In addition to the C1/C2 polymorphism in human transferrin, position 589 toggles exclusively between proline and serine across the primate lineage (Fig. 2E and fig. S13), a potential signature of antagonistic pleiotropy at a largely constrained position, as observed for other host-pathogen interfaces (*7*). Previous work has also implicated the C2 transferrin variant as a risk factor for disorders involving iron metabolism, including Alzheimer's disease; however, these associations remain controversial and appear dependent on the populations tested and interactions with other susceptibility loci (*25*, *26*). Our findings provide a functional basis for human transferrin variation and establish an important role for nutritional immunity in recent human evolution.

Although canonical innate immunity factors have been appreciated as nodes of host-virus evolution, our work demonstrates that nutritional immunity has played a fundamental role in the survival of primate populations challenged by bacterial pathogens. *H. influenzae* and *N. meningitidis* remain a major source of morbidity and mortality in regions where vaccine coverage is poor (*27*, *28*) and drug-resistant *N. gonorrhoeae* is developing into an urgent public health threat (*29*). By illuminating the battle for iron as a major driving force of host-pathogen evolution, from 40 million years of primate divergence to emerging human epidemics today, our studies reveal new reservoirs of genetic resistance to infectious diseases.

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SUPPLEMENTARY MATERIALS

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POLITICAL SCIENCE

When contact changes minds: An experiment on transmission of support for gay equality

Michael J. LaCour[1] and Donald P. Green[2]

Can a single conversation change minds on divisive social issues, such as same-sex marriage? A randomized placebo-controlled trial assessed whether gay (*n* = 22) or straight (*n* = 19) messengers were effective at encouraging voters (*n* = 972) to support same-sex marriage and whether attitude change persisted and spread to others in voters' social networks. The results, measured by an unrelated panel survey, show that both gay and straight canvassers produced large effects initially, but only gay canvassers' effects persisted in 3-week, 6-week, and 9-month follow-ups. We also find strong evidence of within-household transmission of opinion change, but only in the wake of conversations with gay canvassers. Contact with gay canvassers further caused substantial change in the ratings of gay men and lesbians more generally. These large, persistent, and contagious effects were confirmed by a follow-up experiment. Contact with minorities coupled with discussion of issues pertinent to them is capable of producing a cascade of opinion change.

Foremost among theories of prejudice reduction (*1*) is the contact hypothesis (*2*), which contends that outgroup hostility diminishes when people from different groups interact with one another. Although contact is credited with reducing prejudice toward a wide array of outgroups (*3*), in practice it is often difficult to facilitate intergroup contact of sufficient duration to dispel negative stereotypes and build empathy. For this reason, research attention has recently focused on alternative interventions that may be deployed in a more compressed time frame. Examples include brief personal contact with outgroup members during the course of a conversation (*4*) and the "extended contact" that occurs when one learns that a close friend has experienced positive contact with an outgroup (*5*). The question is whether brief or indirect contact is sufficient to produce meaningful and enduring attitude change. Recent literature reviews have been tentative on this point, noting the lack of randomized experiments that track attitudes months after the intervention (*6*).

Our theoretical contribution is to introduce the distinction between active and passive contact, which are posited to produce different effects in the context of a brief intergroup encounter. Whereas passive contact involves personal exposure to an outgroup member (e.g., through collaborative activity), active contact involves, in addition, communication about an issue that divides the two groups (e.g., discussion of recent communal violence). The effects of active contact doubtless depend on whether the conversation is respectful or accusatory, but in principle, active contact has the potential to both reduce hostility toward outgroups and to change attitudes on divisive issues. Our empirical contribution is the first field-based experimental demonstration of persistent attitude change in the wake of active

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contact. The effects were substantively large among those who received the messages directly, and these effects diffused to other members of the receiver's household. Both direct and secondhand effects were estimated with a high degree of statistical precision, and findings were confirmed in a follow-up experiment.

Experimental design

Overview

Registered voters who had previously been enrolled in an Internet panel survey were contacted at their doorstep by canvassers. Random assignment determined whether contact was initiated by a gay or straight canvasser and whether the canvasser discussed the subject of same-sex marriage or recycling. Outcomes were assessed unobtrusively by online surveys conducted days, weeks, and months afterward.

Participants

Participants in the study were Southern California residents who (i) are registered to vote in precincts that supported a ballot measure banning same-sex marriage in 2008, (ii) reside at the same address as at least one other registered voter, and (iii) live in neighborhoods composed of detached dwellings (e.g., single-family homes). Using the publicly available California voter file as our sampling frame, we first recruited voters meeting the above criteria to participate in an online survey panel about politics. Second, in an effort to impanel multiple voters per household, individuals were offered additional financial incentives to refer their friends and family to participate in the survey panel. If the referred individual was a registered voter who met the above criteria, he or she was invited to participate in the study. Respondents received compensation for each successful referral. This recruitment procedure enables us to estimate how experimentally induced treatments diffuse through voters' social networks (*7*, *8*).

Random assignment

Households in which at least two registered voters completed the first wave of the online panel survey (29–30 May 2013) were randomly assigned to five experimental conditions. Simple random assignment occurred at the household level to facilitate the analysis of within-household spillovers. The first group was assigned to receive the same-sex marriage script from a gay canvasser. The second group was assigned to receive the same-sex marriage script from a straight canvasser. Groups three and four were encouraged to recycle household waste by gay or straight canvassers, respectively; however, canvassers did not reveal their sexual orientation when delivering the recycling script. The fifth group was a control group to which no canvassers were assigned. The resulting distribution of household assignments is described in table S3.

Canvassers and contact

Canvassers were recruited and trained by the Los Angeles LGBT Center, our nongovernmental organization partner. When approaching each targeted address, canvassers were instructed to (i) administer the assigned script to the first voter who answered the door, (ii) speak to only one voter per household, and (iii) confirm his or her name. The purpose of speaking with and identifying a single voter in each household is to facilitate the estimation of spillover effects due to within-household conversations, as explained below. Apart from a single canvassing conversation on 1 June 2013, neither the canvassers nor the center had further interaction with voters.

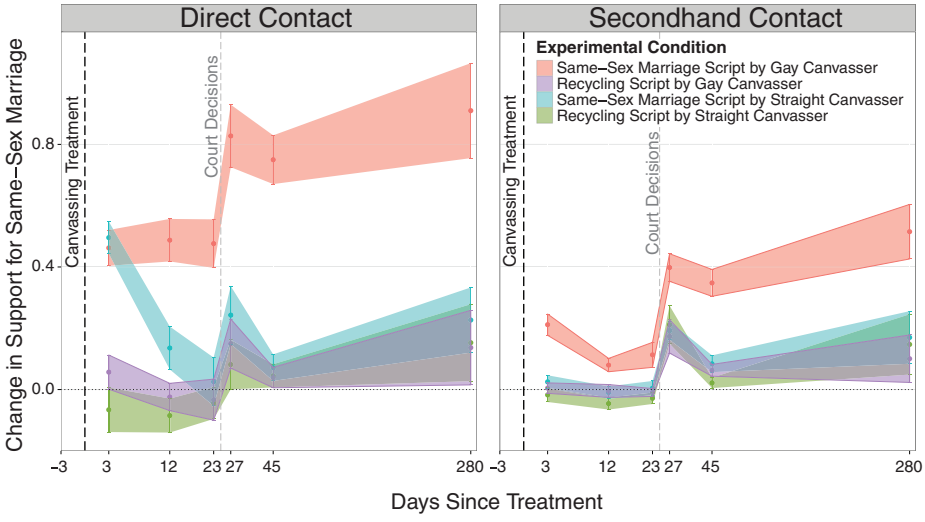

Fig. 1. Direct and secondhand effects on support for same-sex marriage, by assigned message and messenger, and time since treatment. The first vertical dashed line represents the canvassing intervention, which was administered between Internet survey waves 1 and 2. The second vertical dashed line represents the U.S. Supreme Court decisions striking down California's ban on same-sex marriage. The *y* axis is opinion change between the baseline survey and subsequent survey waves, with higher scores indicating more support for same-sex marriage. Points represent mean values, and bars display 95% bootstrap confidence intervals.

A survey administered to canvassers measured demographic attributes, canvassing experience, and sexual orientation. Table S1 shows that gay (n = 22) and straight (n = 19) canvassers are similar on dimensions other than sexual orientation. This characterization was confirmed by independent coders, who viewed videotaped recordings of the canvassers and rated their personal attributes and communication style (table S2).

Messages

Canvassers were coached to be polite and respectful at all times, to listen attentively to voters when discussing either same-sex marriage or recycling, and to refrain from arguing with voters. Talking points for the same-sex marriage and recycling scripts are presented in fig. S1. The same-sex marriage script invited voters to share their experiences with marriage. This script was the same for gay and straight canvassers, with one important exception. After establishing rapport with the voter, midway through the conversation gay canvassers revealed that they are gay or lesbian and that they would like to get married but that the law prohibits same-sex marriage. Straight canvassers instead described how their child, friend, or relative would like to get married but that the law prohibits same-sex marriage. Voters were asked to share their thoughts on this dilemma. These doorstep conversations lasted on average 22 min.

Outcome measurement

Before canvassers went into the field, the study first gathered baseline positions on a range of political attitudes for all participants, using an ostensibly unrelated online survey. The survey included 50 questions, as described in the supplementary materials. The two questions concerning same-sex marriage and feelings about gay people were buried amid a large number of items on unrelated topics, so that respondents would not suspect any connection between the survey and the canvassing visit. The panel survey included the two outcome measures in every wave, but the overall content of the survey was kept fresh by rotating new questions in each wave. Another important feature of the design concerns blinding of canvassers and survey respondents. Voters were unaware that the online survey was related to the canvassing effort, and canvassers had no knowledge that voters were participants in an online survey. Finally, to prevent housemates from completing each other's surveys, extensive precautions were taken, including issuing distinct personal login instructions to take differently named surveys, tracking of distinct IP addresses and session cookies, and sending invitations to take the survey during working hours (91% were in fact completed at work), when housemates would be less likely to be together.

Verifying design assumptions

Statistical tests presented in tables S4 to S7 confirm that (i) the assigned experimental groups have statistically indistinguishable background attributes and baseline opinions about same-sex

marriage; (ii) canvassers contacted a similar proportion of their intended targets, regardless of whether the message to be delivered concerned same-sex marriage or recycling; and (iii) survey panel attrition occurred at a similar rate across the five experimental conditions.

Identifying causal effects

Because voters who answered the door were randomly presented with either a treatment (same-sex marriage) or placebo (recycling) script, their average treatment effect may be estimated by comparing average outcomes among those who received the same-sex marriage script to outcomes among those who received the recycling script. All people who answered the door to canvassers were coded as receiving the script, regardless of the length of the ensuing conversation. In 11 cases, canvassers were told to go away before completing their script; we code these attempts as successful contacts for the purposes of (conservatively) estimating the average treatment effect among door-answerers (*9*), as explained in the supplementary materials. Treatment versus placebo comparisons may be further subdivided according to whether the canvasser was gay or straight, as every canvasser delivered both the same-sex marriage and recycling scripts in random sequence. In order to estimate the spillover effect of communication within the household, we compared the housemates of those who received the same-sex marriage script to the housemates of those who received the recycling script.

Results

Direct effects of conversations with canvassers

The left panel of Fig. 1 tracks responses to the same-sex marriage question among voters who conversed directly with canvassers in the four experimental conditions. The question reads: "Do you favor or oppose allowing gays and lesbians to marry legally?" Response options ranged from strongly oppose (1) to strongly favor (5). Outcomes displayed in Fig. 1 are the change in views toward same-sex marriage between the baseline survey and each post-treatment survey. The six post-treatment surveys occurred 3, 12, 23, 27, 45, and 280 days after canvassing took place.

Before the canvassing intervention, all four randomly assigned groups expressed similar views toward same-sex marriage. Three days after treatment, however, the groups diverged markedly. Figure 1 indicates that those receiving the recycling message became no more supportive of same-sex marriage. In contrast, those receiving the same-sex marriage message from gay canvassers became 0.46 scale points more supportive of same-sex marriage. Those who spoke with straight canvassers about same-sex marriage became 0.50 scale points more supportive. As Table 1 indicates, the latter two message effects are each statistically significant at $P < 0.0001$, using a two-tailed test.

The treatment effects for people who conversed with gay or straight canvassers are not only statistically significant; they are substantively large. Pooling over both types of canvassers, the estimated effect of the message is approximately 0.48. To put this estimate in perspective, note that when the same question was asked in the 2012 Cooperative Campaign Analysis Project (CCAP), an online survey of the national adult population, the average response of residents of Nebraska and Ohio (3.14) was roughly the same as the average response in the treatment group before visits from canvassers. The same-sex marriage script bumped the treatment group up by an average of 0.48 points to roughly the same mean as respondents from Connecticut and Massachusetts (3.61). On the issue of same-sex marriage, the canvassing treatment in effect transformed Midwesterners into New Englanders.

Tracing direct opinion change effects over time

The preceding discussion suggests that canvassing had a substantial effect on policy views expressed less than a week after the intervention. Although the treatment scripts employed by gay

Table 1. Experimental results. Support for same-sex marriage in study 1, by assigned message and messenger, form of contact, and time elapsed since treatment. Entries in plain type are the average changes in support for same-sex marriage, where changes are the difference from pretreatment survey responses (wave 1). Entries in boldface indicate the estimated average treatment effect of message for each messenger. The same-sex marriage question drawn from (*12*) reads: "Do you favor or oppose allowing gays and lesbians to marry legally?" Response options ranged from strongly oppose (1) to strongly favor (5), forming a five-point scale. "Treatment assigned" refers to the randomly assigned message and messenger pairings. "Contact" refers to whether the respondent spoke directly with a canvasser ("direct") or was the housemate of someone who spoke directly with canvassers ("secondhand"). *n* indicates the number of voters who answered each online survey, 5 days and 9 months post-treatment. See table S6 for the number of responses by condition and wave. Standard errors (shown in parentheses) are clustered at the household level for secondhand contact.

		Direct contact		Secondhand contact	
Treatment assigned		**Time since treatment**			
Message	Messenger	5 days	9 months	5 days	9 months
Same-sex marriage	Gay	0.46 (0.05)	0.91 (0.14)	0.21 (0.04)	0.52 (0.09)
Recycling	Gay	0.06 (0.05)	0.14 (0.11)	0.00 (0.02)	0.10 (0.07)
Treatment effect for gay messengers		**0.41 (0.07)**	**0.77 (0.18)**	**0.21 (0.04)**	**0.41 (0.11)**
n		242	184	437	324
Same-sex marriage	Straight	0.50 (0.05)	0.23 (0.10)	0.03 (0.02)	0.17 (0.08)
Recycling	Straight	−0.07 (0.07)	0.15 (0.11)	−0.02 (0.02)	0.15 (0.09)
Treatment effect for straight messengers		**0.56 (0.08)**	**0.07 (0.15)**	**0.04 (0.03)**	**0.02 (0.12)**
n		225	182	371	282

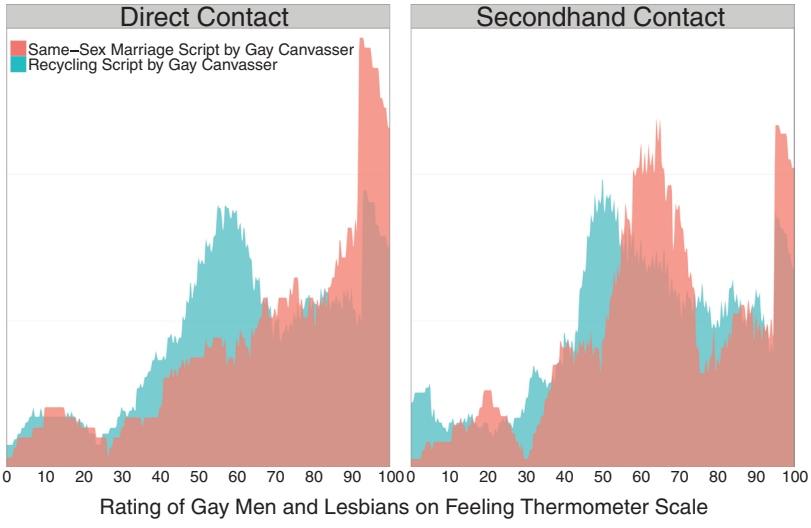

Fig. 2. Direct and secondhand contact effects on evaluations of gay men and lesbians 9 months after canvassing. The figure displays rectangular kernel density estimates of ratings of gay men and lesbians on the feeling thermometer scale 0 (unfavorable) to 100 (favorable) in study 1, among those contacted by gay canvassers. As shown in table S13, the large, persistent, and contagious effects of contact with gay canvassers on ratings of gay men and lesbians were replicated in study 2.

and straight canvassers were slightly different, they proved to be equally effective in changing minds in the short run. How long-lasting were these shifts in opinion? Those who discussed same-sex marriage with straight canvassers quickly reverted to their pretreatment baseline opinions, and 90% of the initial treatment effect dissipated a month after the conversation with canvassers. Some of the initial effect was revived in the immediate aftermath of the landmark Supreme Court decisions of 26 June 2013, which effectively legalized same-sex marriage in California. However, this surge in support, too, subsided within a few days. In contrast, among those who discussed same-sex marriage with gay canvassers, the treatment effects remained unabated after 1 month and strengthened markedly after the Supreme Court decisions. Nine months after their initial conversations with gay canvassers, those who conversed about same-sex marriage were 0.77 scale points more supportive of this policy than those who discussed recycling ($P < 0.0001$). Again, to put this treatment effect into perspective, note that in the 2012 CCAP survey, 0.78 scale points separate the states of Georgia and Massachusetts.

Spillover effects

How much of the canvassing effect was transmitted to housemates of the voters who answered the door? Figure 1 (right panel) presents housemates' average support for same-sex marriage, classified according to the experimental condition to which their household was assigned. Although housemates did not receive the gay equality message directly, our evidence strongly suggests that they were influenced by secondhand exposure to the treatment. Housemates of those who received the placebo treatments expressed opinions about same-sex marriage that were essentially unchanged over time. Those whose housemates conversed with gay canvassers about same-sex marriage became 0.21 scale points more supportive of same-sex marriage when surveyed 3 days later (two-tailed $P < 0.0001$). No apparent change occurred among respondents whose housemates conversed with straight canvassers about same-sex marriage. Although the spillover effect we observed after 3 days subsided 3 weeks later, it was rekindled after the Supreme Court decisions. Thereafter, all groups became more supportive of same-sex marriage initially, but those whose housemates conversed with gay canvassers about same-sex marriage moved significantly farther than their counterparts in other groups. Six months later, cohabitants of those who spoke with gay canvassers about same-sex marriage were 0.41 scale points more supportive of same-sex marriage than cohabitants of those who spoke with gay canvassers about recycling. The two-tailed P value of the estimated long-term spillover effect is just 0.0002.

A follow-up experiment to verify key findings

In August of 2013, we conducted a second study to verify the three key findings from study 1: large, persistent, and contagious effects of conversations with gay canvassers discussing same-sex marriage. All three findings were confirmed with similar effect sizes and P values of less than 0.001, as described in tables S10 to S13.

Further evidence suggesting causal mechanisms

Our results contribute new evidence to the literature on opinion change and prejudice reduction. Face-to-face appeals on behalf of same-sex marriage led people who conversed with canvassers to express substantially higher levels of support for this proposal when their views were measured a few days later. However, the script itself recedes in importance as we trace the effects over time or through voters' social networks. Gay and straight canvassers produced distinctive patterns of attitude change. Both gay and straight canvassers produced large effects of similar magnitude initially, but only gay canvassers' effects persisted in 3-week, 6-week, and 9-month follow-ups.

Three additional statistical results provide hints about the psychological process by which attitude change occurred in the wake of contact with gay canvassers. The first is that overall evaluations of gay men and lesbians became significantly more positive. Figure 2 shows how voters rated "gay men and lesbians" on a scale ranging from 0 (cold) to 100 (warm) 9 months after canvassing took place. Voters who spoke with gay canvassers about recycling gave ratings that were on average 4.5 points higher than their baseline rating before the intervention. In contrast, voters who spoke with gay canvassers about same-sex marriage offered average ratings that were 15.1 points higher than the scores they registered at baseline. This effect ($15.1 - 4.46 = 10.64$) is significant at $P < 0.001$ (table S8). A highly significant spillover effect ($10.25 - 3.23 = 7.02$) was also apparent among the housemates of those who spoke with gay canvassers about same-sex marriage (P value < 0.0001, table S9). The same-sex marriage script produced no such long-term direct or spillover effects when delivered by straight canvassers.

The preceding fact suggests that contact changes attitudes, but what evidence distinguishes active from passive contact? The second fact comes from a follow-up experiment conducted on a fresh set of voters drawn at random from the same pool of survey respondents. In this study, gay canvassers discussed either the subject of abortion or a placebo topic (recycling). Space constraints prevent us from describing the study in detail, but the key finding is that lengthy conversations with canvassers who revealed themselves to be gay while discussing abortion rights had no effect on people's opinions about same-sex marriage or gay people more generally. Evidently, the profound attitude change described in Fig. 1 hinges on active contact: discussing gay equality with an openly gay person.

A further indication of the distinctive impact of contact with gay canvassers is that their treatment message resonated throughout the household, as would be predicted by theories of extended contact (*10*). Only gay canvassers produced large and statistically significant secondhand effects on the housemates of those who came to the door. It may be that a conversation with a gay canvasser about same-sex marriage was more likely to be recounted to a housemate. Or it may be that the attitude change brought about by gay canvassers was more deeply felt by voters who participated in the conversation, which in turn made them more effective spokespersons for their newfound view. Interestingly, the secondhand effects of contact with gay canvassers were amplified after the Supreme Court decisions, suggesting that the extensive news coverage (*11*) surrounding this change in policy sparked new conversations and concomitant attitude change within treated households.

Our experimental results demonstrate that active contact is capable of producing a cascade of enduring opinion change. Further research is needed to assess the extent to which the strength, diffusion, and persistence of active contact's effects depend on how groups come together, the salience of their identities, the issues they discuss, and the manner in which deliberation takes place.

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SUPPLEMENTARY MATERIALS

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