units (fig. S9) [paired t test, $P < 0.02$, $n = 19$ pairs; median distances from the granular layer were 0.45 mm (source units) and 1.05 mm (target units)].

The present study demonstrated that canonical feed-forward signal flow across cortical layers during sensory coding reverse to the feed-back direction during memory retrieval phase, which suggests flexible recruitment of interlaminar connectivity depending on the cognitive demands in the monkey association cortices (Fig. 4C). We used CSD analysis to estimate cortical layers (Fig. 1, C to E, and fig. S1), and the observed stimulus-evoked CSD profiles were quite similar to those in the primary sensory cortices (*17*, *27*). For some penetrations, we observed that the current sink positioned superficially next to the earliest-sink contact exhibited larger peak amplitudes and much longer durations than that of the earliest current sink. This observation might reflect the cytoarchitectural nature of A36 as a dysgranular cortex (*28*) as well as the direct inputs to the deepest part of the superficial layer, which is consistent with anatomical observations (*29*).

A recent study in the rat primary auditory cortex demonstrated that the direction of interlaminar signal flow depends on the cortical "state": Sensory-evoked responses were initiated in the thalamorecipient layers and then propagated to the superficial and deep layers, whereas in spontaneously active "up-states," neuronal activity was initiated in the deep layers and then propagated to the superficial layers (*27*). These state-dependent changes in the interlaminar signal flows in rats are consistent with our results obtained in monkeys performing a memory task. Together, these findings highlight the flexibility of cortical laminar circuits. Further experiments will be needed to determine whether such flexible interlaminar connectivity is also implemented and used in other cortical areas for other cognitive demands.

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Supporting Online Material

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A Brief Social-Belonging Intervention Improves Academic and Health Outcomes of Minority Students

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A brief intervention aimed at buttressing college freshmen's sense of social belonging in school was tested in a randomized controlled trial ($N = 92$), and its academic and health-related consequences over 3 years are reported. The intervention aimed to lessen psychological perceptions of threat on campus by framing social adversity as common and transient. It used subtle attitude-change strategies to lead participants to self-generate the intervention message. The intervention was expected to be particularly beneficial to African-American students ($N = 49$), a stereotyped and socially marginalized group in academics, and less so to European-American students ($N = 43$). Consistent with these expectations, over the 3-year observation period the intervention raised African Americans' grade-point average (GPA) relative to multiple control groups and halved the minority achievement gap. This performance boost was mediated by the effect of the intervention on subjective construal: It prevented students from seeing adversity on campus as an indictment of their belonging. Additionally, the intervention improved African Americans' self-reported health and well-being and reduced their reported number of doctor visits 3 years postintervention. Senior-year surveys indicated no awareness among participants of the intervention's impact. The results suggest that social belonging is a psychological lever where targeted intervention can have broad consequences that lessen inequalities in achievement and health.

An important question facing society concerns the origins of inequalities between socially marginalized and nonmarginalized groups. Among the most consequential of inequalities is the poorer school and health outcomes experienced by African Americans, Latino Americans, and other non-Asian ethnic minorities relative to European Americans. These differences occur at all levels of socioeconomic status (*1*–*3*).

Although many structural factors contribute to these inequalities, the present research examines a psychological factor: concern about social belonging. Social belonging—a sense of having positive relationships with others—is a fundamental human need (*4*, *5*). Social isolation, loneliness, and low social status harm not only subjective well-being (*6*) but also intellectual achievement (*7*) and immune function and health (*8*–*11*). Even a single instance of exclusion can undermine well-being (*12*, *13*), intelligence quotient (IQ) test performance, and self-control (*14*).

Members of socially stigmatized groups, such as African Americans, may be relatively more uncertain about their social belonging in mainstream institutions like school and work (*7*). Because their ethnic group is often negatively stereotyped and marginalized, they may be unsure of whether they will be fully included in positive social relationships in these settings (*2*). As the sociologist Erving Goffman wrote, "The central feature of the stigmatized individual's situation in life…is a question of…'acceptance'" (*15*). Uncertainty about belonging, especially when chronic, can undermine minorities' performance (*7*, *16*) and health (*3*, *17*, *18*). Social belonging may thus constitute a psychological lever where targeted intervention could yield broad benefits.

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Such an intervention is reported here. Critical to its rationale is the insight that it is people's subjective interpretations of the quality of their relationships, more so than the objective number or attributes of those relationships, that strongly affects well-being (*5*, *19*). The present intervention, delivered to students during the challenging transition to college, was designed to encourage nonthreatening interpretations of adversity. During the transition to a new school, students can face frequent social setbacks and feelings of isolation. Their well-being and performance may depend, to a great extent, on whether they construe such experiences as evidence that they do not belong.

Because African-American students experience relatively greater uncertainty about their belonging in school, they were expected to benefit from the intervention more than nonminority students (*7*). Further if, as we intended, the intervention triggered an enduring perceptual change in the encoding of social experience, its effects might persist over time. Short-term effects might compound into long-term effects through a recursive virtuous cycle, in which early performance gains assure students of their belonging in school, which in turn improves their performance, in a repeating feedback loop (*20*). Students who feel more assured of their belonging may also initiate more social interactions and form better relationships on campus, facilitating their social integration and further benefiting their well-being, performance, and health (*21*).

The intervention was delivered to two cohorts of African-American (N = 49) and European-American (N = 43) students in the second semester of their first year at a selective college (*22*, *23*). To assess psychological responses to adversity, we asked participants to complete daily surveys in the first week after the intervention. To assess their long-term sense of belonging, health, and well-being, we asked them to complete an end-of-college survey 3 years later (completion rate 78.26%) (*23*). At the end of this survey, participants were asked to authorize the release of their complete college academic transcript (authorization rate 97.22%) (*23*).

Participating students were randomly assigned to either the belonging-treatment condition or a control condition. In cohort 1, participants were recruited through convenience sampling; in cohort 2, through random sampling (*23*). An additional campus-wide control group was obtained by collecting the anonymized official grade-point averages (GPAs) of all European Americans (N = 1362) and African Americans (N = 194) in the same class years as participants but who did not participate in the study (*23*). This group was included in secondary analyses of GPA.

The intervention provided students with a narrative that framed social adversity in school as shared and short-lived (*24*). This message encouraged students to attribute adversity not to fixed deficits unique to themselves or their ethnic group but to common and transient aspects of the college-adjustment process. Upon arrival in a research lab, participants read a report of the ostensible results of a survey of more senior students at their school. Most students, the report indicated, had worried about whether they belonged in college during the difficult first year but grew confident in their belonging with time. The survey results were said to be consistent across ethnic and gender groups. For instance, one survey respondent was quoted as saying, "Freshman year even though I met large numbers of people, I didn't have a small group of close friends…I was pretty homesick, and I had to remind myself that making close friends takes time. Since then…I have met people some of whom are now just as close as my friends in high school were" (*23*). Concerns about belonging were thus represented as common at first, as temporary, and as due to the challenging nature of the college transition.

To encourage participants to internalize the message, several steps exploited the "saying-is-believing effect"—the tendency to endorse messages that one has freely advocated (*25*). Participants were asked to write an essay describing how their own experiences in college echoed the experiences summarized in the survey. They then turned their essay into a speech, which they delivered to a video camera. These materials, participants were told, would be shown to future students to help ease their transition to college. Beyond facilitating internalization, this procedure averted the potential stigma of receiving an intervention, because it encouraged participants to see themselves as benefactors and not as beneficiaries (*24*, *26*). In the control condition, the procedure was the same but the survey addressed topics unrelated to belonging (e.g., change in social-political attitudes) (*23*). The intervention lasted about 1 hour.

Few analyses were moderated by cohort (i.e., no more than would be expected by chance alone and none involving the primary outcomes of GPA, health, or well-being). Thus, data from the two cohorts were combined to increase statistical power. First, analyses examined the trajectory of students' official GPA over time. In contrast to all other groups, African Americans in the control group showed no improvement in GPA from the fall of their freshman year, the semester before the intervention, through their sophomore, junior, and senior years [linear trend $F < 1$]. By contrast, the GPAs of intervention-treated African Americans rose over time [for linear trend, $F(1,34) = 13.79$, $P = 0.0007$; for time × condition, $F(1,34) = 4.16$, $P = 0.049$]. The GPAs of European-American students also rose over time [$F(1,29) = 6.88$, $P = 0.014$] with no difference by condition [$F < 1$]. As Fig. 1 shows, the intervention set African Americans on an upward trajectory such that the gap between them and their European Americans classmates closed over time. By students' senior year, the gap was cut by 79% (*23*).

Multiple regression, with student gender controlled, tested the effect of student race and condition (randomized control versus social-belonging treatment) on change in GPA—mean postintervention GPA (sophomore through senior years) minus mean preintervention GPA (fall term, first year) (*23*). There was no condition effect on preintervention GPA for either racial group [t values < 1] (table S1) (*23*). However, a significant condition effect on change in GPA emerged for African Americans [$B = 0.30$, $t(65) = 2.54$, $P = 0.014$] with no effect for European Americans [$t < 1$] [race × condition $B = –0.43$, $t(65) = –2.41$, $P = 0.019$]. Virtually identical results were obtained when preintervention GPA was used as a covariate in an analysis of postintervention GPA [treatment effect for African Americans, $B = 0.24$, $t(64) = 2.65$, $P = 0.010$; treatment effect for European Americans, $t < 1$; race × condition: $B = –0.31$, $t(64) = –2.27$, $P = 0.027$]. The intervention closed the minority gap in 3-year GPA (SD = 0.36) from 0.29 points in the control condition to 0.14 points in the treatment condition, a 52% reduction.

Adding the campus-wide sample further supports treatment efficacy. An agreement with uni-

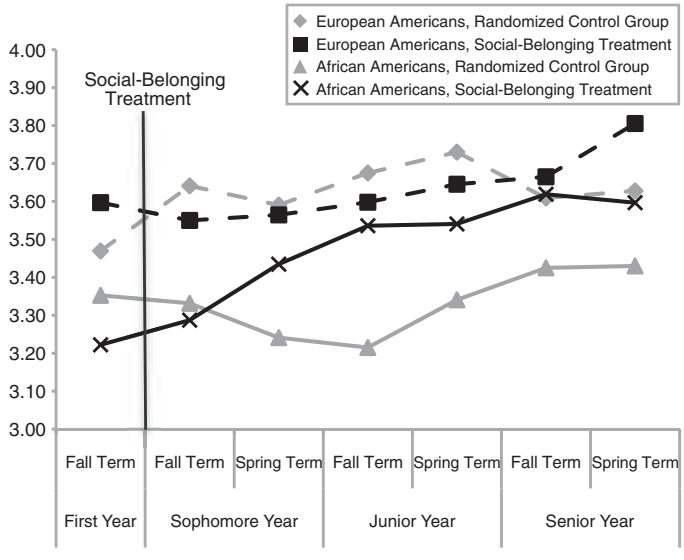

Fig. 1. Raw GPA by student race, experimental condition, and academic term. Means are noncumulative and were combined across cohorts. Ranges in sample sizes and standard errors for European Americans are N = 25 to 33 and SE = 0.08 to 0.14; for African Americans, N = 30 to 37 and SE = 0.09 to 0.12.

versity officials precludes the reporting of raw or adjusted means in this sample. To honor this agreement but present the results graphically, we performed analyses on residual postintervention GPA with preintervention GPA and gender controlled. Multiple regression on change in GPA and on raw postintervention GPA with preintervention GPA included as a covariate yield virtually identical results (*23*). As shown in Fig. 2A, treated African Americans had higher residual GPA scores than did African Americans campus-wide [$B = 0.28$, $t(1620) = 3.97$, $P = 0.00008$] and African Americans in the randomized control group [$B = 0.24$, $t(1620) = 2.62$, $P = 0.009$]. The latter two groups did not differ [$t < 1$]. (Fig. 2A) (*23*).

Illustrating its broad impact, the intervention tripled the percentage of African Americans earning postintervention GPAs in the top 25% of their class, as measured by both residual and raw postintervention GPA, and tended to reduce the percentage of African Americans performing in the bottom 25% of their class on both indices (Fig. 2, B and C) (*23*).

What accounts for these treatment effects? Daily surveys, collected the week after the intervention, suggest that the intervention buffered African Americans against adversity (*23*). Among untreated African Americans, feelings of belonging in school rose and fell with the degree of adversity students reported having experienced earlier that day and the day before. As adversity rose, belonging fell (mean within-subjects $R = –0.45$, derived from the average of individual participants' within-subjects correlations, after each was subjected to a Fisher *r*-to-*z* transformation) (*23*). For treated African Americans, this relationship was reduced to nil [mean within-subjects $R = 0.01$], a significant reduction [$t(59) = 2.99$, $P = 0.004$]. In summary, the intervention robbed adversity of its symbolic meaning for African Americans, untethering their sense of belonging from daily hardship (*27*). Like treated African Americans, European Americans showed little relationship between adversity and belonging [for both conditions, mean within-subjects $R = –0.09$; condition difference, $t < 1$] [race × condition: $t(59) = –2.04$, $P = 0.046$].

These results provide a window into the shift in African-American students' psychology caused by the intervention. This shift benefited their long-term performance. African Americans whose belonging was more robust to daily adversity—whose sense of belonging was relatively independent of their day-to-day adversity—showed greater improvement in their 3-year postintervention GPA [$R = 0.51$, $P = 0.001$] (*23*). The effect of the intervention in protecting African-Americans students' sense of belonging from daily adversity mediated its effect on their GPA (*23*). The intervention thus planted a change in social perception that, it appears, accompanied students long after the intervention ended to affect their performance in college.

Three years after the intervention, at the end of their college tenure, participants completed a survey to assess long-term effects on psychology, well-being, and health. Also, to assess whether the intervention operated beneath conscious awareness, we asked participants whether they remembered the intervention from 3 years previously, whether they thought it had affected them, and whether they agreed with its message. On no outcome did European Americans differ by condition [t values < 1.35, P values > 0.18]. African Americans, however, showed consistent treatment effects. The race × condition interaction was not always significant, indicating that the treatment effect was not always larger for African Americans than for European Americans. Degrees of freedom vary because some measures were completed only by participants in cohort 2 (*23*).

If the intervention lessened how much African Americans' belonging fluctuated with adversity, and if it did so by lessening how much they viewed campus life through the lens of race, then intervention-treated African Americans should (i) report greater stability and less uncertainty about their belonging in school {less agreement with items like, "When something bad happens, I feel that maybe I don't belong at [school name]"} (*7*) and (ii) exhibit less cognitive accessibility of negative racial stereotypes and self-doubt (*23*). They did [self-reported belonging uncertainty, $t(36) = –2.01$, $P = 0.052$; accessibility of negative racial stereotypes, $t(66) = –2.01$, $P = 0.049$; accessibility of self-doubt, $t(64) = –2.64$, $P = 0.010$] (Fig. 3) (*23*).

Given the importance of social belonging for reducing stress and improving immune function and physical health (*5*, *8*–*11*, *19*) and the relatively poorer health experienced by African Americans, even those high in socioeconomic status (*3*), we examined effects on health. We assessed self-reported health, an important predictor of morbidity and mortality (*28*), using the five-item general health component of the Medical Outcomes Study Short-Form Health Survey (*23*). We also asked participants how many times they had visited the doctor in the previous 3 months (cohort 1) or 1 month (cohort 2). African Americans reported being healthier and visiting the doctor less frequently in the treatment condition than in the control condition [$t(32) = 2.48$, $P = 0.019$ and $t(63) = –2.23$, $P = 0.030$,

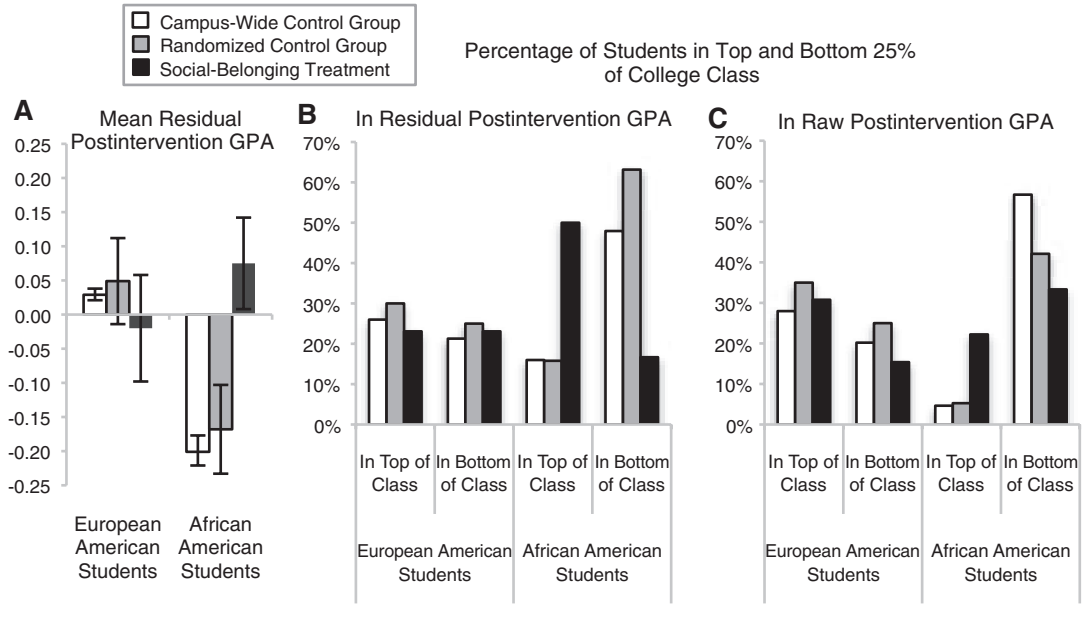

Fig. 2. Cumulative academic performance from sophomore through senior year. Data were combined across cohorts. **(A)** Residual sophomore-through-senior-year GPAs adjusted for student gender and preintervention (fall term, first year) GPA. Error bars represent ±1 SE. Means represent the degree to which students performed better (positive values) or worse (negative values) than expected after the intervention in GPA units based on their gender and preintervention performance. **(B)** Percentage of students in the top and bottom 25% of their college class in residual postintervention GPA (i.e., postintervention GPA adjusted for student gender and preintervention GPA). **(C)** Percentage of students in the top and bottom 25% of their college class in raw postintervention GPA. For analytic details, see (*23*). Sample sizes for European Americans are $N_{\text{campus-wide control group}} = 1362$ and $N_{\text{experimental groups}} = 33$; for African Americans, $N_{\text{campus-wide control group}} = 194$ and $N_{\text{experimental groups}} = 37$.

respectively] (Fig. 4, A and B). Whereas 60% of untreated African Americans had seen a doctor recently, only 28% of treated African Americans had [$\chi^2(1, N = 38) = 3.98$, $P = 0.046$]. The race gap in self-reported health was eliminated in the treatment condition; interestingly, there was no gap for doctor visits (*23*). Future research should examine whether these patterns generalize to physiological and physical indicators of health (*9*) to assess the robustness of the effect beyond self-report outcomes and to identify biological pathways (*11*).

As further evidence of improved well-being, African Americans also scored higher on the Subjective Happiness Scale (*23*) [$t(35) = 2.61$, $P = 0.013$] (Fig. 4C). The happiness gap with European Americans higher than African Americans disappeared in the treatment condition (*23*). The finding of a lasting positive impact on subjective happiness is noteworthy in light of research showing that individual happiness is relatively stable (*6*).

Participants were unaware of the intervention's effect, suggesting that its efficacy did not depend on conscious awareness. Most students reported that they remembered participating in the study 3 years earlier (79% did). But when asked to describe "the most memorable and important" information they had learned in the study, few recalled the key content of the survey they had read (8% did), and few reported that the study had had "any" effect on their college experience (14% did) (table S3). There was no condition difference on any of these outcomes for African Americans [$\chi^2(1, N = 37$ to $38)$ values < 1.40, P values > 0.20]; treated African Americans ascribed no more effect to the study than untreated African Americans. However, indirect measures of recall and beliefs did show treatment effects. When asked to "guess" the process of change described in the survey they had read, more treated than untreated African Americans wrote that it concerned how students' social experiences in college improve over time (50% versus 20%) [$\chi^2(1, N = 38) = 3.79$, $P = 0.052$]. Additionally, treated students endorsed this message. When asked to describe their own experiences, more treated than untreated African Americans volunteered that their own social experiences in college had improved over time (50% versus 20%) [$\chi^2(1, N = 38) = 3.79$, $P = 0.052$]. The subtle nature of this intervention, with its influence occurring outside conscious awareness (*29*), may contribute to its efficacy. In some cases, conscious awareness may undo the effects of an intervention (*30*). More overt interventions risk sending the stigmatizing message that the beneficiaries are seen as in need of help. They may also cause resistance and reactance and undermine the sense of accomplishment people take in their success (*26*).

This study provides an experimental, longitudinal demonstration that a brief intervention to buttress feelings of social belonging can have significant effects on a wide range of important outcomes. The social-belonging intervention improved the academic performance, self-reported health, and well-being of ethnic minority students over 3 years. The results suggest that inequality between marginalized and nonmarginalized groups arises not only from structural factors but also from concern about social belonging.

This concern can be mitigated by using a psychological remedy. The intervention provided students a nonthreatening frame for interpreting the daily challenges of school. By encouraging students to adopt this message as their own, the intervention made this message stick psychologically. Along with other recent research, this study highlights how the impact of adversity depends on its perceived meaning—how it is subjectively construed (*24*–*26*, *31*–*33*). Changing subjective construal is a fruitful avenue for intervention because many events are ambiguous and amenable to multiple interpretations. Moreover, a change in construal can become self-reinforcing. Students who feel confident in their belonging may experience the social world in a way that reinforces this feeling. They may initiate more relationships and thus obtain more opportunities for belonging and growth. Brief interventions that shore up belonging can thus promote performance

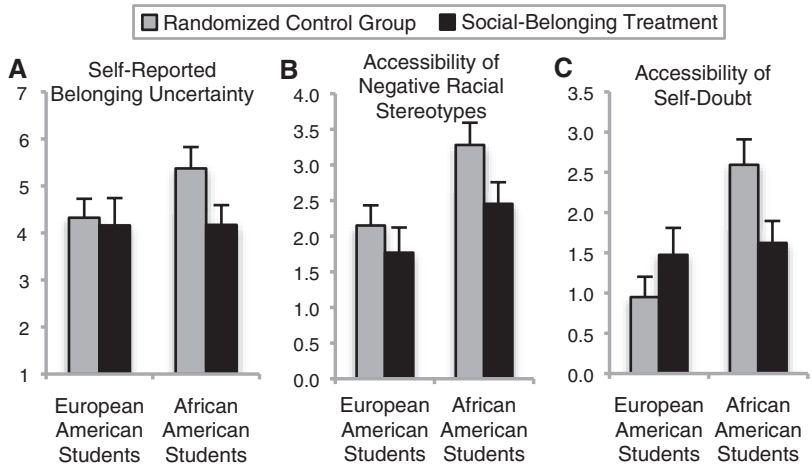

Fig. 3. Self-reported belonging uncertainty and the cognitive accessibility of negative racial stereotypes and of self-doubt 3 years postintervention. Error bars represent ±1 SE. Data were combined across cohorts where measures were completed by both cohorts. (**A**) Self-reported belonging uncertainty (cohort 2). (**B**) Accessibility of negative racial stereotypes (cohorts 1 and 2). (**C**) Accessibility of self-doubt (cohorts 1 and 2). The *y* axis in (A) represents the full range of the scale. The *y* axes in (B) and (C) represent about 3.00 standard deviations. Sample sizes in cohort 2 only are $N_{\text{European Americans}} = 20$ and $N_{\text{African Americans}} = 23$. Sample sizes in cohorts 1 and 2 are $N_{\text{European Americans}} = 31$ and $N_{\text{African Americans}} = 38$.

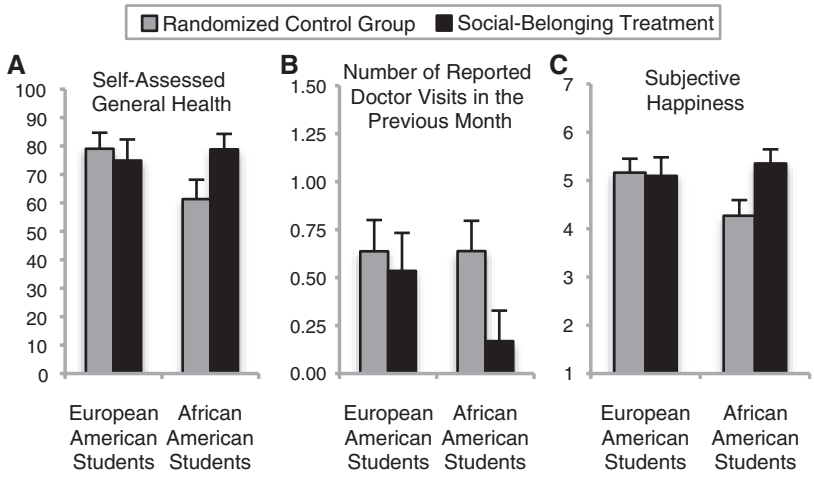

Fig. 4. Self-reported health and happiness 3 years postintervention. Error bars represent ±1 SE. Data were combined across cohorts where measures were completed by both cohorts. (**A**) Self-assessed general health (cohort 2). (**B**) Reported doctor visits in the previous month (cohorts 1 and 2). (**C**) Subjective happiness (cohort 2). The *y* axes in (A) and (C) represent the full range of each scale. The *y* axis in (B) represents about 2.00 standard deviations. Sample sizes in cohort 2 only are $N_{\text{European Americans}} = 20$ and $N_{\text{African Americans}} = 23$. Sample sizes in cohorts 1 and 2 are $N_{\text{European Americans}} = 31$ and $N_{\text{African Americans}} = 38$.

and well-being even long after their delivery (*7*, *20*, *25*, *31*, *34*).

Importantly, the effectiveness of social-psychological interventions depends on factors in the context. Such interventions are unlikely to be effective in contexts without opportunities for learning. Also, because the present intervention works by changing people's subjective interpretation of ambiguous events, it may be ineffective in openly hostile environments. Lastly, whether this intervention would work among younger or less-select students, or students from other marginalized groups, is an important question for future research (*20*, *31*, *34*). These qualifications noted, the results underscore the importance of social belonging and subjective construal in contributing to social inequality and show how this insight can inform our collective efforts to promote equality in performance, health, and well-being.

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Supporting Online Material

www.sciencemag.org/cgi/content/full/331/6023/1447/DC1
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Direct Interaction of RNA Polymerase II and Mediator Required for Transcription in Vivo

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Gene transcription is highly regulated. Altered transcription can lead to cancer or developmental diseases. Mediator, a multisubunit complex conserved among eukaryotes, is generally required for RNA polymerase II (Pol II) transcription. An interaction between the two complexes is known, but its molecular nature and physiological role are unclear. We identify a direct physical interaction between the Rpb3 Pol II subunit of *Saccharomyces cerevisiae* and the essential Mediator subunit, Med17. Furthermore, we demonstrate a functional element in the Mediator–Pol II interface that is important for genome-wide Pol II recruitment in vivo. Our findings suggest that a direct interaction between Mediator and Pol II is generally required for transcription of class II genes in eukaryotes.

Mediator is a large multisubunit complex conserved in all eukaryotes (*1*). It acts as a link between specific protein regulators and the RNA polymerase II (Pol II) transcription machinery (*2*). Mediator is required at most Pol II–transcribed gene promoters for regulated gene expression (*3*–*5*). In *Saccharomyces cerevisiae*, Mediator is composed of 25 subunits and is organized in four structural modules: the tail, middle, head, and Cdk8 modules (*6*). A direct Mediator–Pol II interaction is indicated by previous copurification, coimmunoprecipitation (CoIP) experiments (*7*–*9*) and by in vivo formaldehyde cross-linking (*10*). A model of the Mediator–Pol II complex determined by electron microscopy (EM) at 35 Å resolution suggests that several Pol II subunits (Rpb1, 2, 3, 6, and 11) might contact the middle or the head of Mediator (*11*). It was recently suggested that Rpb4 and Rpb7 could also be implicated in interactions with Mediator (*12*–*14*). However, the requirement of a direct interaction between Mediator and Pol II for transcription activation has not been demonstrated. Moreover, the identity of the Mediator subunits contacting Pol II is unknown because of the low resolution of the Mediator structure. As a consequence, the mechanism by which Mediator recruits Pol II is poorly understood.

To identify the subunit(s) of Mediator that directly contact Pol II and determine the role of these interactions in transcription regulation, we used an in vivo photo–cross-linking approach based on the incorporation by the cell-translation system of photo-activable analogs of methionine and leucine in proteins [see supporting online material (SOM) text and figs. S1 and S2] (*15*, *16*).

Because EM results (*11*) suggested potential interactions of 16 Mediator subunits belonging to the head (Med6, 8, 11, 17, 18, 19, 20, 22) and middle (Med1, 4, 5, 7, 9, 10, 21, 31) modules with Rpb1, 2, 3, 6, or 11 Pol II subunits, we immunoprecipitated hemagglutinin (HA)–tagged proteins after in vivo cross-linking. Among the 80 pairwise contacts that we tested, only Myc-tagged Rpb3 and HA-tagged Med17 cross-linked (Fig. 1). These results demonstrate that the Rpb3 Pol II

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