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# Lonely traits and concomitant physiological processes: the MacArthur social neuroscience studies

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**Abstract**

Loneliness is a complex set of feelings encompassing reactions to unfulfilled intimate and social needs. Although transient for some individuals, loneliness can be a chronic state for others. Prior research has shown that loneliness is a major risk factor for psychological disturbances and for broad-based morbidity and mortality. We examined differences between lonely and socially embedded individuals that might explain differences in health outcomes. Satisfying social relationships were associated with more positive outlooks on life, more secure attachments and interactions with others, more autonomic activation when confronting acute psychological challenges, and more efficient restorative behaviors. Individuals who were chronically lonely were characterized by elevated mean salivary cortisol levels across the course of a day, suggesting more discharges of corticotropin-releasing hormone and elevated

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activation of the hypothalamic–pituitary–adrenocorticol axis. An experimental manipulation of loneliness further suggested that the way in which people construe their self in relation to others around them has powerful effects on their self concept and, possibly, on their physiology. 

*Keywords:* Loneliness; Heart rate; Salivary cortisol; Blood pressure; Cardiovascular reactivity; Socially embedded

## 1. Introduction

Humans are social animals, so much so that a basic 'need to belong' has been posited (Baumeister and Leary, 1995; Gardner et al., in review; Gardner et al., in press). People form associations and connections with others from the moment they are born. The very survival of newborns depends on their attachment to and nurturance by others over an extended period of time. It should be no surprise that evolution has sculpted the human genome to be sensitive to and succoring of contact and relationships with others. For instance, caregiving and attachment have hormonal (e.g. Uvnäs-Mosberg, 1997) and neurophysiological substrates (cf. Carter et al., 1997). Communication, the bedrock of complex social interaction, is universal and ubiquitous in humans. In the rare instances in which human language is not modeled or taught, language develops nevertheless (e.g. Goldin-Meadow and Mylander, 1983, 1984).

The need to belong does not stop at infancy but rather affiliation and nurturant social relationships appear to be essential for physical and for psychological well-being across the lifespan. Disruptions of social connections, whether through ridicule, separation, divorce, or bereavement, are among the most stressful events people must endure (Gardner et al., in press). Berkman and Syme (1979), for instance, operationalized social connections as marriage, contacts with friends and extended family members, church membership, and other group affiliations. They found that adults with fewer social connections suffered higher rates of mortality over the succeeding 9 years even after accounting for self-reports of physical health, socioeconomic status, smoking, alcohol consumption, obesity, race, life satisfaction, physical activity, and preventive health service usage. House et al. (1982) replicated these findings using physical examinations to assess health status. In their review of five prospective studies, House et al. (1988) concluded that social isolation was a major risk factor for morbidity and mortality from widely varying causes. This relationship was evident even after statistically controlling for known biological risk factors, social status, and baseline measures of health. The negative health consequences of social isolation were particularly strong among some of the fastest growing segments of the population: the elderly, the poor, and minorities such as African-Americans. Astonishingly, the strength of social isolation as a risk factor was comparable to smoking, high blood pressure, obesity, and sedentary lifestyles.

Social isolation and loneliness are associated with poorer mental as well as physical well-being (e.g. Perkins, 1991; Gupta and Korte, 1994; Ernst and Cacioppo, 1999). Conversely, people who report having contact with five or more intimate friends in the prior 6 months are 60% more likely to report that their lives are 'very happy', as compared to those who do not report such contact (Burt, 1986). People appear to be cognizant of the importance of social relationships. When asked 'what is necessary for happiness?' most rated relationships with friends and family as being the most important factor (Berscheid, 1985).

Although social isolation is multi-dimensional, it generally appears that the intimacy and emotional nourishment provided by at least one other individual are key to buffering the effects of the majority of stressors. In their seminal review, House et al. (1988) concluded that:

> ... the mere presence of, or sense of relatedness with, another organism may have relatively direct motivational, emotional, or neuroendocrinal effects that promote health

either directly or in the face of stress or other health hazards but that operate independently of cognitive appraisal or behavioral coping and adaptation (p. 544).

Our goal here is to provide a preliminary report of an ongoing study of the psychological and physiological differences between individuals differing in social embeddedness. Although there are gripping states of loneliness that everyone experiences transiently in specific circumstances or interactions, some individuals live in the devastating clutches of loneliness even though they are not physically and socially isolated. Our target sample was college undergraduates because (a) this is an active period of dating, mate selection, and sexual activity; (b) habitual patterns of health behaviors and of interacting with others are being established; and (c) social relationships undergo an upheaval when individuals first go to college yet ample opportunities exist for making new acquaintances and friends.

## 2. Loneliness on college campus

We tested 2632 male and female undergraduates at the Ohio State University to determine their feelings of loneliness and their living circumstances. Loneliness was unrelated to various features of college life such as the number of roommates with whom they lived, the percent who belonged to organizations, the number of quarters of college completed, the number of hours in college in which they were enrolled, the number of quarters needed to graduate, and the number of hours they exercised weekly. Despite these superficial similarities, lonely individuals clearly felt less connected to the people around them. Loneliness, for instance, was negatively correlated with the extent to which roommates reduced feelings of isolation, and positively related to feelings of dysphoria and fears of public speaking. Lonely individuals rated their primary roommate less positively than embedded individuals, and lonely individuals who lived in dormitories reported having fewer positive relationships with suitemates, floormates, and hallmates than embedded individuals.

Lonely individuals were slightly though significantly less likely to consume alcohol than socially embedded (i.e. low in loneliness) individuals — a result that is consistent with a study reported recently by Eccles et al. (1997). They conducted a 6-year study of teens' free-time activities, academic performance, and alcohol use in 1259 10th graders from 12 school districts around Detroit. They found that high school athletes had higher grades and stayed in college longer but were also more likely to use alcohol and drugs. The authors noted that athletes tend to form popular cliques who party, and alcohol is part of that entertainment. The same appears true of socially connected students in college.

We recruited approximately 5% from our original sample of 2632 students for more intensive follow-up study. Inclusion criteria included their being enrolled in at least 6 credit hours in the quarter they were tested, none were first quarter freshman or last quarter seniors, none scored higher than mildly dysphoric on the Beck Depression Inventory, none were obese (body mass index $< 27$), none were speech or needle phobic, none were married or living with a significant other, and all were US citizens. We recruited an equal number of male and female students whose scores on the UCLA loneliness scale (Russell et al., 1980) fell into the top (lonely group), middle (normal group), or bottom quintile (socially embedded group). The middle group was included to allow us to determine whether differences between lonely and socially embedded reflected something special about lonely individuals, something unique about embedded individuals, or something that varied monotonically between these two extreme groups.

## 3. Differences in social capital

We first examined the hypothesis that individuals who were lonely simply had less social capital to offer than others. By social capital, we mean the resources they bring to a social interaction — their physical attractiveness, intelligence, height, weight, age, socioeconomic status, or scholastic

achievements. Analyses revealed the groups did not differ on any of these variables.

We next examined the hypothesis that individuals who were lonely reported more traumatic life histories, were dealing with more major life events, or were suffering from more intrusive events. Again, no differences were found among the groups. Instead, the differences among groups were in the way they appraised people and events around them and the way in which they related to others. For instance, lonely individuals reported higher levels of perceived stress, more frequent and more severe hassles, and less severe uplifts than embedded individuals. The lonely and normal participants responded similarly on most of these measures, however, it was the socially embedded group who appeared the least stressed. The same pattern was found on the Profile of Moods States, which revealed embedded individuals reported feeling more vigor and less tension, hostility, confusion, fatigue, and dejection than the normal and lonely groups; of these states, the normal and lonely individuals differed only on feelings of dejection.

The social world also emerged as a less rewarding place for lonely individuals. Lonely relative to embedded individuals, reported comparable social desirability motives but had less secure adult romantic attachment styles. Lonely individuals were also characterized by greater anxiety, anger (including anger-in), and shyness, less sociability, less optimism, and poorer social skills, and they expressed stronger fears of negative evaluation. Lonely individuals were no less assertive than embedded individuals in terms of the likelihood of a behavior, but they reported much higher levels of discomfort and anxiety about being assertive.

This does not mean that lonely individuals do not know how to interact socially; they do so fairly well with their most important contact (though less well with their most frequent contact). Several different measures revealed that lonely, relative to embedded, individuals were more likely to attribute problems in social relationships to others, to view themselves as victims who are already giving as much as they can to their relationships with others. The normal group generally fell between the lonely and embedded groups on these measures.

What happens when you draw upon social capital? Does seeking social support and assistance draw down the balance subsequently available, like a bank account, or does it renew itself through mutually reinforcing interactions? The latter was suggested when we found that lonely individuals drew less upon social capital than normals and embedded individuals. To examine how our participants generally coped with stressors in their lives, we had the participants complete the COPE scale (Carver et al., 1989). The COPE contains 15 subscales of four items each: active coping, planning, seeking instrumental social support, seeking emotional social support, suppression of competing activities, religion, positive reinterpretation and growth, restraint coping, acceptance, focus on venting of emotions, denial, mental disengagement, behavioral disengagement, alcohol/drug use, and humor. The groups were found to differ on four of these subscales: lonely individuals were less likely to actively cope, seek instrumental support from others, or seek emotional support from others and were more likely to behaviorally disengage than were embedded individuals. Apparently, the balance of social capital is not governed like bank accounts, with the total available decreasing with each request for assistance. Instead, they suggest that being a friend in need, especially when the assistance is effective and duly appreciated, may build closer ties between the helper and requester.

## 4. Differences in autonomic activation

If anxiety and anger are especially powerful in lonely individuals, then they might be expected to show greater autonomic activation than embedded individuals. If, however, behavioral or emotional disengagement from the social environment is especially powerful in lonely individuals, then they might be expected to show less autonomic activation than embedded individuals. To examine this issue, participants were tested at the

General Clinical Research Center at The Ohio State University Hospitals at approximately the same time in the late afternoon.

Participants completed two social speeches (e.g. asking someone out for a date, describing why you're a likable person), two non-social speeches (e.g. describing the objects in the room, describing the route from your residence to your first class of the week), and a mental arithmetic task (Cacioppo et al., 1995). These five tasks were randomly ordered for each participant. Before each speech task there was a 2-min sitting rest period, and preceding the verbal mental arithmetic task there was a 4-min sitting rest period. The experimental tasks then concluded with the orthostasis task followed by a 4-min sitting rest period and a speech task about one being accused of shoplifting (Saab et al., 1989).

The results, which are displayed in Fig. 1, revealed that across tasks the lonely individuals were characterized by lower basal heart rate and lower heart rate reactivity than normal or embedded individuals. Basal blood pressure was comparable across the tasks, although again cardiovascular reactivity tended to be lowest for the lonely individuals. These data are consistent with the notion that lonely individuals are more emotionally withdrawn than normal or embedded individuals when in a new social setting.

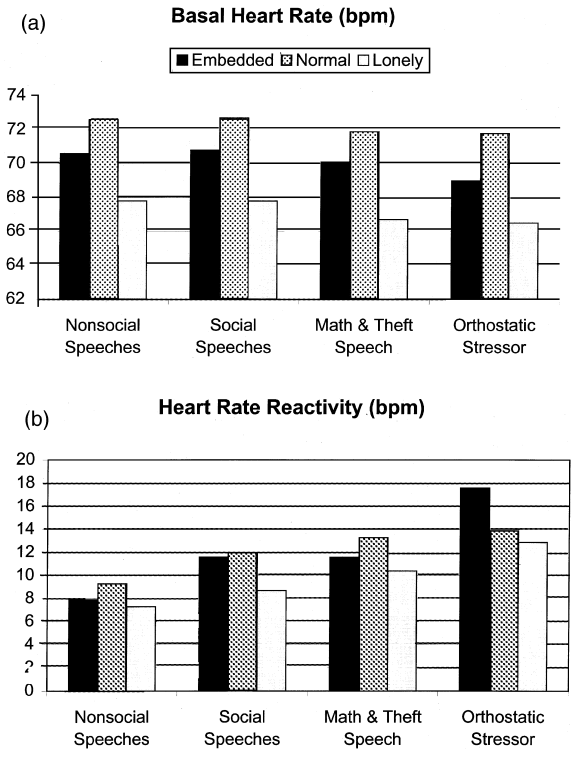


Fig. 1. Basal heart rate (a) and heart rate reactivity to four classes of stressors (b).

## 5. Differences in attentional control

Why might lonely individuals be more emotionally withdrawn in new social settings? Personality differences such as shyness, sociability, negativity, and fear of negative evaluation provide a partial explanation. New social settings can be overwhelming, however, and people must exert voluntary control over their attentional focus to be effective. Do lonely individuals differ in their ability to voluntarily control their attentional focus?

To explore this possibility, participants performed a dichotic listening task (Hugdahl, 1995) while at the Clinical Research Center. The dichotic listening task requires that participants identify the consonant–vowel pair that was presented to their right or left ear. Because the auditory system is predominantly crossed and because language is left-lateralized in most right-handed individuals, right-handed individuals tend to perform better when verbal stimuli are presented to the right than left ear. (All of the participants in our sample were right-handed.) Superimposed on this general right-ear advantage, however, are the effects of attention, as individuals generally perform better whenever verbal stimuli are presented to the ear to which they are focusing their attention, as well.

As expected, there was an overall right-ear advantage across groups and instructional conditions (see Fig. 2). In addition, a significant main effect for attentional instruction showed that individuals performed better with left-ear stimuli when they were instructed to focus on stimuli presented to their left ear than in the other conditions. The two-way interaction between at-

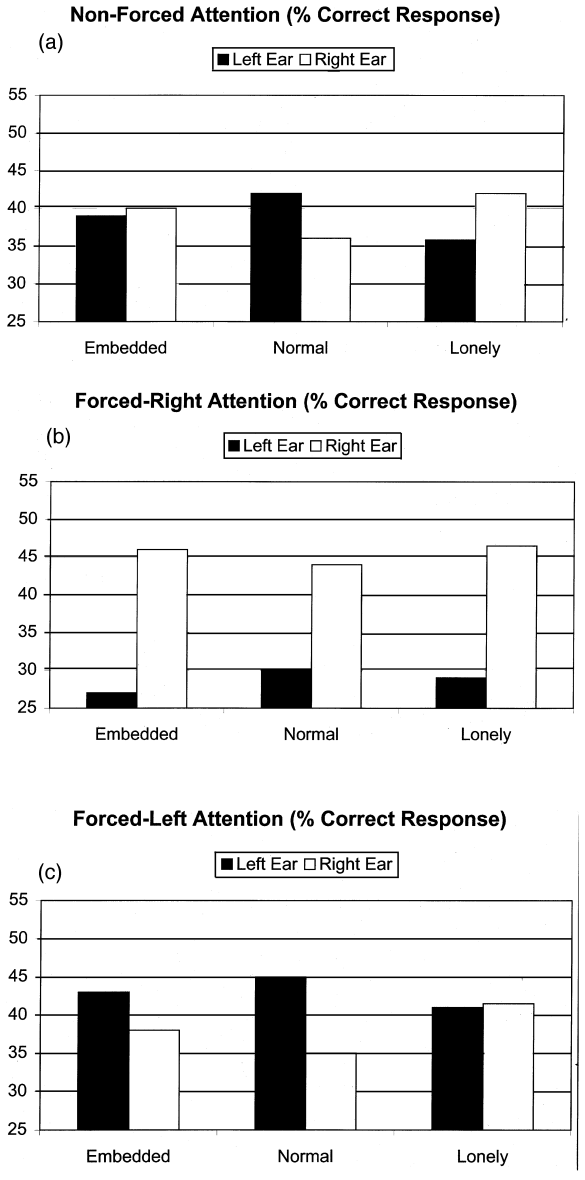


Fig. 2. Dichotic listening performance under no attentional instructions (a), instructions to attend to the right ear (b), and instructions to attend to the left ear (c).

tentional instruction and ear was also significant, showing a significant right-ear advantage during the no-instruction and focus on right-ear conditions and a significant left-ear advantage during the focus on left-ear condition.

As can also be seen in Fig. 2, lonely individuals tended to show the strongest right-ear advantage in the no-instruction condition, presumably reflecting the potency of bottom-up (i.e. stimulus-driven) attentional processing. More interestingly, lonely individuals apparently failed to shift to an a priori predicted left-ear advantage in the focus on left-ear condition, despite showing a large right-ear advantage when instructed to shift attention to the right ear. Specific planned contrasts confirmed that all three groups showed a significant right-ear advantage during the focus on right-ear condition, but only the normal and embedded individuals were able to revert to a significant left-ear advantage in the focus on left-ear condition. Thus, attentional control appeared comparable in lonely and embedded individuals until voluntary attentional control conflicted with automatic attentional processes, at which point lonely individuals showed an attentional deficit. This result raises the possibility that lonely individuals feel overwhelmed and withdraw from the social environment, especially new or complex social environments, because they have less control over the focus of their attention (i.e. they are more distractable).

## 6. Differences in neuroendocrine activation

As noted above, a major objective in this study was to explore potential mechanisms underlying the relationship between social isolation and morbidity and mortality. Our data indicated that lonely, relative to embedded, individuals engaged in comparable or better health behaviors (e.g. cigarette smoking, alcohol consumption, drug abuse, and exercise). Autonomic reactivity to acute psychological stressors also tended to be diminished in lonely, relative to embedded, individuals. Prior research has shown autonomic activation to vary with the quality of a person's social relationship with others, but this prior research has tended to use either more powerful manipulations of social relationships (see review by Gardner et al., in press) or older individuals for whom the cumulative stress of loneliness is higher (see review by Uchino et al., 1996). Thus, both health behaviors and heightened sympathetic tonus remain possible contributors to differences

in morbidity and mortality in later life, but these do not play much of a role in young adults.

Given the behavioral and autonomic evidence that lonely individuals disengage from the social environment and the suggestive evidence of their relative inability to override automatic attentional processing, we hypothesized that lonely individuals would show either elevated tonic activation of the hypothalamic–pituitary–adrenocortical system or a muted diurnal pattern. If so, this would provide a potential neurophysiological link between loneliness and later-life morbidity and mortality because the pituitary and adrenal hormones and other neuropeptides play an important role in the modulation of the immune system (Munck et al., 1984).

Cortisol is released in a pulsatile fashion, with major secretory episodes appearing during the early morning with the frequency and amplitude of secretory episodes declining over the course of the day (Van Cauter, 1990). Given the pulsatile nature of cortisol releases, multiple assessments over the course of the day may provide a more reliable assessment of HPA activity. Participants in our study were beeped at nine random intervals during a normal day, at which time they were asked to sit, place a roll of dental cotton in their mouth, and complete a short questionnaire. After each such period, the cotton roll was returned to a test tube, which participants returned to us the following day. Subsequently, assays were performed to quantify salivary cortisol, which is unbound (biologically active) and correlates well with plasma and urinary assessments (Kirschbaum and Hellhammer, 1994).

The salivary cortisol levels across the day, which are depicted in Fig. 3, reflected the typical diurnal rhythm, with no differences among groups. Spearman correlations revealed that the mean daily cortisol level was significantly correlated with the participants' perceived stress as well as the number of major life events with which they were dealing. Loneliness was related to mean salivary cortisol levels across the course of a normal day but only when loneliness was chronic. UCLA loneliness scores and state loneliness scores were positively but non-significantly correlated with mean salivary cortisol levels, whereas trait loneliness scores were positively and significantly correlated with mean cortisol levels. The stress of loneliness and associated events may simply take time to alter HPA function.

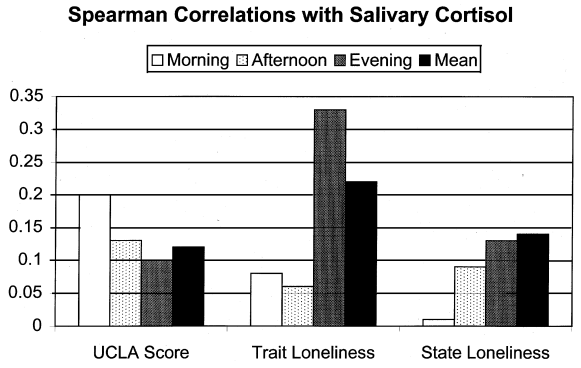


Fig. 3. Spearman correlations between salivary cortisol and three different measures of loneliness. Salivary cortisol was assayed up to nine random times during a normal day. 'Morning' represents the correlation between the mean cortisol during the morning and each loneliness measure. Similarly, 'Afternoon' and 'Evening' represent the correlation between the mean cortisol during the afternoon and evening, respectively, and each loneliness measure. 'Mean' represents the correlation between the mean salivary cortisol across the entire day and each loneliness measure.

Our participants attended classes during the morning and afternoon but were left to their own devices in the evenings. Students study during the evening but this is also the most popular time for students to socialize or to think about the absence of satisfactory social interactions. Inspection of Fig. 3 reveals that it was during the evening that our participants' trait loneliness was most highly related to salivary cortisol levels despite HPA activity being at its nadir during the evening.

## 7. Differences in the salubrity of sleep

The salubrity of nourishing social relationships has been documented previously, but the beneficial effects of nurturant or intimate social relationships are usually attributed to direct assistance or stress-buffering (Cohen and McKay, 1984; see Gardner et al., in press). For example, medical students undergoing exams showed stress-induced decrements in immune function-

ing, but this decline was particularly pronounced for the medical students who reported being lonely (Kiecolt-Glaser et al., 1984; Glaser et al., 1992). The association between trait loneliness and salivary cortisol, particularly in the evening, could be explained in terms of stress buffering or direct effects of social support. Preliminary analyses of diaries completed at random intervals by participants during the course of their day suggested yet another possible means by which social embeddedness contributes to lower levels of salivary cortisol and long-term well being.

We had anticipated that lonely individuals would be socially isolated and would be participating in fewer restorative behaviors (e.g. sleep, exercise, going to the movies, spending time with others, reading, relaxing, praying or meditating). In fact, lonely undergraduates were just as or more likely to engage in these putatively restorative acts than were normal and embedded individuals. Yet they did not show the salubrious effects normals and socially embedded individuals seemed to show. This led us to hypothesize that restorative behaviors were more potent (i.e. salubrious) when individuals felt socially connected than when they felt lonely.

To test the hypothesis that feeling socially embedded enhanced the salubrious effects of restorative behaviors, we measured sleep — a quintessential act of restoration that is performed without immediate social contact, indeed without much explicit awareness at all. Survey data indicated that lonely individuals slept as many hours per day as normal and socially embedded individuals. We used the Pittsburgh Sleep Quality Index (PSQI; Buysse et al., 1989) to assess our participants' reports of sleep disturbances, and we used the Nightcap to measure sleep of a subset of our participants during the night they spent in the Clinical Research Center.

Results from the PSQI, which are depicted in Fig. 4, revealed that lonely individuals reported poorer sleep quality, longer sleep latency, longer perceived sleep duration, and greater daytime dysfunction due to sleepiness than embedded individuals. Data from the Nightcap confirmed that lonely individuals slept less efficiently, took slightly longer to fall asleep, evidenced longer

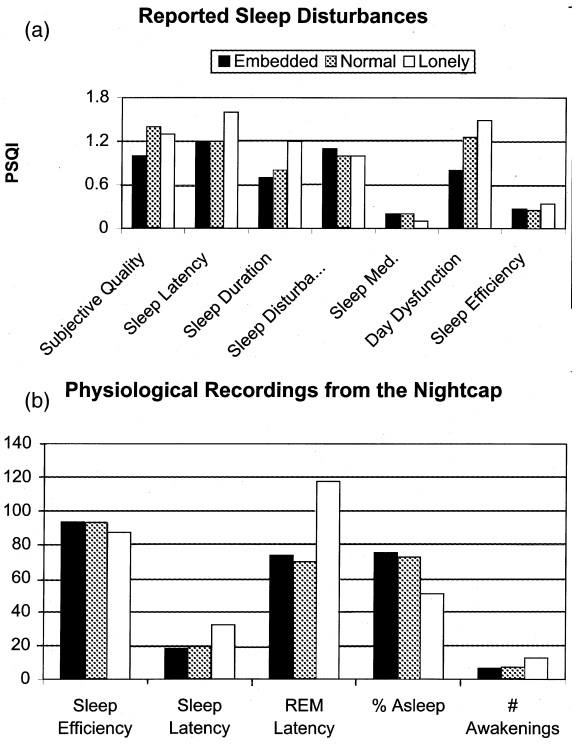


Fig. 4. Sleep disturbance as indexed by the Pittsburgh Sleep Quality Index, a self-report measure that measures sleep disruptions (a), and Nightcap recordings during the night participants slept in the Clinical Research Center (b).

REM latency, and awoke more frequently during the night than embedded and normal individuals (see Fig. 4). Importantly, the Nightcap recordings revealed that total time asleep did not differ across the groups. Thus, the restorative act of sleep was more efficient and effective in socially embedded than lonely individuals.

To what extent are feelings of loneliness or social embeddedness causal in producing the effects outlined above? Are the elevated anxiety and cortisol levels in individuals high in trait loneliness the result of cumulative stressors or are individuals who are characterized by anxiety or elevated HPA activation likely to feel socially disconnected? Both are possible, and interesting, and either could help account for the higher morbidity and mortality found in socially isolated individuals (House et al., 1988). If only the latter were true, however, there would be little reason

to intervene, to try to overcome the feelings of loneliness, to try to reach out and connect with others. Fortunately, there is preliminary evidence for both processes operating.

## 8. Manipulating feelings of loneliness

Uchino et al. (1996) reviewed intervention studies that have been performed to increase social support. A meta-analysis of these studies showed that improving social support and connectedness, especially within families, had beneficial physiological effects (e.g. lowered blood pressure in hypertensives). Such findings are important because they indicate that feelings of loneliness or social embeddedness are not simply markers or epiphenomena, and that loneliness is not an invariant trait but rather is subject to some manipulation.

Although people develop characteristic ways of appraising, attaching, and interacting with others, it is conceivable that how we feel about ourselves in relation to others is the bedrock upon which these appraisals, attachment, and interactive styles are built. If so, then feelings of loneliness may prime memories, associations, and behaviors of alienation and social awkwardness, whereas feelings of connectedness may prime the opposite. That is, how individuals construe and feel about themselves in terms of those around them may be so central to some dimensions of personality (e.g. shyness, sociability, extraversion, agreeableness, fear of negative evaluation) that such construals represent a deep structure that influences the surface manifestations of these personality dimensions. To test this hypothesis, we used hypnosis to *manipulate* feelings of loneliness and embeddedness within-subjects. Twenty high hypnotizable individuals at Stanford University were identified based on high scores on the Harvard Group Scale (scores 9–12) and the Hypnotic Induction Profile (scores 8–10).

Following each hypnotic induction, participants received the suggestion that they felt lonely or socially embedded (the order of which was counterbalanced across participants). In the lonely condition, for instance, participants were told to: 'Think of a time in which you felt isolated. You felt lonely. Perhaps you felt like you just didn't belong — that you had no friends...'. In the embedded condition, participants were told to: 'Think of a time in which you felt a sense of belonging. Perhaps you were a member of a group. Perhaps you had a best friend with whom you felt you could share anything...'. After each suggestion, participants completed a set of questionnaires designed to measure sociability, optimism, fear of negative evaluation, anger, anxiety, social skills, shyness, self esteem, mood, impact of events, loneliness, and perceived social support.

As would be expected if the manipulations were effective, participants scored higher on loneliness and lower on social support measures in the lonely than embedded condition. More interestingly, the participants' responses to the psychological surveys revealed that they were significantly lower on social skills, sociability, optimism, self esteem, and positivity, and higher on anger, anxiety, negativity, and fear of negative evaluation in the lonely than embedded condition. Importantly, the participants in the lonely and embedded condition scored comparably on the subscales (intrusion and avoidance) of the impact of events scale — just as had the participants in our cross-sectional study. Thus, the same differences — and lack of differences — we observed between our lonely and embedded groups were replicated within subjects when they were induced to feel very lonely or socially embedded. Together, these results support the hypothesis that how individuals construe and feel about themselves in terms of those around them can affect the surface manifestations of states and traits and, presumably, their physiology.

## 9. Conclusion

The current research underscores the centrality of social relationships to human existence and experience. For instance, lonely individuals were more anxious, angry, and negative, and less positive, optimistic, comfortable, and secure than embedded individuals, a pattern of findings that was

associated with feelings of loneliness whether examined between-subjects or within-subjects. Attentional control appeared comparable in lonely and embedded individuals until voluntary attentional control conflicted with automatic attentional processes, at which point lonely individuals showed an attentional deficit. Interestingly, lonely and embedded individuals were found to have comparable social capital (e.g. attractiveness, SES, intelligence) and social contacts, but lonely individuals, in contrast to embedded individuals, made less use of social capital, expected negative outcomes, were less likely to reach out or to seek help from others, and were more likely to think they were already doing all they could do in their relationships. Loneliness was associated with a range of altered physiological processes, as well, including muted autonomic activation, elevated activation of the HPA axis at least in the subset of individuals who were chronically lonely, and disregulated sleep. These data converge to suggest that the unfulfilled need to belong is associated with complex yearnings for intimacy yet feelings of insecurity and mistrust, anger combined with anger suppression, punishing feelings of isolation coupled with a fear of negative evaluation by others, emotional dysphoria and withdrawal rather than active coping attempts. Given this psychological complex, it is no surprise why daily encounters yield fewer uplifting events and more frequent hassles for lonely than embedded individuals; across a lifetime, the allostatic load (McEwen and Stellar, 1993) of daily challenges and stressors should be greater, as well.

The social world has tended to be ignored in psychophysiology and in the neurosciences because it falls outside the physical boundaries of the body. Yet our genetic makeup compels us to be social animals, and social contact and relationships are among the most powerful stimuli in the environment. Isolation from the social world is known to be as significant a risk factor as smoking and high blood pressure, but the absence of an obvious physical mechanism has made rigorous scientific analysis difficult. The current research suggests that 'social neuroscience' is not an oxymoron, that instead it represents a viable, multilevel integrative approach for understanding the mind and brain. It is also consistent with the notion that the social world in large part defines who we are, how we appraise and relate to events in our lives, and how our biology develops, responds, and ages.

A multi-level integrative approach spanning biological and social levels of organization does not imply dualism (Cacioppo and Berntson, 1992). Multiple levels of analysis do not imply independent (non-reductionistic) determinants. There is a single set of determinants that may be conceptualized at different levels of organization. Hormonal effects, for instance, are mediated by their chemistry but their actions on mating are not optimally organized by chemical/receptor interactions alone. The early American psychologist William James (1890/1950) was among the first to articulate the notion that neurophysiological processes underlie psychological phenomena. James further argued that developmental, environmental, and sociocultural factors influence the neurophysiological processes underlying psychological and social phenomena. Although these influences could be studied as neurophysiological transactions, James recognized that unnecessary diseconomies and conundrums would result if psychological phenomena were described only as neurophysiological events. Social and psychological constructs such as loneliness and social embeddedness, both of which undoubtedly have neurophysiological implementations, are simpler to measure and are more reliably measured using self-report instruments than some physiological processes (e.g. cortisol levels).

There is growing evidence that multilevel analyses spanning neural and social perspectives can foster comprehensive accounts of cognition, emotion, behavior, and health. This is in part because the social environment shapes neural structures and processes and vice versa. Meaney and colleagues (Meaney et al., 1993; Liu et al., 1997), for instance, have found that variations in maternal care influence the development of individual differences in neuroendocrine responses to stress in rats. As adults, the offspring of mothers that exhibited more licking and grooming of pups during the first 10 days of life were also characterized by reduced adrenocorticotropic hormone and cor-

ticosterone responses to acute stress. As mothers, these rats also tended to lick and groom their pups. This research raises the possibility that lonely and socially embedded individuals have very different experiences early in life that shape their HPA functioning as well as their social behavior. That is, although the stress of chronic loneliness may affect HPA activation, the reciprocal influence also appears likely.

Our results also raise a number of interesting questions, many of which require experimental and prospective studies to unravel. What does seem clear, however, are that these questions are amenable to social, cognitive, and biological levels of analysis and that the questions are worth asking. As E.O. Wilson (1998) noted,

> 'people must belong to a tribe; they yearn to have a purpose larger than themselves. We are obliged by the deepest drives of the human spirit to make ourselves more than animated dust, and we must have a story to tell about where we came from, and why we are here' (p. 6).

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