Does hugging provide stress-buffering social support? A study of susceptibility to upper respiratory infection and illness

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Abstract

Perceived social support has been hypothesized to protect against the pathogenic effects of stress. How such protection might be conferred, however, is not well understood. In 406 healthy adults, we examined the roles of perceived social support and received hugs in buffering against interpersonal stress-induced susceptibility to infectious disease. Perceived support was assessed by questionnaire, and daily interpersonal conflict and receipt of hugs by telephone interviews on 14 consecutive evenings. Subsequently, participants were exposed to a virus that causes a common cold, and monitored in quarantine to assess infection and illness signs. Perceived support protected against the rise in infection risk associated with increasing frequency of conflict. A similar stress-buffering effect emerged for hugging, which explained 32% of the attenuating effect of support. Among infected participants, greater perceived support and more frequent hugs each predicted less severe illness signs. These data suggest that hugging may act as an effective means of conveying support.

Keywords

Health; Interpersonal Interaction; Psychological Stress; Social Support; Touch; Stress-buffering

Social support refers to a social network's provision of psychological and material resources intended to benefit an individual's ability to cope with stressful events (e.g., Cassel, 1976; Cobb, 1976; Cohen, 2004; Thoits, 1986). The perceived availability of social support has been found to protect against the potential of stressful events to elicit psychological distress, depression and anxiety (reviews by Cohen & Wills, 1985; Kawachi & Berkman, 2001;

Schwartzer & Leppin, 1989). Perceived support may also protect against stress-elicited increases in risk for physical morbidity and mortality (Rosengren, Orth-Gomer, Wedel, & Wilhelmsen, 1993; Falk, Hanson, Isacsson & Ostergren, 1992). Offering support of any kind can be viewed as an expression of empathy, caring and reassurance, resources thought to be most beneficial in the face of stressful events (Cobb, 1976). However, the aforementioned evidence for stress-buffering derives from studies assessing global perceptions of support, and we know little about the specific behaviors most effective in conveying the availability of these resources to others (cf. Gottlieb, 1988; Lewis & Rook, 1999; Uchino, 2004).

Several investigators have proposed nonsexual, caring physical touch such as hugging or hand-holding as an important means of conveying empathy, caring and reassurance (e.g., Holt-Lunstad, Birmingham & Light, 2008; Grewen, Anderson, Girdler & Light, 2003; Reis & Patrick, 1996). In fact, laboratory studies have generally found that touch from a trusted other buffers the usual effects of stress on pain (Masters, Eisenberger, Taylor, Naliboff, Hirinyan & Lieberman, 2009), and on activation of autonomic pathways (Ditzen, Neumann, Bodenmann, von Dawans, Turner et al., 2007; Grewen, Anerson, Girdler, & Light, 2003), the hypothalamic-pituitary-adrenal axis (Ditzen et al., 2007), and the brain (Coan, Schaefer, Davidson, 2006). However, evidence for whether such nonverbal gestures act to buffer stress effects on disease is lacking, as is evidence of touch buffering stress effects in natural settings (suggestive evidence in Ditzen, Hoppmann, & Klumb, 2008).

Interpersonal stressors, especially conflicts, have been found to have potent aversive effects on psychological well-being (e.g., Rook, 1984; 1992; Bolger, DeLongis, Kessler & Schilling, 1989), and to activate stress physiology and dysregulate immune response (Kiecolt-Glaser & Newton, 2001). At the same time, those experiencing interpersonal stressors may be particularly receptive to the stress-buffering effects of behaviors indicating care and intimacy such as physical touch. That is, *social wounds* may be best healed by intimate behaviors of others. Touch itself may be an especially effective means of conveying support in that it is *invisible*—i.e., it is unlikely to provoke feelings of weakness or neediness on the part of the recipient (Bolger & Amarel, 2007; Jukubiak & Feeney, 2014)— and it is easy to enact well.

In our own work, interpersonal stressors have been associated with an increased risk of developing a cold when participants are experimentally exposed to a common cold virus (Cohen et al., 1998; Cohen, Tyrrell & Smith, 1991). This increased susceptibility under stress is attributable to stress associated risk of the virus replicating (infection) and/or stress associated production of signs (objective markers) of illness in infected persons (e.g., Cohen et al., 1991; Cohen, Doyle & Skoner, 1999). Here we examine whether global perceptions of social support and the actual receipt of physical touch during daily life—i.e., being hugged, attenuate the association of an interpersonal stressor (social conflict) with subsequent risk for infection, cold signs, and clinical disease in response to an experimentally administered cold virus. We expect that more frequent conflict will be associated with increased susceptibility. However, these associations will be attenuated (buffered) among those who perceive higher levels of social support and those who receive hugs with greater frequency (see Figure 1a and 1b using infection as example). We also expect that the buffering effects

of perceived support are partly or wholly attributable to being hugged on a regular basis (see Figure 1c).

METHODS

Participants

The analyses presented here combine archival data from two viral-challenge studies that followed a common set of procedures. These included a physical exam, questionnaire assessments of demographics and social support, a 2-week evening interview protocol assessing daily interpersonal interactions, and subsequent participation in a viral-challenge trial. The total sample included 406 participants (193 from study 1 and 213 from study 2). Study 1 was conducted between 2000–2004 and study 2 between 2007–2011. The maximum available sample size was employed. The participants were healthy adults, aged 18 to 55 years (mean = 33.5, standard deviation [SD] = 10.5). Participants from both studies were recruited from the Pittsburgh, PA metropolitan area via newspaper advertisements and community postings. All participants provided informed consent and received financial compensation for study participation. Study procedures were approved by the appropriate institutional review boards. The total sample was 46.3% female and 38.4% non-white (32.0% African-American; 1.5% Asian or Pacific Islander; 0.5 % Native American, Eskimo or Aleut ; 1.0% Hispanic, Latino; 3.5% "other"). One quarter (24.3%) of the sample was married (only one member of a couple could participate); 27.3% had less than or equal to a high school education; and 25.5% had earned a bachelor's or higher degree. Two participants were missing data on relevant covariates, and thus were excluded from the present analyses resulting in a total of 404.

Procedures

Figure 2 depicts the temporal sequence of study activities. Volunteers underwent medical screenings and were excluded from study eligibility if they had a history of psychiatric illness, major nasal or otologic surgery, asthma or cardiovascular disorders, or abnormal urinalysis, complete blood count, or blood enzymes, were pregnant or currently lactating, seropositive for HIV, or on regular medication (except birth control). Baseline immunity to the challenge virus (viral specific antibody titers), demographics, weight and height were also assessed at screening. To maximize the rate of infection, only participants with low levels of immunity to the virus (viral-specific antibody titers 4) at the medical screening were eligible for the study.

At study baseline, volunteers meeting inclusion criteria completed a questionnaire assessing perceived availability of social support and were interviewed by telephone for 14 consecutive evenings. Interviews included queries about social activities, interpersonal tension or conflicts, and whether participants were hugged on each interview day.

One to three weeks following completion of the interviews participants were quarantined in separate rooms on an isolated floor in a local hotel. All procedures conducted while participants were in quarantine were identical for both studies. Blood was drawn for assessment of baseline antibody levels during the 5 day period before viral-exposure. During

the first quarantine day and prior to viral exposure, participants in both studies completed personality questionnaires, received an examination of the ears, nose, and throat, and provided a nasal wash specimen that was cultured for existing viral infection. Baseline objective measures of congestion (nasal mucociliary clearance time) and nasal mucus production were assessed. Five volunteers (not included in the N of 406) were excluded from study participation at this point if they reported having a cold or symptoms of a cold, or retroactively if a viral pathogen was later isolated from the nasal wash.

After collection of baseline data, participants were then given nasal drops containing 100–300 Tissue Culture Infectious Dose$_{50}$ (TCID$_{50}$) of rhinovirus (RV) 39 or 10^5 TCID$_{50}$ of influenza A/Texas/36/91, both viruses that cause common cold-like illnesses. We used two viruses in order to establish the generalizability of observed associations. The quarantine continued for five (RV39) or six (influenza) days. On each day, participants were assessed for nasal mucociliary clearance and nasal mucus production, and nasal wash samples were collected for virus culture. Approximately 28 days after virus exposure, blood was collected to assay for antibody to the challenge virus. The on-site investigators were blinded to all interview, questionnaire and biological measures.

Measures

Standard control variables—Eight control variables (covariates in analyses) were collected at screening including age (continuous), sex (male/female), race (white/other), virus (RV or influenza), season of the year (spring, summer, fall, winter), body mass index (BMI; weight [kg]/height [meters]^2), marital status (married/or living in a marital-like relationship vs. all others [separated/divorced, widowed, never married]), and educational attainment (high school or less, some college, 2 years with degree or certificate, bachelor's degree or greater). The remaining two controls included Study (1 or 2), and viral-specific immunity (the pre-exposure specific antibody to the challenge virus). Although only volunteers with antibody titers 4 were invited to participate at screening (8–12 weeks pre-challenge), some evidenced titers >4 when pre-exposure levels were re-assessed (0–5 days pre-challenge; see Figure 2). The apparent elevation in antibody levels could be due to assay error or natural exposure to the virus in the interim. Accordingly, we included a control variable indicating whether participants' antibody to the challenge virus as assessed just prior to viral exposure was <4 or 4.

Perceived social support—Support was assessed using the 12-item version of the Interpersonal Support Evaluation List (ISEL; Cohen, Mermelstein, Kamarck & Hoberman, 1985; http://www.psy.cmu.edu/~scohen/ISEL12.html). The ISEL-12 contains items drawn from three of the four subscales included in the original scale, with each subscale represented by the four highest-loading component items. The three represented subscales assess availability of persons with whom the respondent can talk about his or her problems; persons with whom the respondent can spend time doing things; and persons who would provide the respondent with material aid if needed. Responses to each item ranged from definitely true (scored 4) to definitely false (scored 0). Total perceived support scores were derived by summing the 12 items. Because the scale is counterbalanced, negatively (low

support) stated items were reverse-scored (e.g., 0=4). The internal reliability (Cronbach's α) for the scale was .82.

Interactions, conflicts and hugs—Telephone interviews were conducted on 14 consecutive evenings. During each interview, participants were asked whether they engaged in each of 5 types of activities *with other persons* (plus 2 open-ended questions about any activities not included in the 5 categories) during the last 24 hours. Activity categories included eating (e.g., having a meal, dessert, cup of coffee, etc.); leisure activities at home (e.g., watching TV, reading, playing a game); leisure activities away from home (e.g., going to a movie, a sporting event, for a walk or hike); work around the house (e.g., yard work, home improvements, cleaning, laundry, paperwork); and family or personal errands (e.g., grocery shopping, going to the doctor, taking the kids somewhere). From these data we calculated the average number of interactions (activities with others) per day and the percent of days interacting with others (any activity). At the end of every interview, participants were also asked whether they were involved in any interpersonal tension or conflict during the day (yes/no) and whether anyone had hugged them that day (yes/no).

Personality—In Study 1, extraversion, agreeableness, and neuroticism were assessed using items derived from Goldberg's Adjective Scale (Goldberg, 1992; Cohen, Doyle, Skoner, Rabin & Gwaltney, 1997). Each personality dimension was represented by the 5 highest-loading items for the relevant factor. Internal reliabilities for each scale were α = .74 for extraversion and agreeableness and α = .80 for neuroticism. In Study 2, these same personality dimensions were measured using the relevant 10-item Big-Five subscales of the International Personality Item Pool (Goldberg et al, 2006), with internal reliabilities of α = .88 for extraversion and neuroticism and α = .85 for agreeableness. To establish equivalency across the two studies, standardized scores (z-scores) were computed for each subscale prior to inclusion in analysis.

Disease Outcomes

<u>Infection:</u> Infection is the replication of the virus. When upper respiratory viruses replicate, they can be found in nasal secretion samples. Samples collected daily in a saline wash of the nose were frozen and later cultured for the challenge virus using standard techniques (Gwaltney, Colonno, Hamparian, & Turner, 1989; Dowdle, Kendal & Noble, 1979). Because the immune system responds to infection by producing antibody to the virus, increases in viral-specific antibody level provide an indirect marker of infection. Hence we compared virus-specific antibody levels measured in serum collected before and 28 days after exposure using a criterion (4-fold increase) that has been validated by virologists as an indicator of infection (Gwaltney et al., 1989; Dowdle et al., 1979). In sum, infection was operationally defined as recovery of the challenge virus on any of the five (RV39) or six (influenza) post-challenge days or a four-fold rise in virus-specific serum neutralizing antibody titer (pre-exposure to 28-days post-exposure) (Cohen et al, 1997).

<u>Signs of illness:</u> We assessed two objective markers of upper respiratory illness: nasal mucus production and nasal mucociliary clearance function. Daily mucus production was assessed by collecting used tissues in sealed plastic bags (Doyle, McBride, Swarts, Hayden,

& Gwaltney, 1988). The bags were weighed and the weight of the tissues and bags subtracted resulting in the weight of mucus produced. Clearance function refers to the effectiveness of nasal cilia in clearing mucus from the nasal passage toward the throat and is subjectively experienced as congestion. Clearance function was assessed as the time required for a saccharin-dyed solution administered into the anterior nose to be tasted by the participant (Doyle et al., 1988).

To create baseline-adjusted daily scores for each measure, we subtracted the appropriate baseline (day before challenge) score from each of the 5 (RV39) or 6 (influenza) post-challenge daily scores (Cohen et al., 1997). Negative adjusted scores were re-assigned a value of 0. Average daily mucus production and nasal clearance scores were calculated by averaging the respective adjusted daily scores for each measure over all post-challenge days. Total mucus weight scores were created by multiplying the average daily scores by 5 (to equate 5 [RV] and 6 [influenza]) day sampling periods.

Clinical illness: Participants were determined to have developed a clinical cold if they were both infected with the challenge virus and met either of the following criteria: total baseline-adjusted mucus weight of 10g or more; or average (across all post-challenge days) baseline-adjusted nasal mucociliary clearance time of 7 minutes or longer (Cohen et al., 1997).

Data Analysis—Separate multivariable logistic regression models were used to examine whether perceived social support and being hugged, respectively, attenuate the association of daily interpersonal tension with the dichotomous outcome infection. Analogous multivariable linear regression models were run to examine the buffering effects of social support and hugging, respectively, on the association of daily tension with each of the continuous measures of illness expression (nasal mucociliary clearance function and nasal mucus production) among infected persons. Finally, logistic models were also used in examining clinical illness.

In both the logistic and linear models, test of main effects included social tension and either social support or hugs. Moderation models included the main effects of tension and either social support or hugs (all centered at their respective means), as well as the cross-product of the relevant centered variables (i.e., tension-X-support or tension-X-hugs). If both cross-product terms emerged as significant predictors of a given outcome, an additional model was run that examined both effects simultaneously—i.e., one that included all main effects (i.e., daily tension, social support, and daily hugs) and the two cross-product terms (tension-X-support and tension-X-hugs).

All models included the ten standard covariates (age, sex, race, marital status, BMI, pre-challenge antibody, virus, season of trial, education, and study). In cases of significant associations, results from a model without the standard covariates are also reported. To rule out personality as a potential third factor explanation for observed effects, an additional set of models was conducted that included controls for relevant personality variables and their interactions with tension in addition to the standard covariates.

Main effects results of logistic regression models are reported as odds ratios (ORs) and 95% confidence intervals (CIs). Interaction results are reported as the unstandardized regression coefficient (B) and 95% CI, with chi-squared (X^2) values (1 degree of freedom) provided to indicate the improvement in prediction associated with the addition of the interaction term to the model. For the linear models, all results are reported as B (95% CI), standardized coefficient (β), and change in the squared multiple correlation coefficient associated with adding the predictor to the model (R^2). P-values are reported for all analyses, and all tests were two-tailed.

Because it is possible that the effects of the predictor variables examined here may differ depending on whether participants were infected with rhinovirus or influenza virus, we ran an additional set of analyses that incorporated virus type as an additional moderator. Specifically, we examined the three-way interactions of tension-X-support-X-virus AND tension-X-hugs-X-virus in predicting each of the four study outcomes. These models also included the main effects, the component two-way interactions, and the standard covariates.

RESULTS

Descriptive Data

Seventy-eight percent (n = 315) of participants became infected with the challenge virus, and 31.4% (n = 127) met criteria for clinical illness. The median total adjusted mucus production was 2.90 grams (range 0–345.00) and the median average adjusted nasal clearance time was 2.60 minutes (range 0–19.60). When examined among infected participants only, the corresponding values were 3.77 grams (range 0–345.00) and 2.92 minutes (range 0–19.60), respectively. On average, participants completed 13.93 (95% CI = 13.17, 14.69) daily interviews, with 97.5% (*n* = 394) completing all 14 interviews. Participants were more likely to be hugged than to experience interpersonal tension/conflict (*t*[403] = 28.34, *p* < .001), with hugs being reported on 67.86% (median; range 0–100) of interview days and tension/conflict on 7.14% (median; range 0–85.71%) of days. The median ISEL score was 42.00 (range 18–48). Higher levels of perceived support were associated with more frequent hugging (r = 0.37, p < .001), but were unrelated to frequency of experiencing tension/conflict (r = −0.01, p = .86).

Associations of Covariates with Outcomes

Ten separate models, each entering only a single variable, were fit to estimate the association of each of the standard covariates with each outcome. Six of the standard covariates were associated with at least one outcome. Having a pre-challenge virus-specific antibody titer 4 was associated with reduced odds of becoming infected (OR [95% CI] = 0.30 [0.18, 0.48], p = .001, n = 404) and of developing a cold (OR [95% CI] = 0.33 [0.20, 0.56], p = .001 n = 403), having lower mucus weights (B [95% CI] = −0.18 [−0.34, −0.02], p = .024, n = 315) and more rapid nasal clearance (B [95% CI] = −0.12 [−0.21, −0.03], p = 0.012, n = 315). Increasing age was related to increased odds of developing a cold (OR [95% CI] = 1.03 [1.01, 1.05], p = .005, n = 403) and greater mucus weights (B [95% CI] = 0.01 [0.003, 0.02], p = .003, n = 315), as was increasing BMI (cold, OR [95% CI] = 1.03 [1.00, 1.06], p = .068; mucus weights, B [95% CI] = 0.01 [0.00, 0.02], p = .052). Exposure

to the challenge virus during the winter months was associated with reduced risk of infection (OR [95% CI] = 0.43 [0.24, 0.77], p = .004), whereas exposure during the spring was associated with reduced risk of developing a cold (OR [95% CI] = 0.63 [0.41, 0.97], p = .037) and shorter nasal clearance times (B [95% CI] = −0.07 [−0.15, 0.01], p = .085). Those exposed to the influenza virus were less likely to become infected than those exposed to RV39 (OR [95% CI] = 0.27 [0.13, 0.53], p = .001); and women had increased mucus weights relative to men (B [95% CI] = 0.23 [0.09, 0.37], p = .001).

Risk for Infection

Tension and perceived social support—When examined in the same model, there was neither a main effect for % days with tension (OR = 1.74, 95% CI = 0.27, 10.93, p = 0.56) nor for perceived social support (OR = 0.99, 95% CI = 0.95, 1.04, p = 0.70) in predicting infection. However, social support moderated the association between % days with tension and infection risk (interaction, B [95% CI] = −0.40 [−0.79, −0.003], p = 0.048; $X^2[1] = 4.72$, p = .03); without standard covariates, B [95% CI] = −0.43 [−0.79, −0.07], p = 0.019). Consistent with the buffering hypothesis, the form of the tension-X-support interaction was such that experiencing more frequent tension was associated with increased risk of infection among those with lower levels of social support while among those with higher support, tension was unrelated to infection. The interaction is presented graphically in Figure 3, where the adjusted predicted values generated from the regression equation (ordinate) are plotted against % days with tension (abscissa). For purposes of illustration (the analysis used continuous data), the sample was split at the median scores for social support to create high and low groups. When testing the simple slopes based on the median split of social support, there was a trend (p = .066) for increasing infection risk with increasing tension among those with low support, but no association among those with high support (p = .32).

Tension and hugs—To determine whether interpersonal touch also has a buffering effect on the association between tension and risk for infection, we conducted the above analyses a second time substituting % days with hugs for perceived social support. Again, there was no main effect of % days with tension on infection risk (OR = 2.08, 95% CI = 0.32, 13.45, p = 0.44). However, % days with hugs was inversely related to infection risk such that being hugged more frequently was associated with a decreased risk of infection (OR = 0.39, 95% CI = 0.16, 0.96, p = 0.04; without standard covariates, OR = 0.36, 95% CI = 0.17, 0.77, p = 0.009). Including the tension-X-hugs cross-product term in the model indicated a moderating effect of hug frequency on the association of tension frequency with infection risk (interaction, B [95% CI] = −12.31 [−20.94, −3.69], p = 0.005; $X^2[1] = 9.35$, p = .002; without standard covariates, B [95% CI] = −10.06 [−17.49, −2.63], p = 0.008). Analogous to the results of the tension-X-support model described above, experiencing more days with tension was associated with increased risk of infection among those who were hugged on fewer days relative to those who were hugged more frequently. To illustrate the nature of the interaction, Figure 4 presents the data dichotomizing (median split) % days with hugs. The adjusted predicted values were generated from the regression equation using the continuous variables. When testing the simple slopes based on the median split of hugs, infection risk

increased with increasing tension (p = .008) among those in the low group, but was unrelated to tension in the high group (p = .17).

Controlling for frequency of social interaction—Frequencies of both tension and hugging are intrinsically confounded with the *frequency of social interaction*. We cannot experience interpersonal tension or receive a hug on any given day unless that day included some social interaction. Moreover, engaging in more *social interactions per day* would increase the probability of conflicts and hugs. Here, both % days with hugs and % days with tension increased as the number of days that involved at least one social interaction increased (r = 0.42 and r = 0.21, respectively, p < .001) and as the average number of social interactions per day increased (r = 0.53 and r = 0.32, respectively, p < .001). Hence we refit the relevant model making the following adjustments. We substituted into the model terms that express days with tension and days with hugs as *proportions of social interaction days* rather than as proportions of total interviews. To control for daily social interaction frequency, we included as covariates the average number of interactions per day, and the tension-X-average interactions per day cross-product term. Using this adjusted model, % days with hugs continued to moderate the association of % days with tension with infection risk (tension-X-hug interaction, B [95% CI] = −9.47 [−16.82, −2.13], p = .010; $X^2[1]$ = 7.39, p = .007), and the form of the interaction was such that more frequent tension was associated with increased risk of infection when hugs were received infrequently but not when received frequently. Although the adjustments made to the model did not affect the moderating effect of % days with hugs on the association of % days with tension with infection risk, their incorporation did result in the loss of the main effect of hugs on infection (OR = 0.57, 95% CI = 0.23, 1.38, p = .21).

Is the buffering effect of hugs responsible for support buffering tension?—To determine the overlap of the respective moderating effects of perceived support and hug frequency on the association of tension frequency with infection, we entered both relevant cross-product terms into the same model along with the standard covariates and the main effects of % days with tension, % days with hug, and perceived social support. Simultaneous examination of the two interactions resulted in a 32% reduction in the moderating effect (interaction regression coefficient) of perceived support in the association between % days with tension and infection risk, as well as a loss of statistical significance (interaction, B [95% CI] = −0.29 [−0.68, 0.10], p = .15). Moreover, the addition of the tension-X-support cross-product did not improve model fit ($X^2[1]$ = 2.35, p = .125). By comparison, the moderating effect of % days with hugs remained largely unchanged (interaction, B [95% CI] = −11.08 [−20.07, −2.09], p = 0.016), and addition of the tension-X-hug interaction term to a model already including the interaction with social support significantly improved model prediction ($X^2[1]$ = 6.44, p = .011).

Do 'buffering' hugs occur on tension days?—A possible explanation for the buffering effects of hugs is that participants engaged in hugs with persons involved in the tension/conflict as a means of resolving that conflict or at least its emotional effects. As data were not collected on the sources of tension/conflict or on who provided hugs, we could not test this hypothesis directly. However, we could address the question indirectly by first

determining whether hugs were received more frequently on days with tension/conflicts than on non-tension days; and second, whether hugs received on tension relative to non-tension days were more likely to buffer the association of tension with infection.

Among those reporting tension/conflict during at least one interview (n = 279), comparison of tension and non-tension days revealed only a marginal difference in the frequency of being hugged (z = −1.63, p = .103), with hugs occurring on 69.1% (95% CI = −8.5, 146.7) *versus* 66.9% (95% CI = 3.2, 130.6) of tension and non-tension days, respectively. In regard to the buffering effect, receiving hugs on a greater proportion of *non-tension* days was associated with a reduced risk of infection for those with a high % of conflicts (OR = 0.19, 95% CI = 0.06, 0.64, p = .007; n = 279). Receiving hugs on a greater proportion of tension days also was related to reduced infection risk, but the association failed to meet the p = .05 criterion (OR = 0.54, 95% CI = 0.23, 1.30, p = .170; n = 279).

Signs of Illness Among Infected Participants

An independent set of analyses were conducted to assess whether tension, social support and hugging could predict which of those who were infected by the experimental virus (315 of the original 404) went on to develop objective signs of illness.

Tension and perceived social support—We examined whether % days with tension, perceived social support, and their interaction were associated with severity of two objective signs of illness—nasal mucus weights and nasal mucociliary clearance time. More social support was associated with more rapid nasal clearance (B [95% CI] = −0.01 [−0.02, 0.00], β = −0.12, p = .046, R^2 = 0.013; without standard covariates, B [95% CI] = −0.01 [−0.02, −0.001], β = −0.12, p = .038, R^2 = 0.014), but was unrelated to mucus production (B [95% CI] = 0.01 [−0.01, 0.02], β = 0.05, p = .39, R^2 = 0.002). By contrast, percent days with tension was unrelated to nasal clearance (B [95% CI] = 0.04 [−0.25, 0.33], β = 0.02, p = .78, R^2 = 0.0003), but was marginally associated with greater mucus production, B [95% CI] = 0.34 [−0.15, 0.83], β = 0.08, p = .17, R^2 = 0.007; without standard covariates, B [95% CI] = 0.46 [−0.02, 0.93], β = 0.11, p = .059, R^2 = 0.012). Perceived support did not interact with % days with tension to predict either outcome (*p* > 0.13).

Tension and hugs—Analogous to the findings for social support, more frequent hugs were associated with more efficient nasal clearance (B [95% CI] = −0.14 [−0.28, −0.004], β = −0.13, p = .044, R^2 = 0.013; without standard covariates, B [95% CI] = −0.13 [−0.24, −0.01], β = −0.12, p = .04, R^2 = 0.013), but were unrelated to mucus production (B [95% CI] = 0.02 [−0.20, 0.25], β = 0.01, p = .83, R^2 = 0.0004). There was no interaction between % days with tension and % days with hugs for either illness outcome (*p* > 0.26).

To determine whether the association of being hugged more frequently with shorter nasal clearance time overlaps with the effect of perceived support, we entered both variables simultaneously into a single model that included the standard covariates. When examined in this way, neither variable emerged as an independent correlate of nasal clearance (% days with hug: B [95% CI] = −0.10 [−0.24, 0.04], β = −0.09, *p* = 0.16, R^2 = 0.006; perceived support: B [95% CI] = −0.01 [−0.01, 0.002], *p* = 0.13, R^2 = 0.007). Further, subsequent addition of either % days with hugs or social support to a model examining the other

variable as the predictor resulted in a 25% reduction in the association of the predictor with nasal clearance time.

Clinical Illness

Colds were evaluated in analyses with all participants. Neither % days with tension (OR = 1.23, 95% CI = 0.26, 5.81, p = 0.79) nor perceived social support (OR = 1.00, 95% CI = 0.96, 1.04, p = 0.98) was associated with risk for clinical illness, and the tension-X-support interaction indicated no moderating effect (B = 0.15, SE = 0.13, p = .26; $X^2[1]$ = 1.30, p = .26). Likewise, % days with hugs was unrelated to illness risk (OR = 1.02, 95% CI = 0.48, 2.16, p = 0.96) and the tension-X-hugs interaction was not significant (B = −2.53, SE = 2.55, p = 0.32; $X^2[1]$ = 0.98, p = .32).

Controlling for Personality

An alternative explanation for the findings reported above is that perceptions of social support and the frequency of being hugged and/or experiencing interpersonal tension are influenced largely by relevant personality characteristics (i.e., extraversion, agreeableness, and neuroticism), and that it is between-person differences in these traits that account for the associations of tension and hugs with the examined outcomes. Perceiving more social support was correlated with higher extraversion (r = .24, p < .001) and agreeableness (r = .22, p < .001) and lower neuroticism (r = −.24, p < .001). Reporting more frequent hugs was correlated with higher extraversion (r =.11, p = .021) and agreeableness (r = .21, p <. 001), whereas reporting more frequent tension was related to higher extraversion (r = .12, p = .013) and neuroticism (r = .23, p < .001).

Main effects—In regard to main effects, including extraversion, agreeableness, and neuroticism as additional controls along with the standard covariates and % days with tension did not affect the association of % days with hugs with decreased risk of infection (OR = 0.34, 95% CI = 0.13, 0.87, p = 0.025). Among infected participants (n = 315), inclusion of the three personality characteristics similarly did not affect the association of either perceived social support (B [95% CI] = −0.01 [−0.02, −0.002], β = −0.16, p < .014, R^2 = 0.019) or % days with hugs (B [95% CI] = −0.16 [−0.30, −0.02], β = −0.15, p = .027, R^2 = 0.015) with more rapid nasal clearance.

Interaction effects—In regard to the moderating effect of perceived social support on the association between % days with tension and infection, including additional controls for agreeableness, extraversion, neuroticism and their respective interactions with tension had little impact on the size of the % days with tension-X-perceived support interaction effect, (B = −0.37, 95% CI = −0.77, 0.03, p = .074; $X^2[1]$ = 3.72, p = .054). Similarly, in the analogous model that substituted % days with hugs for perceived support, including the additional controls for personality did not have an appreciable effect on the results (interaction, B = −7.46, 95% CI = −14.53, −0.39, p = .039; $X^2[1]$ = 4.57, p = .033).

Pathogen Effects

None of the results reported above were modified by type of virus (influenza or rhinovirus; 3-way interaction *p*s > .28).

DISCUSSION

Interpersonal stressors have been found to predict an increased likelihood of developing clinical illness in viral-challenge studies. Disease risk in these studies has been attributed to stress influences on the susceptibility to infection and/or the development of illness signs once infected (e.g., Cohen et al., 1991; Cohen et al., 1999). Here we find associations of interpersonal stress, social support and hugs with both infection and illness signs, but not with developing a clinical illness. Lack of a clinical effect could be attributable to insufficient power, or to support and hugs playing different roles in the component disease processes (stress-buffering for infection; direct effect for signs of illness). That said, infection and illness signs are both necessary causes of clinical disease and provide valuable information about how our bodies respond to infectious challenges. Immune processes involved in preventing infection (blocking viral entry into host cells via binding of antibody; killing host cells that have been infected) and in producing signs of illness (release of pro-inflammatory proteins; virus-induced structural damage) have important implications for understanding the roles of stress, support and hugs in response to other viral pathogens.

In predicting infection, we found evidence consistent with the social support stress-buffering hypothesis (House, 1981; Cohen & Wills, 1985). For those perceiving low social support, more frequent interpersonal tension/conflict was associated with an increased probability of infection subsequent to viral exposure. In contrast, among persons perceiving greater support, frequency of tension/conflict was unrelated to infection susceptibility. Virtually identical results emerged when hugs were examined as the potential stress buffer. Moreover, the tension-X-hugs interaction explained 32% of the buffering effect of support, evidence consistent with close contact acting as a behavioral mediator of perceived support.

These data are consistent with the hypothesis that nonsexual physical touch, such as hugging, is a means of conveying empathy, caring and reassurance (e.g., Holt-Lunstad et al., 2008; Reis & Patrick, 1996; Hertenstein, Keltner, App, Bulleit, & Jaskolka, 2006), and that this implicit communication of affection and concern contributes importantly to the protective influence of perceived support against the pathogenic effects of stress. These data are also consistent with a small literature providing evidence for social support buffering the effects of stress on physical health (Rosengren et al., 1993; Falk et al., 1992), as well as with laboratory studies showing physical contact with a close other to reduce the effects of stress on biological markers thought to be precursors of disease (Ditzen et al., 2007; Grewen et al., 2003). Finally, they are also consistent with those from comparative research wherein cynomolgus macaques that displayed more affiliative behaviors (touch, closeness, grooming) were protected from social stress-induced suppression of cellular immunity (Cohen, Kaplan, Cunnick, Manuck, & Rabin, 1992).

A possible explanation for the buffering effect of being hugged is that hugs might be exchanged between individuals involved in a tension/conflict either as a means of resolving that conflict or as a counter to associated emotional after-effects. In predicting infection, we found that hugs on non-tension days were at least as important as those reported on tension days, thus suggesting that the buffering effects of hugging were not limited to hugs given as an immediate (same day) response to tension/conflict. These findings suggest that those who

regularly receive hugs are more protected than those who do not, although we cannot discount the possibility that those who are hugged more frequently also are more likely to use hugs to resolve conflicts.

In contrast to the stress-buffering effect we observed when predicting infection, our analyses revealed main effects of social support and of hugs when predicting objective signs of illness. Specifically, those perceiving greater support and those reporting more frequent hugs showing more rapid nasal clearance, i.e., less indication of illness. Neither support nor hugs interacted with tension in this case. The lack of a buffering effect may be attributable to those who were hugged most frequently not having been infected (and hence not included in these analyses), and/or the decrease in sample size and hence power when examining only infected subjects. Alternatively, support and hugging may directly affect the expression of illness signs through either physiological or behavioral pathways. Importantly, these analyses examined continuous illness outcomes. Similar analyses (not reported here) substituting dichotomous illness outcomes based on the clinical thresholds revealed no associations with support, hugs, or their interactions with tension.

No significant associations emerged when total mucus weight, the other disease indicator, was examined as an outcome. This inconsistency might be explained by mucus production and nasal mucociliary clearance function being driven by different physiological mechanisms. Whereas mucus production is thought to be controlled by biochemical processes (Cohen, Doyle & Skoner, 1996), impaired nasal clearance is thought to be influenced by microstructural damage to the nasal epithelium (Carson, Collier & Hu, 1985).

A seldom tested explanation for the effectiveness of perceived social support and/or touch in ameliorating the detrimental effects of stress is that it is actually attributable to correlated personality characteristics. Here we controlled for extraversion, agreeableness, and neuroticism, all traits that have been associated with both social interaction styles and disease risk, and found that none of them (alone or together) could explain any of the effects we reported.

The apparent protective effect of hugs may be attributable to the physical contact itself or to hugging being a behavioral indicator of support and intimacy. Either way, those who receive more hugs are somewhat protected from infection and illness-related symptoms. The overall positive associations with hugs are consistent with experimental research wherein married couples who were trained to increase warm touch evidenced higher levels of salivary oxytocin, and lower levels of salivary alpha amylase and blood pressure (Holt-Lundstat et al., 2008). However, whether touch had an overall positive effect or was operating only when individuals were being challenged by stressors—interpersonal or otherwise, was not addressed in this study.

Also possible is that support and hugs are protective because both are markers of physical contact and having a history of physical contact may have led to previous exposure to viral pathogens that in turn provided immunity in the face of further exposures. We addressed this issue by enrolling only volunteers with low levels of immunity to the challenge virus (viral-

specific antibody) in addition to statistically controlling for pre-existing levels of viral specific antibody assessed just prior to viral exposure.

A limitation of this study is we do not know with whom participants engaged in conflict or by whom they were hugged. This information could provide insight into potential explanatory mechanisms. The correlational nature of this work limits causal inference. However, the prospective viral-challenge paradigm eliminates reverse causation as an explanation. That is, neither infection with the challenge virus nor subsequent illness expression could have caused interpersonal tension, support or hugs. Finally, the design of the viral challenge was such that the likelihood of infection would be maximized. Thus, it is possible that those who resisted infection despite the favorable conditions may have been distinguished in some important way from those who did become infected. Our incorporation of multiple controls for potential third factor explanations, however, substantially reduces this possibility.

Viewed in light of the experimental studies demonstrating a buffering effect of interpersonal touch on physiologic response to laboratory stress (Masters et al., 2009; Ditzen et al., 2007; Grewen et al., 2003), and the intervention demonstrating the impact of touch on sympathetic activation (Holt-Lundstat et al., 2008), these data suggest the potential importance of touch in health-related outcomes. Moreover, that the buffering effect of hugs could explain much of the attenuating effect of social support suggests that hugging is a behavior that may be manipulated to provide the beneficial effects associated with support.

Acknowledgments

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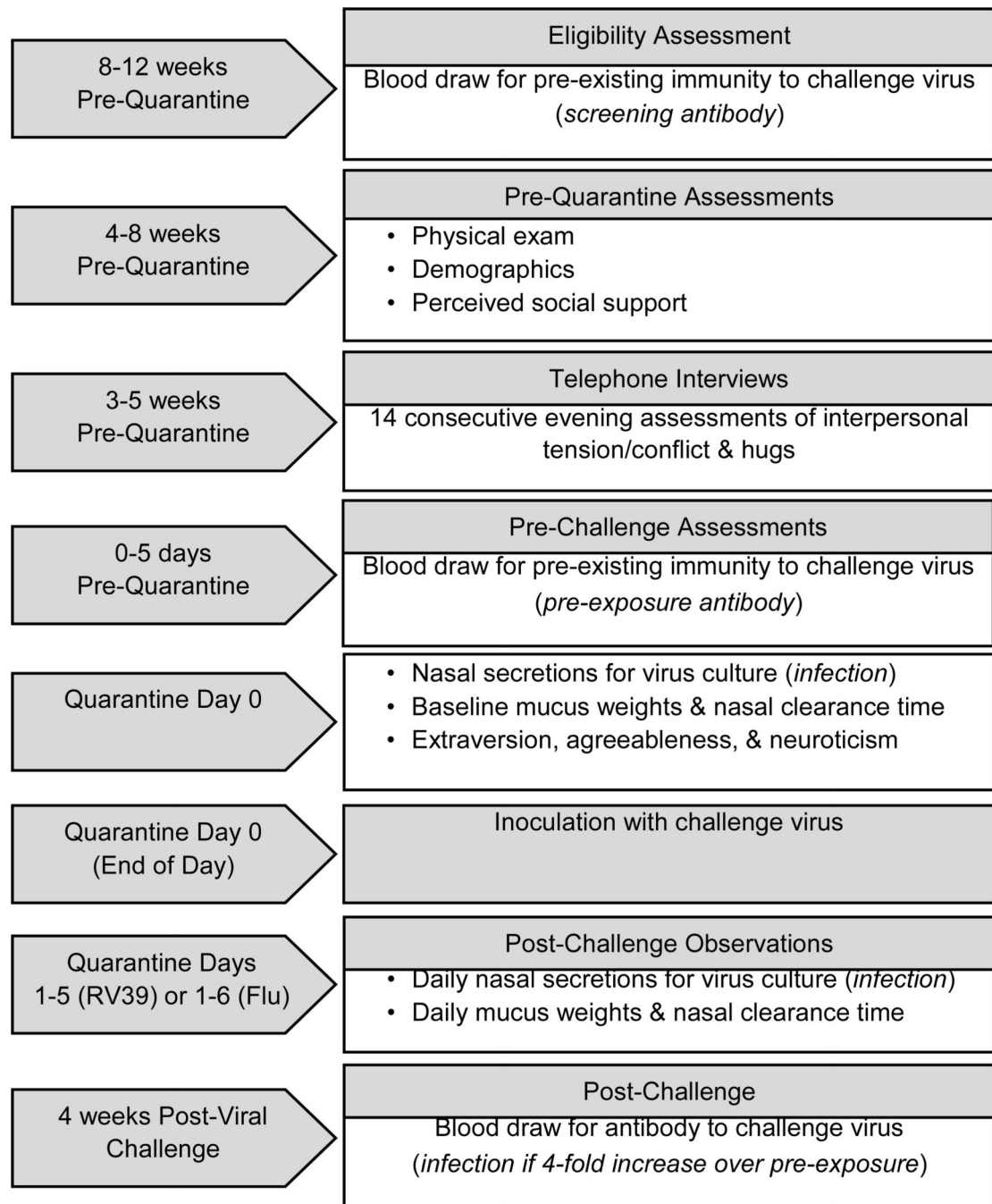
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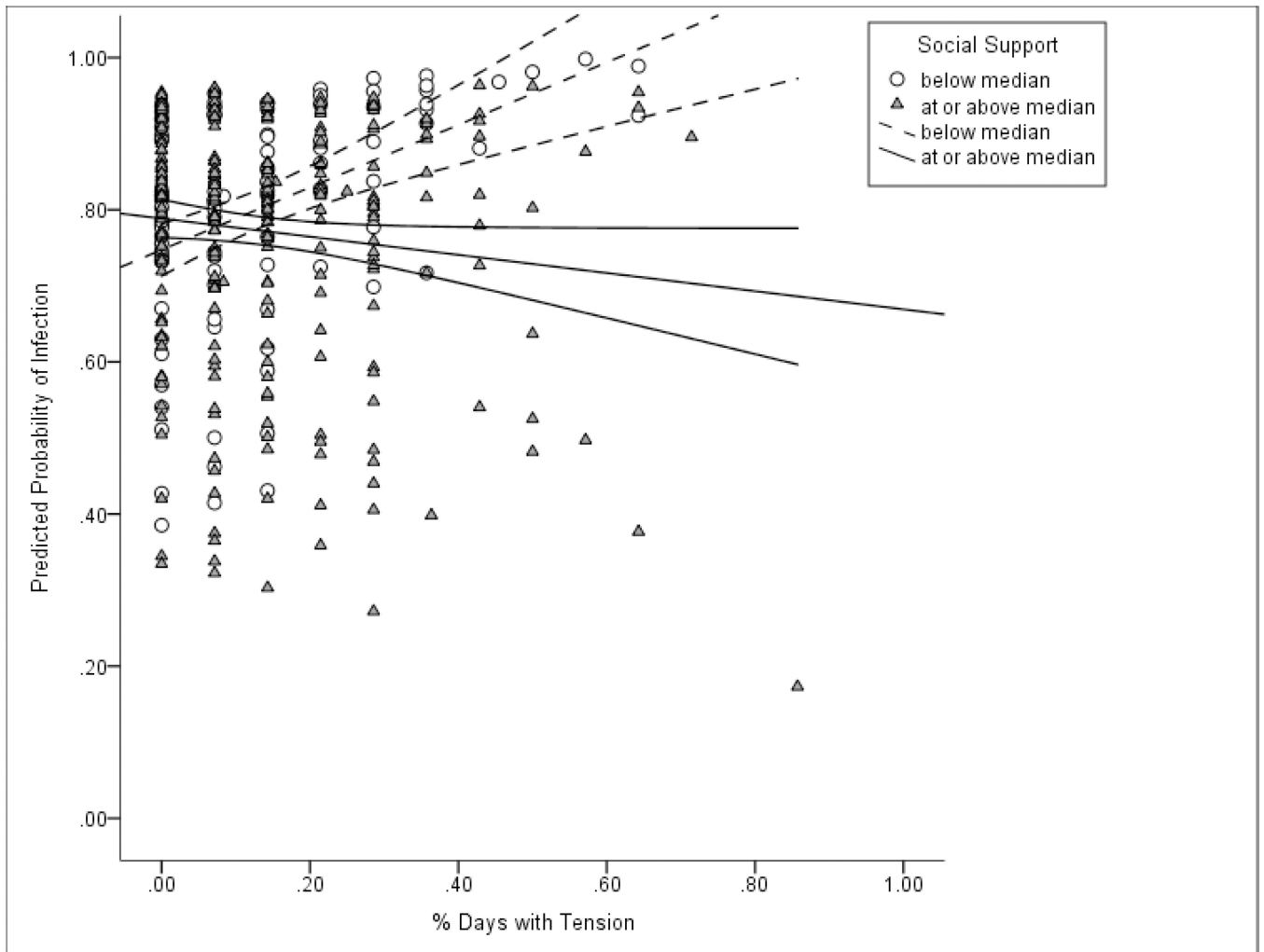
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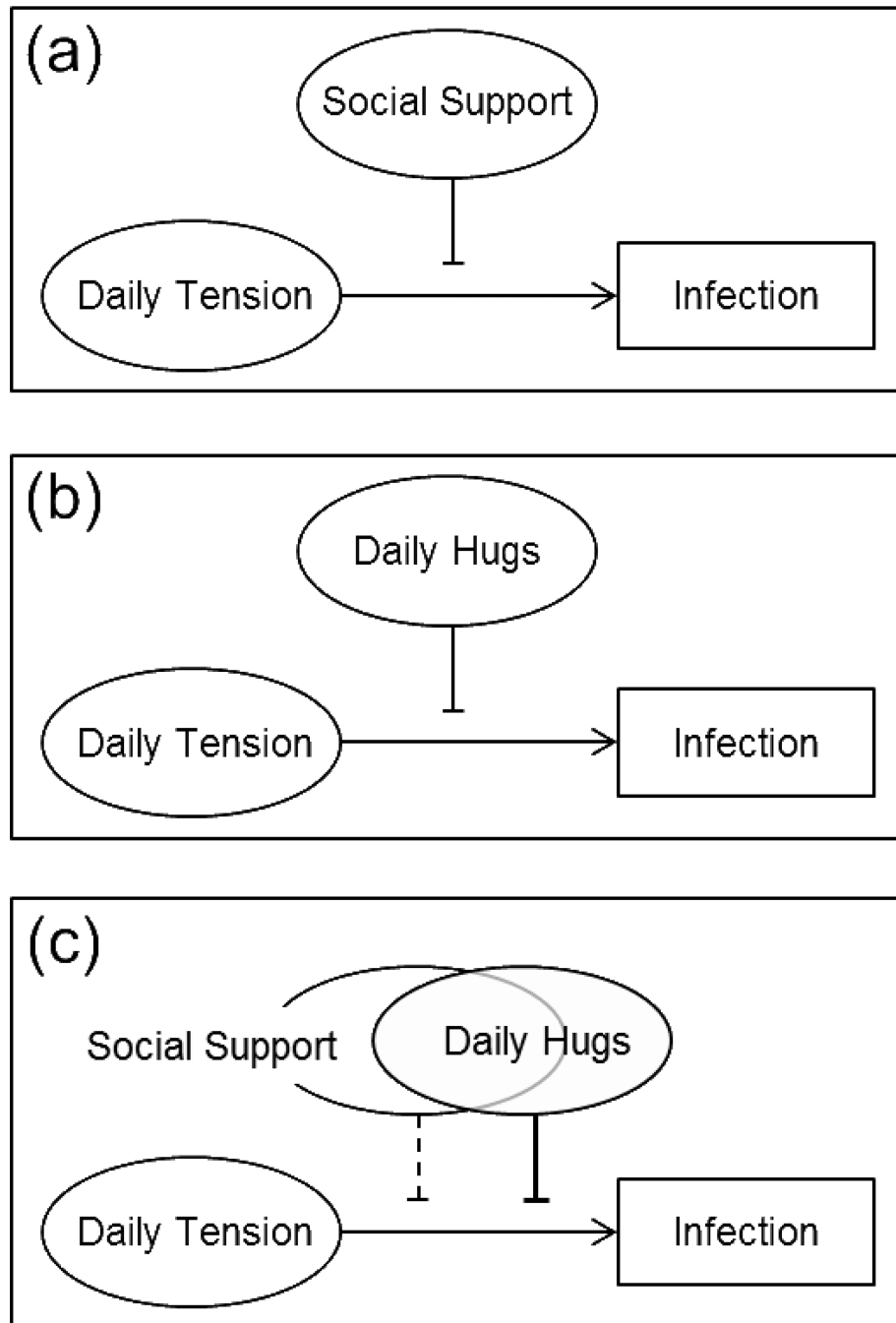
Fig. 1.
Buffering effects of (a) social support and (b) daily hugs on the association of daily social tension with risk for infection. We expect that the buffering effect of support will be partly or wholly attributable to the attenuating effect of hugs on infection risk (c).

| 8-12 weeks Pre-Quarantine | **Eligibility Assessment** |
| | Blood draw for pre-existing immunity to challenge virus (*screening antibody*) |

4-8 weeks Pre-Quarantine	**Pre-Quarantine Assessments**
	• Physical exam
	• Demographics
	• Perceived social support

| 3-5 weeks Pre-Quarantine | **Telephone Interviews** |
| | 14 consecutive evening assessments of interpersonal tension/conflict & hugs |

| 0-5 days Pre-Quarantine | **Pre-Challenge Assessments** |
| | Blood draw for pre-existing immunity to challenge virus (*pre-exposure antibody*) |

Quarantine Day 0	• Nasal secretions for virus culture (*infection*)
	• Baseline mucus weights & nasal clearance time
	• Extraversion, agreeableness, & neuroticism

| Quarantine Day 0 (End of Day) | **Inoculation with challenge virus** |

Quarantine Days 1-5 (RV39) or 1-6 (Flu)	**Post-Challenge Observations**
	• Daily nasal secretions for virus culture (*infection*)
	• Daily mucus weights & nasal clearance time

| 4 weeks Post-Viral Challenge | **Post-Challenge** |
| | Blood draw for antibody to challenge virus (*infection if 4-fold increase over pre-exposure*) |

Fig. 2.
Temporal sequence of study activities.

Fig. 3.
Adjusted predicted probability of infection with increasing days of interpersonal tension among participants with high or low levels of perceived social support. High and low groups were created by splitting the sample at the median social support score (42.00). Curved lines indicate 95% confidence intervals.
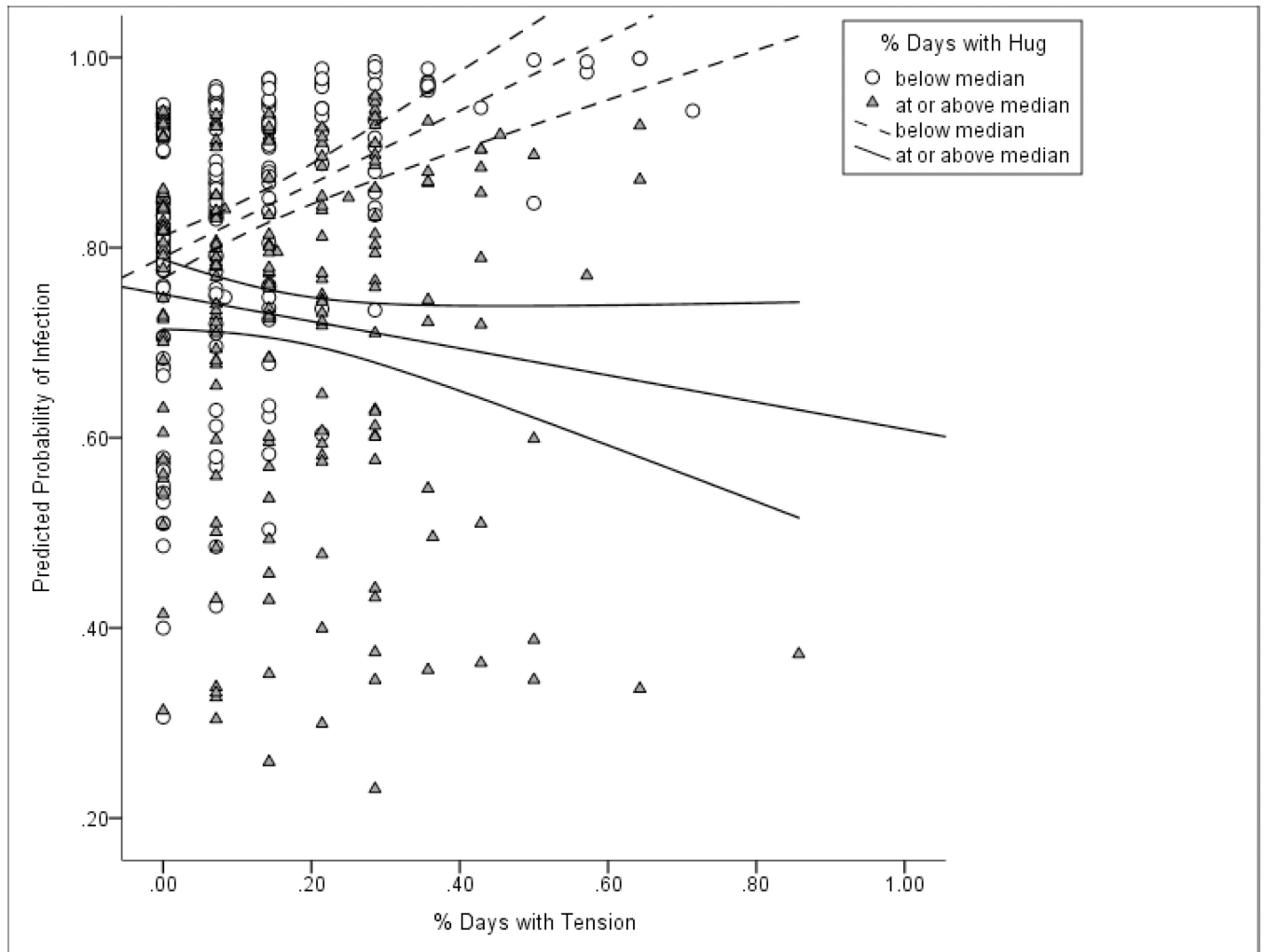
Fig. 4.
Adjusted predicted probability of infection with increasing days of interpersonal tension among participants with high or low frequency of being hugged. High and low groups were created by splitting the sample at the median % days with hugs (67.9%). Curved lines indicate 95% confidence intervals.