recurrent, be associated with increased risk for deleterious health consequences (McEwen, 1998; Smith et al., 2003; Treiber et al., 2003). Eighteen separate studies have examined associations between trait or behavioral dominance/submissiveness and cardiovascular stress responses[1]. By examining cardiovascular reactivity, and in some cases cardiovascular recovery, these studies provide insight into the hierarchical power domain and associated dynamics of physiological adaptation to acute stressors. Moreover, by also assessing emotional responses, some studies provide information to illuminate the dynamics of emotional adaptation to acute stressors. Of the 18 studies, six employed nonsocial stressors (e.g., mental arithmetic and isometric handgrip), nine employed socially relevant stressors that, to varying degrees, were designed to activate interpersonal motives relevant to dominance (e.g., speech tasks; simulated interviews or role-plays where one individual is a research participant and the other is an interviewer or confederate), and six employed dyadic social interaction stressors (i.e., social interactions where both individuals are research participants).

Across these 18 studies, four different measures of trait dominance were used, with all but three studies that measured traits employing either the masculinity/agency subscale of the Personality Attributes Questionnaire (Spence et al., 1979) or the dominance subscale of the Jackson Personality Research Form (Jackson, 1974). As discussed above, for men, the former measure maps onto the hostile-dominant quadrant of the interpersonal circumplex, although with a close alignment to the dominant axis (Ghaed and Gallo, 2006; Lippa, 1995), whereas for women it maps onto both the hostile-dominant (Lippa, 1995) and friendly-dominant quadrants (Ghaed and Gallo, 2006), but with close alignment to the dominant axis in both cases. Similarly, the latter measure does not strongly or exclusively tap either aggressive or sociable forms of dominance. It exhibits small to moderate positive correlations with trait measures of both aggression (0.16–0.29) and affiliation (0.16–0.30) in men and women and, in factor analytic investigations, the dominance, aggression, and affiliation subscales of the Jackson Personality Research Form load on separate factors (i.e., ascendance, aggression, and social contact, respectively).

3.1. Nonsocial stressors

Two studies that included men and women and evaluated potential gender differences (Allen et al., 1993; Hughes and Callinan, 2007), and one study that included women only (Saab et al., 1989), revealed no significant associations between trait dominance and cardiovascular reactivity during nonsocial stressors, including no

[1] In addition to these 18 studies, six other potentially relevant studies were identified but not included in the present review. Three of these studies formed groups of subjects using a combination of masculinity and femininity measures. Therefore, high and low dominance were confounded with levels of femininity, making it difficult to draw conclusions about the specific role of dominance in cardiovascular stress reactivity (Davis and Matthews, 1996; Hirokawa et al., 2004; Myrsten et al., 1984). Three other studies included men and women and evaluated cardiovascular parameters and either trait dominance (Evans and Steptoe, 2003; Fritz et al., 2003) or behavioral submissiveness (Sgoifo et al., 2003), but did not conduct analyses by gender. Given the prominent pattern of gender differences in the present review, these three studies were excluded from consideration.

associations with indices derived from impedance cardiography (Allen et al., 1993). An additional study of men and women employed an experimental manipulation to lead participants to appraise an otherwise neutral anagram-solving task as either "masculine" or "feminine" (Weidner and Messina, 1995). The premise, that when labeled "masculine" the task would generate elevated cardiovascular responses among dominant individuals, was not supported. Despite successfully manipulating participants' appraisals, trait dominance was not significantly associated with blood pressure or heart rate reactivity in either condition, for either men or women.

In contrast, in two studies that evaluated only men during mental arithmetic stressors, trait dominance was significantly and positively associated with systolic blood pressure (SBP) reactivity (Gramer, 2003) and, for DBP reactivity, a curvilinear association was observed (Gramer and Huber, 1997). Specifically, high and low trait dominant men showed significantly greater DBP reactivity than did men with intermediate levels of trait dominance.

All studies of nonsocial stressors employed trait dominance measures that either align closely to the dominant axis of the circumplex, or that have no strong or exclusive association with either aggression or affiliation, suggesting that the varying pattern of associations across studies is unlikely to be due to differences in the measurement of trait dominance. Instead, subtle technical differences in the tasks may have contributed to variations in results. Specifically, in the two studies that observed significant associations between blood pressure reactivity and trait dominance, participants' responses to the arithmetic stressor were delivered verbally and participants were explicitly told that the experimenter would record their performance (Gramer, 2003; Gramer and Huber, 1997). These task characteristics might have caused participants to construe this administration of the mental arithmetic stressor as relatively more social, compared to the administrations used in other studies (e.g., typing answers into a computer, Allen et al., 1993; Hughes and Callinan, 2007). Furthermore, math performance in a social versus nonsocial setting could conceivably amplify the salience of relative social rank and status, and thereby heighten interpersonal motives central to social dominance.

Four of the studies of nonsocial stressors assessed post-task emotional states. Three of these studies reported no significant associations between trait dominance and post-task emotions (encompassing a range of positive and negative emotions), including two of the studies where elevated reactivity was observed (Gramer, 2003; Gramer and Huber, 1997; Weidner and Messina, 1995). In contrast, Hughes and Callinan (2007) reported significant *negative* associations between trait dominance and state anxiety for men, whereas there were no significant associations for women. In this study, post-task anxiety was assessed once following completion of both a nonsocial and socially relevant stressor.

3.2. Socially relevant stressors

Ten studies have examined associations between dominance or submissiveness and cardiovascular responses to socially relevant stressors in either men (three studies), women (four studies), or both men and women (three studies). Most of these studies employed trait measures of dominance, but some experimentally manipulated dominance/submissiveness by having participants read structured scripts designed to characterize each of these two interpersonal motives, and one study assessed behaviors rather than traits. The results of these studies, compared with those from studies employing nonsocial stressors, clearly reveal associations between dominance/submissiveness and cardiovascular responses. They also demonstrate, however, that gender and task demands moderate these associations.

Among women, four studies observed significant, positive associations between trait dominance and cardiovascular reactivity. These results include elevated SBP and DBP reactivity among dominant women while they debated a female confederate (Rejeski et al., 1990) or while they participated in a series of tasks designed to simulate a job interview (i.e., written test under time pressure; mental preparation of speech and speech delivery; personal interview in response to standardized audiotaped questions) (Sieverding et al., 2005), along with elevated SBP reactivity (Hughes and Callinan, 2007) and heart rate (HR) reactivity (Saab et al., 1989) among dominant women during a speech task. In the latter study, associations between trait dominance and HR reactivity were limited to postmenopausal, as opposed to premenopausal, women. In addition to exaggerated reactivity, Sieverding et al. (2005) reported that high-dominant women showed less complete post-stressor DBP recovery compared with their low-dominant counterparts. All of these studies except one employed trait measures that align closely with the dominant axis of the interpersonal circumplex. The one exception, Rejeski et al. (1990), employed the dominance subscale of the Adjective Check List, which exhibits moderate correlations with subscale measures of affiliation (0.33) and aggression (0.47), suggesting that it taps components of both aggressive and sociable dominance (Gough and Heilbrun, 1983).

In contrast, one study of women observed significant, negative associations between trait dominance and cardiovascular responses while women "interacted" with an audio-recorded female "partner" in order to provide support, debate a controversial topic, or describe the events of their day (Nealey et al., 2002). This is the only study of a socially relevant stressor that employed the Bem Sex-Role Inventory masculinity subscale as a measure of trait dominance which, for men and women, maps onto the hostile-dominant quadrant of the circumplex, suggesting that it may be considered an index of aggressive dominance (Lippa, 1995). Heart rate, blood pressure, and measures derived from impedance cardiography were taken while women listened to, or spoke to, audio recordings of their partner. Across all three tasks, while participants spoke, *low* trait dominance was characterized by greater reactivity of DBP and HR, and greater decreases in respiratory sinus arrhythmia and pre-ejection period, with these latter two effects interpreted as evidence for greater parasympathetic withdrawal and greater sympathetic activation, respectively (Nealey et al., 2002). Similarly, in a study in which participants read structured responses to an audiotaped interview, women who read responses designed to be submissive-friendly showed significantly greater SBP reactivity than did women who read responses designed to be dominant-hostile (Smith et al., 1996).

Finally, one study examined relationships between submissive *behaviors*, rather than traits, and cardiovascular responses during interviews in which women talked about their personality features while being periodically interrupted by the interviewer (Pico-Alfonso et al., 2007). Submissiveness was quantified by coding nonverbal behaviors exhibited during the interviews, and indices of instantaneous heart rate and parasympathetic nervous system activity were derived from continuous electrocardiograms. Women who showed more frequent nonverbal indicators of submission were characterized by significantly greater heart rate and decreased levels of the index of parasympathetic nervous system activity during the interview and post-interview recovery.

Among men, compared with women, the direction of associations between dominance/submissiveness and cardiovascular responses to socially relevant stressors is less uniform; two studies observed positive associations, three observed negative

associations, and one observed both positive and negative associations. This is true despite the relative uniformity of trait dominance measures across studies; with one exception, all studies of men that assessed trait dominance employed measures that align closely with the dominant axis of circumplex. The one exception, Rejeski et al. (1989), employed a measure of trait dominance taps both aggressive and sociable dominance.

Regarding positive associations, while men engaged in a series of stressors that simulated a job interview, trait dominance was characterized by greater DBP and SBP reactivity, although the latter association held only when dominance was also accompanied by high levels of trait expressiveness (i.e., stereotypical female qualities such as being kind, gentle, helpful, and emotional, Sieverding et al., 2005). In addition, there was a trend for high-dominant men to show more complete post-stressor DBP recovery than low-dominant men. Similarly, when men read structured responses to an audiotaped interview, responses designed to enact a dominant-hostile role elicited greater SBP reactivity than did responses designed to enact a submissive-friendly role (Smith et al., 1996).

Regarding negative associations, SBP reactivity assessed in response to a speech task was negatively associated with trait dominance (Hughes and Callinan, 2007), and HR reactivity assessed during debate with a female confederate was significantly greater among submissive than among dominant men (Rejeski et al., 1989). In addition, Gramer (2003) reported a main effect of trait dominance for DBP reactivity; across a series of stressors (i.e., mental arithmetic, speech preparation and delivery, and a role play requiring assertion) low-dominant men showed greater DBP reactivity than high-dominant men, with no moderation by stressor type. Furthermore, high-dominant men showed more complete post-stressor DBP recovery than low-dominant men following every task. In this same study, men's SBP reactivity during the social stressors was not significantly associated with trait dominance. One final study of men and trait dominance observed both positive and negative associations with cardiovascular responses to social stressors. When male participants were paired into dyads and assigned to be either a leader or a follower in map navigation task, high-dominant men tended to show greater SBP reactivity while following rather than leading, whereas low-dominant men tended to show greater reactivity while leading rather than following (Gramer and Huber, 1997). Thus, high-dominant men appear to be reactive to a loss in status and control, whereas low-dominant men are reactive to a gain in status and control.

Overall, across the studies of socially relevant stressors, positive associations between *trait* dominance and acute cardiovascular responses were more apparent and uniform among women than among men. Indeed, among the five trait studies that included women, four reported positive associations, whereas only one reported negative (i.e., inverse) associations, with low-dominant women showing greater reactivity than high-dominant women (Nealey et al., 2002). In contrast, among the five trait studies that included men, three reported inverse associations (Gramer and Huber, 1997; Hughes and Callinan, 2007; Rejeski et al., 1989). Could differential activation of motives relevant to dominance account for this? Most of the studies of socially relevant stressors employed stressors designed to elicit motives salient to dominance or competitive achievement, such as dominance challenges (Rejeski et al., 1989, 1990), a simulated job interview (Sieverding et al., 2005), a role play requiring assertion (Gramer, 2003), and leading versus following roles (Gramer and Huber, 1997). Two exceptions included a study that used a speech task that has been rated as requiring stereotypically "feminine" qualities (Saab et al., 1989; Stoney et al., 1988) but that nonetheless generated elevated heart rate reactivity in dominant women, and one study that used a speech task without clear salience to dominance motives (Hughes and Callinan, 2007). This latter task activated blood pressure responses among dominant women, but not men. Thus, while the specific stressors differed, most studies used stressors that would presumably activate motives salient to dominance, and therefore this would seem unlikely to account entirely for the observed pattern of gender differences.

Alternatively, it is possible that men's and women's task appraisals differed in ways that culminated in gender differences in activation of dominance motives, even for otherwise identical tasks. More specifically, trait dominance and cardiovascular reactivity might be inversely related in situations where dominant men are not sufficiently motivated by a given task (e.g., the speech task employed by Hughes and Callinan, 2007, or a dominance challenge from a woman as employed by Rejeski et al., 1989). Future research could evaluate this possibility by incorporating assessments of such appraisals.

Finally, of the four studies in this section that assessed post-task emotional states, one study of women observed no significant associations between trait dominance and state anger or state anxiety (Nealey et al., 2002), whereas three other studies revealed that, compared to high-dominant individuals, low-dominant individuals report greater post-task stress (Sieverding et al., 2005) and anxiety (Hughes and Callinan, 2007), along with more tension and less cheerfulness (Gramer and Huber, 1997). Such associations were apparent for men and women. Overall, low trait dominance is more strongly associated with emotional reactivity to acute stressors than is high trait dominance.

3.3. Dyadic social interaction stressors

In contrast to the studies of socially relevant stressors reviewed above, dyadic social interaction stressors are those that involve interactions between two research participants. Depending upon the exact study design, this approach can illuminate social context effects by modeling cardiovascular responses as a function of the personality or behavior of one's interaction partner, in addition to one's own personality or behavior. Three studies employed previously unacquainted dyad partners, whereas three others employed acquainted dyad partners (i.e., friends or spouses). All studies in this group that assessed trait dominance employed measures that align closely with the dominant axis of the circumplex (i.e., the masculinity/agency subscale of the Personality Attributes Questionnaire, or the dominance subscale of the Jackson Personality Research Form).

3.3.1. Unacquainted partners

In a series of three studies, dyads were presented with various problems (e.g., current event or campus dilemma) and, during three discussions that were each 3–4 min in duration, were to arrive at a mutual decision about the best ways to address the problems. In the first study, dyads were composed of a man and a woman (Newton et al., 1999). Clear gender differences emerged, with significant and positive associations between trait dominance and SBP reactivity apparent for men, but not women, during the discussions. This association held after controlling for trait hostility, suggesting that correlated features of dominance and hostility were not responsible for the effect. In contrast, while participants silently prepared to interact, trait dominance was significantly and positively associated with DBP reactivity for men and women. Thus, characteristics of social interactions such as speech patterns or nonverbal behavior are not essential to the linkage between trait dominance and blood pressure reactivity. Finally, underscoring the importance of social context, interacting

with a socially dominant partner was associated with elevated DBP reactivity; whether this varied by gender was not assessed.

A replication and extension of this study evaluated individuals within the context of same-sex dyads (Newton et al., 2005). Among men only, SBP and DBP reactivity were significantly and positively associated with trait dominance, but only in the context of a partner with high levels of trait dominance. Thus, this study replicated the previously observed gender differences, revealed they were not due to the gender composition of the dyad, and also underscored the importance of social context for activating dominant men's blood pressure.

Using an identical social interaction task, but with opposite-sex dyads, cardiovascular reactivity was examined as a function of behavioral dominance and behavioral hostility exhibited during the interaction (Newton and Bane, 2001). Women's expression of behavioral dominance was significantly and positively associated with heart rate reactivity. Moreover, women showed greater SBP reactivity in the presence of men who were behaviorally dominant.

One final study, although not a laboratory study, sheds additional light on blood pressure and social behaviors related to the hierarchical power domain. In this study of women in their early to mid-twenties, resting blood pressure was assessed in the laboratory and, subsequently, women rated their social behaviors in the naturalistic environment three times per day for 32 days. Resting SBP and DBP levels were positively associated with frequency of submissive behaviors, and negatively associated with frequency of dominant behaviors, as recorded in the natural environment (D'Antono et al., 2001).

3.3.2. Acquainted partners

Three studies have examined associations between aspects of dominance and cardiovascular responses in dyads composed of acquainted partners. Gramer and Berner (2005) examined reactivity of young men and women high school students, some of whom were close friends with one another, selected to be high or low on trait dominance. Participants, paired with an opposite-sex partner with an opposite level of dominance, were assigned either pro or con positions on a standardized topic and were instructed to persuade their partners. Trait dominance was positively related to SBP reactivity, but negatively related to DBP reactivity; the latter association was particularly prominent among women. Post-stressor cardiovascular recovery was also assessed. Interacting with a high versus low, dominant partner was associated with attenuated DBP recovery.

Finally, two studies examined associations between cardiovascular responses and aspects of dominance in social interactions between married couples. In one, husbands and wives were assigned opposing positions on a topic that they either discussed, or discussed under conditions of an incentive to persuade and influence their spouse; behavioral coding of the interactions verified that this incentive manipulation generated high frequencies of assertion among both husbands and wives. Husbands, but not wives, showed greater SBP reactivity while persuading and influencing than while simply discussing (Brown and Smith, 1992).

Additional analyses of these couples while they prepared for, and then engaged in, attempts to persuade and influence their spouse evaluated associations between cardiovascular responses and generalized perceptions of spouse dominance relative to one's own level of dominance. Although results were complex, there were two salient patterns for wives. Wives' DBP reactivity while they prepared to speak with their husbands was greater if they perceived their husbands to be relatively more dominant (and therefore themselves relatively more submissive). Further, for wives' SBP reactivity during discussions with their husbands, there was an inverted-U relationship with perceptions of spouse dominance. Wives' SBP reactivity was positively associated with perceived spouse dominance, except at the highest levels of perceived spouse dominance, at which point wives' SBP reactivity was attenuated. Presumably, when wives perceived their spouses to *highly* dominant, they disengaged from attempts to persuade and influence because they perceived limited chances of success (Brown et al., 1998).

3.3.3. Summary

Overall, across the six dyadic social interaction studies, two used tasks that were designed to strongly activate dominance motives by assigning pro/con positions (Gramer and Berner, 2005), or requiring spouses to assert differing opinions (Brown et al., 1998). Elevated cardiovascular reactivity was apparent for men in both cases, whereas results for women were mixed. In three other studies, participants were to work together to come to a mutual decision about solutions to social problems, thus providing an opportunity for participants to persuade and influence, but not requiring it (Newton et al., 1999, 2005; Newton and Bane, 2001). Nonetheless, trait dominance was positively associated with blood pressure reactivity for men, whereas women's blood pressure reactivity was sensitive to expressing, and being exposed to, behavioral dominance.

Three studies in this section assessed post-task emotional responses, and one assessed pre-task appraisals. High-dominant, as opposed to low-dominant, individuals appraised impending stressors as less threatening and approached them with greater perceived coping ability (Gramer and Berner, 2005), despite showing elevated SBP reactivity. High-dominant individuals reported more post-task positive emotion and less anxiety relative to low-dominant individuals (Gramer and Berner, 2005), and submissive feelings increased more among low-dominant men versus high-dominant men, but not women (Newton et al., 1999). Thus, consistent with results from socially relevant stressors, negative emotional reactivity to acute stressors does not characterize high-dominant individuals, despite their general tendencies for cardiovascular activation.

3.4. Summary and conclusions

As a whole, the studies of stress reactivity/recovery provide evidence that dominance and submissiveness, part of the more global interpersonal domain of hierarchical power, are of significance for men's and women's acute cardiovascular stress responses. This evidence is clearest for socially relevant and social interaction stressors, and in two "nonsocial" stressors that appeared to have a social component. This suggests that social context – particularly a context that elicits motives salient to dominance and competitive achievement – may be a critical ingredient for this cardiovascular activation.

With few exceptions, most studies of trait dominance employed trait measures that tap relatively pure dominance, as opposed to aggressive or sociable dominance. Furthermore, although evaluated in only a few studies, there is preliminary evidence that connections between dominant traits and behaviors and elevated cardiovascular reactivity are apparent even after controlling for hostile traits and behaviors. These findings help establish the incremental validity of trait and behavioral dominance vis-à-vis hostility, a construct that is a well-recognized correlate of exaggerated cardiovascular reactivity to social stressors (Suls and Wan, 1993).

Few studies examined submissiveness per se, as opposed to dominance, and therefore it is difficult to draw firm conclusions about the differential roles of these two interpersonal stances for cardiovascular functioning. Notable exceptions to this are two

studies of women, one laboratory and one naturalistic, that revealed that behavioral submissiveness, whether assessed by nonverbal behaviors or participants' self-reports, was associated with heightened cardiovascular responses (D'Antono et al., 2001; Pico-Alfonso et al., 2007). Also, one study observed elevated reactivity among women enacting a submissive-friendly role (Smith et al., 1996). These three studies highlight the importance of directing more attention to submissiveness in future research.

Although assessment of post-task emotions was the exception more than the rule, a consistent pattern emerged nonetheless. When facing acute stressors, high-dominant individuals are generally characterized by heightened cardiovascular reactivity, but not heightened emotional reactivity. Low-dominant individuals, in contrast, are more likely to be emotionally reactive, showing stress-related increases in anxiety, stress, and tension, and decreases in positive emotions. Low-dominant individuals were simultaneously characterized by elevated cardiovascular reactivity in some of these cases (e.g., Hughes and Callinan, 2007), but not all (e.g., Sieverding et al., 2005). Overall, this pattern of results is consistent with a more general finding that dominance-related constructs (e.g., agency and instrumentality) are protective of mental and emotional health, while simultaneously being associated with increased risk for poorer physical health (Helgeson, 1994).

Because the majority of stress studies assessed cardiovascular reactivity to brief social stressors, implications for cardiovascular disease status must be focused on the connections between dominance and submissiveness and acute responses to social challenges. Little information is available about the recurrence or persistence of these cardiovascular responses over time, with the exception of two studies revealing that trait dominance is associated with more complete blood pressure recovery among men (Gramer, 2003; Sieverding et al., 2005), but attenuated blood pressure recovery among women (Sieverding et al., 2005). Also, for men and women, interacting with a dominant partner is associated with attenuated blood pressure recovery (Gramer and Berner, 2005). Furthermore, only two studies employed impedance cardiography (Allen et al., 1993; Nealey et al., 2002) and thus the relative contributions of myocardial versus vascular processes to dominance-associated stress reactivity remains largely unexamined. Nonetheless, prospective, longitudinal studies implicate acute stress-related blood pressure reactivity per se in important biological endpoints, such as the development of coronary artery calcification (Matthews et al., 2006). Thus, the acute blood pressure elevations that characterize dominant individuals when they encounter social circumstances that activate motives to exercise control and influence, or that are perceived as dominance challenges, may have implications for the eventual emergence of cardiovascular disease endpoints.

3.5. Gender-specific patterning

Although a highly diverse set of laboratory paradigms was used to evaluate connections between dominance/submissiveness and cardiovascular reactivity, it is through this diversity that a more general, potentially unifying pattern emerges. Specifically, gender-specific patterning is apparent when connections generated by socially relevant stressors are compared with those generated by dyadic social interaction stressors.

Considering men's patterns first, trait dominance among men is consistently positively related to elevated blood pressure reactivity during dyadic social interactions. This is true whether the interaction is with another man or with another woman, and whether men are acquainted or unacquainted with their interaction partners. Moreover, dominant men show elevated blood pressure while simply anticipating a social interaction and, during actual interactions, the presence of another highly dominant man is a specific trigger for heightened blood pressure responses. In contrast, with respect to socially relevant stressors, low-dominant men were just as likely as high-dominant men to exhibit elevated cardiovascular reactivity.

What might explain this pattern? It may be illuminating to conceptualize dominance (and submissiveness) as personality traits that are characterized by "biological sensitivity to context" (Boyce and Ellis, 2005, p. 271). According to Boyce and Ellis (2005), such "biological sensitivity" is a manifestation of a neurobiological mechanism that attunes organisms to context, especially social context, in the service of promoting adaptation to the social world. This model reconceptualizes "...exaggerated reactivity as context sensitivity" (Boyce and Ellis, 2005, p. 272).

In this framework, men with high levels of trait dominance appear to be "biologically sensitive" to situations that involve formation, maintenance, or management of a social dominance hierarchy. Essentially, interactions between two previously unacquainted individuals constitute a dyadic social group without an established dominance hierarchy. In such situations, social rank ordering begins immediately and automatically, as individuals "size up" the dominance capacity of one another and initiate the process of forming hierarchical relationship structures (Kalma, 1991). Efforts in this regard appear to be particularly pronounced for dominant men, and especially so when they are interacting with another dominant man, who would presumably also be striving to establish control and influence. In dyads composed of previously acquainted partners, a situation in which there may be an established dominance hierarchy, the socioemotional task becomes maintaining and managing, rather than establishing, and the hierarchy. In contrast, such socioemotional processes would presumably not be activated during socially relevant stressors that primarily involve individual performance (e.g., speech tasks) or that involve interactions with an experimenter that are highly structured and scripted and therefore are already characterized by strong situational constraints.

Among women, in contrast, an opposite pattern is apparent. Although not entirely uniform, trait dominance is consistently, positively associated with elevated cardiovascular reactivity during socially relevant stressors, but less so during social interactions between unacquainted partners. Thus, trait dominance is clearly relevant for activating women's stress responses, but this is more likely to occur in situations that entail socially relevant individual performance, rather than those that involve formation of a social dominance hierarchy.

This female pattern is reminiscent of behavioral patterns that have been observed among women in opposite-sex task-oriented dyads. Specifically, when women are paired with men for laboratory task-oriented interactions, dominant women by and large do not typically assume leadership roles (Lips and Keener, 2007; Nyquist and Spence, 1986). In fact, in these situations, low-dominant men are more likely than high-dominant women to exhibit leadership behaviors. Similarly, dominant women exhibit significantly fewer dominance behaviors in the context of men versus women (Klein and Willerman, 1979).

The present review did, however, reveal circumstances where dominant women exhibit elevated cardiovascular responses during opposite-sex social interactions. Specifically, in dyads composed of previously acquainted partners, women's trait dominance was significantly and positively associated with systolic blood pressure reactivity (Gramer and Berner, 2005). Participants, however, were given explicit instructions to persuade their partners. In contrast, in the social interaction stressors involving unacquainted dyads, participants were given instructions only to arrive at a mutual

decision about the best ways to solve the problem at hand (Newton et al., 1999). Thus, although both studies employed opposite-sex dyads, they differ in terms of whether the social interaction stressor was characterized by expectations to behave dominantly. Notably, when there are explicit expectations to be dominant and assertive, women in mixed-sex interactions express just as much behavioral dominance as do women in same-sex interactions (Klein and Willerman, 1979), an effect that appears to extend to cardiovascular correlates of dominance. It is also possible, of course, that familiarity with one's male interaction partner, which differed across these studies, contributed to the differential pattern of results.

These accounts do not address the absence of associations between women's trait dominance and cardiovascular reactivity in same-sex dyads (Newton et al., 2005), but other gender-related factors may be operating here. For example, although both all-male and all-female groups are characterized by the development of dominance hierarchies, the timing of this process varies by gender composition of the group (Mast, 2002). In all-male groups hierarchies form early and immediately during the interaction (i.e., during the first 8 min), whereas, in all-female groups, hierarchies appear much later (i.e., up to 35 min into the interaction). The same-sex dyadic interactions at question in the present paper were 4 min in duration. Perhaps they were too brief for women to have begun the formation of a dominance hierarchy, and for associations between women's trait dominance and cardiovascular reactivity to emerge (Newton et al., 2005).

In sum, through the diversity of laboratory paradigms used to evaluate linkages between dominance and cardiovascular responses, gender-specific patterns were revealed. Men's pattern can be characterized by a stable sensitivity that emerges primarily in social settings that involve formation and maintenance of a dominance hierarchy. Women's pattern, in contrast, is characterized by a variable sensitivity, emerging in socially relevant individual performance situations, social settings where situational expectations explicitly support the use of dominance and persuasion, but not in social settings without such explicit expectations.

What are the origins of these gender-related patterns? In terms of proximal origins, it has been suggested that women's communal orientation, which tends to be greater than that of men's, may conflict with motives to control, persuade, and express dominance (Smith et al., 1996; Twenge, 1997). That is, dominant women who are simultaneously motivated to foster relationship warmth and harmony may restrain their tendencies to control and influence with the goal of maintaining relationship cohesiveness. Because this process would be expected to occur only during actual social interactions, rather than during socially relevant but individual achievement stressors, it could conceivably contribute to the gender-specific patterning apparent in the present review.

In terms of distal origins, gender-specific developmental experiences should be considered. For example, it has been proposed that, on average, males and females have different socialization experiences with regard to the hierarchical power domain (Maccoby, 1990). Social interactions organized around power and dominance hierarchies are more common among young men than among young women and occur primarily within same-sex interactions (Maccoby, 1990). Thus, gender-linked experiences may differentially calibrate dominance traits in men and women, and culminate in gender differences in the way high-dominant individuals appraise and respond to social interactions. Given their early developmental experiences, highly dominant men, compared to highly dominant women, may develop an automatically activated biological sensitivity with respect to social contexts that involve formation of social hierarchies, particularly in the presence of others who are also striving for control. The sensitivity of high-dominant women, in contrast, may be activated only in the context of explicit situational expectations for dominance, rather than automatically.

4. Directions for future research

The interpersonal domain of hierarchical power is of significance for human cardiovascular functioning, whether assessed as disease status or stress responsivity. As a whole, this body of research has focused more on the assessment of dominance than of submissiveness per se. Although, according to the circumplex model, these interpersonal stances they fall on opposite ends of the same interpersonal dimension, they are each characterized by a unique set of motives and behaviors. Similarly, although these interpersonal stances are both activated in the service of navigating the social domain of hierarchical power, they are likely to be associated with very different routes to adaptation. Thus, future research should incorporate independent assessments of both dominance and submissiveness. The potential importance of this is highlighted by studies that specifically assessed submissiveness and observed associations with heightened cardiovascular responses, and also by studies that observed elevated cardiovascular reactivity among low-dominant individuals.

As discussed in the introductory section on measurement, the most comprehensive assessment of the hierarchical power domain will include trait, behavioral, and social rank indicators of dominance/submissiveness. In the present review, no human study that employed all three indicators, along with assessing cardiovascular stress reactivity/recovery, was identified. Most neglected are the social rank assessments which, in the animal literature, have emerged as particularly robust correlates of a range of physiological and health-related outcomes (Abbott et al., 2003; Cohen et al., 1997; Hamm et al., 1983; Kaplan et al., 1984).

One study of married couples suggests that marital conflict interactions may be a promising paradigm for assessing social rank in terms of outcomes of short-term conflict situations (Newton and Sanford, 2003). In this study, raters observed videotapes of husbands and wives discussing specific areas of disagreement (e.g., housework or finances) and rated, for each spouse, the degree to which he or she was likely to prevail in the disagreement. Results illustrated that it is possible, within a simple human dyadic interaction, to reliably identify and differentiate likely winners and losers in a marital conflict. Specifically, spouses seeking change in their partner with regard to a specific area of marital disagreement were rated as less likely to prevail than were spouses defending the marital status quo. Further, these differences in social rank (i.e., seeking change or defending the status quo) moderated associations between blood pressure reactivity and negative behavior during the marital conflict interaction; among couples who showed high levels of negative conflict behavior, spouses seeking change (who were viewed as less likely to prevail) showed significantly greater blood pressure reactivity than did spouses defending the status quo (who were viewed as more likely to prevail). Thus, as assessed within the circumscribed domain of a specific marital disagreement, "social rank" is a significant moderator of spouses' cardiovascular stress reactivity.

The potential importance of marriage and intimate relationships as a relevant context for the study of stress and hierarchical power was foreshadowed by the study of Carmelli et al. (1985), and reiterated by Brown et al. (1998), who showed explicitly that judgments about relative spouse dominance predict cardiovascular responses measured during discussions between husbands and wives. More broadly, marital quality has implications for a broad array of health consequences, including cardiovascular disease outcomes (Kiecolt-Glaser and Newton, 2001). Of note is a

recent study that examined specific aspects of marital functioning as predictors of total mortality over the course of 10 years (Eaker et al., 2007). Although this study did not assess dominance or submissiveness per se, it measured participants' perceptions of the degree to which they "self-silence," or fail to speak up during marital conflicts, a characteristic that is reminiscent of submissive behavioral strategies that are used to de-escalate potential conflict (Allan and Gilbert, 2002; Gilbert, 2000). Although husbands reported more frequent use of self-silencing than wives, self-silencing was related to mortality only among wives, quadrupling the risk of death during the 10-year follow-up period.

Although the disease status and cardiovascular stress reactivity research literatures are each compelling on their own, efforts to empirically test the presumed connections between them are needed. The use of impedance cardiography would be helpful in this regard in order to more precisely evaluate whether specific hemodynamic profiles characterize dominant versus submissive adaptations to acute psychological stressors. In addition, in humans, the domain of hierarchical power has also been associated with other physiological response systems that deserve consideration, including the gonadal endocrine hormone testosterone, the adrenal endocrine hormone cortisol, and serotonergic functioning.

In humans, testosterone measured in either saliva or serum has been associated with various aspects of the domain of hierarchical power, although the pattern of association across studies is highly variable. With regard to personality traits, some studies reveal positive associations between basal testosterone concentrations and trait measures of dominance in adult men (Gray et al., 1991) and women (Grant and France, 2001). One study of male adolescents that differentiated positive (i.e., leadership/popularity) and negative (i.e., aggressiveness) aspects of dominance revealed that salivary testosterone concentrations were positively associated with leadership, but negatively associated with aggressiveness (Schaal et al., 1996). Based upon this differentiation, the authors suggested that heightened testosterone is a biological marker of dominance that confers social success and attractiveness, at least among adolescent males. Other studies, in contrast, have observed positive associations between aggressiveness and testosterone (Harris et al., 1996), and yet others reveal non-significant associations between testosterone and dominance-related personality traits (Josephs et al., 2006).

Beyond personality traits, testosterone may also respond to the social rank aspect of the hierarchical power domain (i.e., winning versus losing in sports competitions or dyadic laboratory competitions). Again, however, the pattern of results is mixed. Some studies observed that testosterone concentrations increase among winners, and decrease among losers, whereas others observed no significant associations between testosterone and social rank indexed by winning and losing (Dabbs, 1992; Schultheiss et al., 1999). Measurements of individual differences in power motives may help clarify these conflicting results; following a laboratory competition task, only men high in personal power motives and low in prosocial motives exhibited elevated testosterone following winning (Schultheiss et al., 1999). Thus, clearer patterns may emerge if both personality and situational factors are incorporated into explanatory models.

In a separate empirical literature, men's endogenous basal testosterone concentrations have been linked with mortality and morbidity, including endpoints due to cardiovascular disease, with low levels being generally associated with poorer outcomes (Basaria and Dobs, 2007). For example, in a recent prospective investigation, low levels of testosterone were associated with significantly elevated risk of mortality due to cardiovascular causes during a 6–10-year follow-up of men 40–79 years of age (Khaw et al., 2007).

Taken together, these research findings suggest that testosterone is a plausible candidate for a biological mediator connecting dimensions of the hierarchical power domain with cardiovascular disease outcomes. The findings indicate, however, that any mediational role served by testosterone will not be simple and straightforward. For example, while dominance-related personality traits are associated with high levels of testosterone in some studies, the emerging literature on disease outcomes suggests that it is low levels of testosterone that confer risk for poorer health status. Speculatively, if testosterone rises in response to winning social competitions, as suggested by some studies, then basal testosterone concentrations may in part be reflective of social status, with higher levels indicating higher social status or social success, and vice versa (Josephs et al., 2006; Mazur and Booth, 1998). Studies that incorporate assessments of multiple aspects of the hierarchical power domain, testosterone, and disease outcomes will be necessary to begin to address such questions.

Connections between the hierarchical power domain and functioning of the hypothalamic-pituitary axis have been well documented in studies of non-human primates (Abbott et al., 2003). For example, in tufted capuchins, submissiveness and related traits (tense, apprehensive and fearful) were positively correlated with cortisol reactivity to acute separation stress, whereas traits related to confidence were negatively related to cortisol reactivity (Byrne and Suomi, 2002). Among humans, however, the empirical literature is limited. In a study of men exposed to an acute laboratory stressor, a personality profile characterized by low dominance and by insecurity and perceptions of external control was associated with heightened cortisol reactivity (Pruessner et al., 1997). Thus, tentatively, personality traits related to submissiveness appear to be positively related to cortisol reactivity to acute stressors. Such associations may, in addition, be moderated by the social rank aspect of the hierarchical power domain. Specifically, in a laboratory task in which participants competed in pairs, those low on power motivation showed elevated cortisol responses after the competition, but only when they won (Wirth et al., 2006). Conversely, individuals high on power motivation showed elevated cortisol responses only after losing. Thus, as reflected in cortisol responses, individuals with a high need for dominance are reactive to losses in social status, whereas those with a low need for dominance are reactive to gains in social status. As with testosterone, both personality and situational factors related to the domain of hierarchical power appear to interact in explaining cortisol responses to stressful social interactions.

While the broad significance of corticosteroids, including cortisol, for successful functioning of many biological systems and is well-known and well-documented (Chrousos and Kino, 2007), data linking cortisol stress responses specifically to cardiovascular disease outcomes are more limited. Two recent studies, however, provide suggestive evidence. In one study, cortisol levels assessed under conditions of anticipatory stress (i.e., immediately prior to undergoing coronary angiography) were significantly and positively associated with severity of coronary artery disease, indexed as the number of coronary vessels with stenosis equal to or exceeding 50% (Alevizaki et al., 2007). In the other study, women with acute coronary syndrome who were found to have coronary stenosis equal to or exceeding 50% in at least one coronary artery were characterized by significantly higher basal serum cortisol concentrations compared to women who did not meet this diagnostic threshold (Koertge et al., 2002). Thus, as with testosterone, preliminary evidence suggests that cortisol deserves consideration in future research as a potential biological mediator connecting aspects of the hierarchical power domain to cardiovascular disease outcomes.

Finally, there is evidence that the serotonergic system is associated with behavioral indicators of dominance/submissiveness and, in one study, preclinical indicators of cardiovascular disease. These associations have been tested using two general approaches: serotonin manipulation, and evaluation of serotonergic functioning. The first approach, serotonin manipulation, involves administration or depletion of tryptophan, a serotonin precursor, or administration of selective serotonin reuptake inhibitors (SSRIs). The second approach, evaluation of serotonergic functioning, involves acute administration of serotonin agonists and subsequent assessment of effects on neuroendocrine probes (Yatham and Steiner, 1993).

With regard to social behaviors, a 2-week SSRIs administration to healthy young adults decreased behavioral submissiveness, and increased behavioral indicators of dominance, compared to administration of placebo (Tse and Bond, 2002). Furthermore, a 12-day administration of tryptophan increased the frequency of healthy adults' reports of dominant behavior during daily social interactions, compared to frequency of reports made during a placebo-control phase (Moskowitz et al., 2001).

With regard to cardiovascular disease, one recent study reported that serotonergic functioning was significantly associated with carotid artery thickening (Muldoon et al., 2007). More specifically, blunted serotonergic responsivity predicted greater maximum intima media thickness of the carotid artery. It has been suggested that cardiovascular stress reactivity may partially mediate this association because the serotonergic system plays a role in orchestrating stress reactivity (Williams, 2007). Despite the current paucity of data, connections among the serotonergic system, stress reactivity, and cardiovascular disease outcomes as they pertain to the domain of hierarchical power deserve examination, particularly because this pathway lends itself to potential interventions.

In closing, the present review reveals a rich pattern of associations between cardiovascular functioning and the interpersonal domain of hierarchical power, particularly as expressed in individual differences in dominance and submissiveness. Future research should emphasize incorporating behavioral, trait, and social rank indicators of the hierarchical power domain, exploring these processes in life domains that are already well-known to have implications for stress and health but that have not been well-characterized in terms of the contributions of hierarchical power (e.g., marriage), and expanding the measurement of potential physiological mediators to include gonadal and endocrine hormones, and serotonergic functioning, systems that have been implicated in hierarchical power and health outcomes. Further, this review underscores the importance of developing and testing gender-specific models of hierarchical power, stress, and disease.

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