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Testing the bargaining vs. inclusive fitness models of suicidal behavior against the ethnographic record

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ABSTRACT

Suicide is responsible for more deaths than all wars and homicides combined. Despite over a century of research on this puzzling and tragic behavior, and a recent increase in the number of treatments and intervention programs, it remains a global scourge. There is abundant research on suicidality in Western populations, but research on suicide among non-Western peoples is limited. Most notably, few studies analyze suicidality within small scale, non-industrial societies. Using ethnographic data from 53 cultures, this study tests two evolutionary theories of suicidal behavior: (1) deCatanzaro's inclusive fitness model, which proposes that successful suicide would increase the inclusive fitness of individuals with low reproductive potential who are a burden on kin, and (2) the bargaining model, which proposes that suicide attempts are a costly signal of need, with completed suicides an unfortunate byproduct. These models were operationalized into two sets of variables, which were used to code 474 textual accounts of suicide extracted from the Probability Sample of the Human Relations Area Files. Results indicate limited support for the inclusive fitness model, which might apply primarily to older adults in harsh environments, and widespread support for most elements of the bargaining model, especially among younger healthy adolescents and adults.

1. Theoretical Background

Suicide accounts for more deaths than all wars and homicides combined (Lozano et al., 2013). Theories of suicidal behavior (SB) in psychiatry emphasize risk factors, such as younger age and substance use, combined with stressors such as psychiatric illness (e.g., Mann, Waternaux, Haas, & Malone, 1999); those in psychology emphasize personality factors (e.g., perfectionism), emotional dysregulation, cognitive factors (e.g., defeat and entrapment), social factors (e.g., isolation), and negative life events (Brown, Comtois, & Linehan, 2002; Joiner, 2009; Linehan, 1993; O'Connor & Nock, 2014); and those in sociology emphasize population-level factors such as social integration, religion, unemployment, modernization, and migration (e.g., Durkheim, 1897; Stack, 2000). Despite the identification of factors that contribute to suicidal behavior, a recent review concluded that "they mostly do not account for why people try to end their lives" (O'Connor & Nock, 2014, p. 73). Suicidal behavior, in short, is an unsolved problem.

All behaviors are either the functional output of psychological mechanisms, byproducts of mechanisms that evolved for other reasons, or the product of dysfunctioning mechanisms. Most mental health researchers assume that SB is a consequence of one or more dysfunctions of evolved psychological mechanisms. However, evolutionary theorists have long recognized that increasing fitness can come at the expense of survival (e.g., Stearns, 1992), raising the possibility that SB has one or more evolved functions. The aim of this study is to test two adaptationist theories of SB, the inclusive fitness model (IFM) and the bargaining model (BRM), using ethnographic data from a broad range of human cultures.

1.1. The inclusive fitness model

Self-sacrifice is seen in non-human species, such as among sterile castes of members of the order Hymenoptera for the purposes of colony defense, and in E. coli, which self-sacrifice to reduce the transmission of a bacteriophage to related organisms even if relatedness is somewhat low (deCatanzaro, 1981, Preti, 2007; Refardt, Bergmiller, & Kümmerli, 2013). deCatanzaro proposed that, in humans, an individual with low reproductive potential who, in addition, is imposing large fitness costs on biological kin, such as someone with a debilitating illness, would improve her inclusive fitness by committing suicide (deCatanzaro, 1981, 1984, 1991). Under this model, the goal of SB is death.

Supporting this model, cross-national suicide rates increase with age as, arguably, reproductive value decreases and burdensomeness on kin increases. Studies from Western nations show that suicidal ideation is tied to the perception of being "better off dead" or making others "better off." Some studies have shown an association between chronic pain and suicide (e.g. Ratcliffe, Enns, Belik, & Sareen, 2008). Perception of oneself as a burden on family is frequent in terminally ill populations, and, in

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one study, a "good death" limited the burden the patient put on her family (McPherson, Wilson, & Murray, 2007). There is a relationship between both physical and mental disorders with the desire for death. Pulmonary heart disease is associated with suicidal ideation even in the absence of clinical depression (Goodwin, Kroenke, Hoven, & Spitzer, 2003), for instance, and there is a high lifetime risk of suicide among schizophrenics (Hor & Taylor, 2010). Among college students, lower measures of health and low satisfaction in romantic relationships were associated with self-destructive motivation. The investigators also found an inverse relationship between maternal age and self-destructive motivation, concluding that the reproductive value of potentially burdened kin may moderate suicidal ideation (Brown et al., 2009). In recent psychological theories of SB, perceived burdensomeness plays a central role (e.g., Joiner, 2009; Van Orden et al., 2010).

1.2. The bargaining model

Most SB does not result in death. In the US, for instance, the rate of suicide attempts in young adults exceeds the rate of completions by factors of 10 to 100 or more, although this ratio diminishes with age (Fig. 1). Current research attempts to distinguish a spectrum of self harmful behaviors, ranging from self-harm with no intent to die (such as cutting), to suicide attempts with no intent to die, to attempts with intent to die (Nock et al., 2008), labeled with a variety of terms, such as deliberate self-harm (DSH), non-suicidal self-injury, suicide gestures, suicide attempts, parasuicide and so forth (Nock & Kessler, 2006). The population of suicide attempters is younger and female biased (Borges et al., 2010), whereas that of suicide completions is older and male biased (Värnik, 2012). There are also demographic differences between SB victims with, and without, intent to die (e.g., Nock & Kessler, 2006).

Though self-harm is distinct from suicide, self-harm is the biggest known risk factor for completed suicide (Sakinofsky, 2000). Hawton, Zahl, and Weatherall (2003), for instance, found a 66-fold increase in risk of suicide in the first year after an episode of self-harm, compared to the general population. Cooper et al. (2005) found a 30-fold increase in risk of suicide in a cohort treated for self-harm, compared to the general population. In a national cohort of individuals who committed non-fatal self-harm (n = 62,689), Tidemalm et al. (2015) found that at 1-year follow-up, the incident rate ratio (IRR) for completed suicide, relative to population controls, was 69.7 for males and 94.7 for females. For young adult women (20-29 years old), the IRR was 177. Non-suicidal self-harm is also associated with future suicidal ideation and attempts (Guan, Fox, & Prinstein, 2012). Conversely, perhaps one half to two-thirds of suicides have a history of self-harm (Cooper et al., 2005).

Because rates of non-lethal self-harm are dramatically higher than suicide (Fig. 1), these findings suggest that an important fraction of completed suicides could be the accidental result of particularly dangerous forms of deliberate self-harm. This possibility is reinforced by the finding that repeated episodes of self-harm increase the risk of death by suicide, relative to a single episode of self-harm (Zahl & Hawton, 2004).

Anthropologists have long recognized that a successful suicide by a valuable member of the community harms others by depriving them of the victim's contributions. Firth (1936, 1939) argued that SB is thus often a gambit to alter others' behavior by threatening them with such harm. A girl whose parents prevent her from marrying her choice of mate, for example, might threaten suicide, forcing them to accede to her wishes. Numerous anthropologists have documented similar patterns, in which powerless individuals employ SB to strike back at powerful others in anger, protest, or revenge (unlike Firth, however, most focused on completed suicides, e.g., Billaud, 2012; Brown, 1986; Counts, 1980; Fenton, 1941; Giddens, 1964; Hezel, 1987; Johnson, 1981; Malinowski, 1926).

Stengel, a psychiatrist, similarly noted that suicide attempts were typically in response to an intolerable social or emotional situation, involved sublethal self-injury, were made in settings where intervention by others was probable or inevitable, and involved prior threats. Suicide attempts were thus "appeals" to other human beings that involved a gamble with death, included motives such as spite and aggression, could elicit outpourings of sympathy and affection, and were, in some sense, "ordeals," successful passage through which rendered a favorable judgment on the attempter or resulted in some other desirable outcome (Stengel, 1952, 1956, 1960; see also Lukianowicz, 1975).

These strategic interpretations of suicide attempts have been framed in game theoretic terms as a costly signal of need, or bargaining strategy. An individual must garner support from social partners when her otherwise high potential fitness is severely constrained by circumstances that she cannot unilaterally ameliorate (powerlessness). When there is conflict with her social partners, however, and they cannot trust that the victim needs support, nor does the victim know if her social partners really value her, then costly signals can reveal this two-sided incomplete information, potentially leading to a mutually beneficial outcome (e.g., Cramton, 1992). Specifically, individuals whose fitness is severely constrained can afford to put their lives in jeopardy, whereas individuals

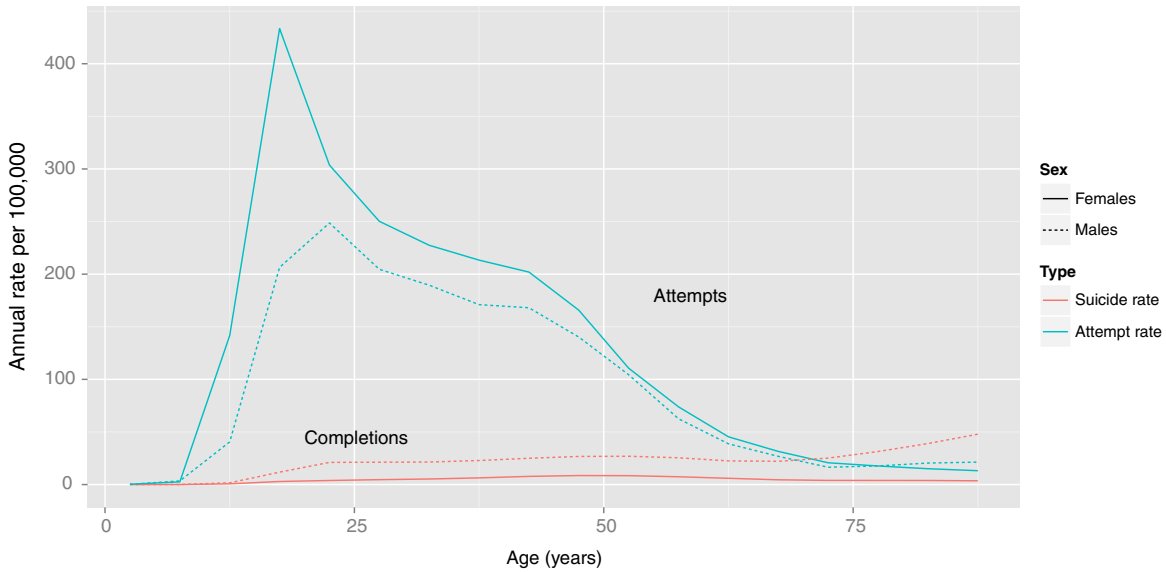

Fig. 1. Population rates of suicide attempts and completions in the US, 2001-2011. Note the especially high rate of attempts during the years of highest reproductive value: late adolescence to the mid forties. Data from CDC (2014). Non-fatal self-harm based on data from hospital emergency departments on confirmed or suspected injury or poisoning resulting from a deliberate violent act inflicted on oneself with the intent to take one's own life or with the intent to harm oneself. Mortality data come from the National Center for Heath Statistics.

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who are currently generating substantial fitness benefits cannot. Social partners who value the victim will provide help to prevent further SB, whereas those who do not value the victim will not provide help (e.g. Andrews, 2006; Hagen, 2002, 2003; Hagen, Watson, & Hammerstein, 2008; Nock, 2008; Rosenthal, 1993; Watson & Andrews, 2002). This strategy is comparable to the loud begging of baby birds that might attract predators to the nest, motivating the parents to provide more food (for review, see Mock, Dugas, & Strickler, 2011, and commentaries). Bargaining models can also accommodate situations with complete information, different commitment devices, and many other variations.

On this view, suicide *attempts* are the phenomenon of interest, and completed suicides are the accidental outcome of a risky strategy to influence social partners.

1.3. Proximate vs. ultimate explanations

The two models of SB tested here are *ultimate* explanations: they attempt to explain why the human species exhibits SB. Although both models posit that SB is an adaptation – that is, under certain conditions it delivered fitness benefits – neither model requires any conscious strategizing on the part of suicidal individuals. Specifically, suicidal individuals are not necessarily consciously trying to increase the reproduction of kin or bargain with them. Instead, these strategies would be realized as psychological adaptations that dramatically alter emotions and cognition. Most theories of SB, in contrast, involve *proximate* explanations, such as escaping psychological pain (e.g., Baumeister, 1990; Brown et al., 2002), which we will test in a future publication.

2. Methods

Virtually all cross-cultural and cross-national studies of suicide aim to account for the variation in rates across populations. This study, in contrast, does not address population variation in rates, which cannot be accurately determined from our dataset. Instead, it assesses the extent to which the social context of (mostly) completed suicides in the ethnographic record supports the IFM or the BRM or both.

The Washington State University Institutional Review Board certified this research as exempt. Data will be provided upon request.

2.1. Data collection

Data for this study were obtained from the Human Relations Area Files (HRAF), a database that contains over a million pages of primary ethnographic source material, such as books and articles, spanning several centuries (Ember, 2009). At the time of this study, documents on 281 cultures had been digitized and could be searched electronically (eHRAF).

We restricted our analyses to the Probability Sample, a stratified random sample of the eHRAF collection in which the world was divided into 60 culture areas and one culture from each area was randomly chosen from a list of societies that met certain data quality control criteria (e.g., the ethnographers stayed for more than a year) (HRAF website). We searched using the keyword 'suicid*', which located any paragraph containing words such as "suicidal" or "suicides". In addition, the HRAF has a paragraph-level index, the Outline of Cultural Materials (OCM), which includes hundreds of topics, one of which is suicide (OCM code 762). Using this index, all paragraphs that discussed suicide were located, even if the keyword 'suicide' was not mentioned. Each contiguous set of suicide-related paragraphs in each document constituted one "report."

The final data set was drawn from 213 documents (e.g., books, journal articles) that discussed suicide in 53 cultures (the remaining 7 cultures in the Probability Sample did not have any records on suicide). The oldest document was published in 1704 and the most recent in 2000. The large majority of documents (94%) were published in the 20th century (median year = 1963.5).

The quality of the reports was extremely heterogeneous, ranging from brief asides and footnotes on suicide, sometimes less than one sentence in length, to entire articles and chapters on the topic. For some cultures, there was only a single report; for others there were numerous reports. Some reports only discussed suicidal behavior in generalities, whereas others described specific cases.

Each report was further divided into *records* based on the appearance of one or more *cultural models* or one or more *cases*. The *cultural models* were cultures' evaluations, explanations, and various perspectives on SB (e.g., suicide in this culture is a form of anger). The *cases* were specific accounts of SB (e.g., so-and-so killed herself in despair). For example, if a report described three separate cases of suicide, and then offered a general account of suicide, this generated three case records and one cultural model record, for a total of four records.

2.2. Coding

Naive coders reduce the possibility of bias, but require considerable training to accurately code complex datasets. Expert coders can accurately code complex datasets with much less training, but might exhibit bias. Because our dataset was complex, involving hundreds of ethnographic descriptions of societies with a diverse range of subsistence, kinship, descent, and marriage systems, we decided to code the data using two independent expert coders (KS and ZG), both of whom were very experienced with the HRAF database, the ethnography of traditional societies, and with the two theoretical models of suicide. To reduce the possibility of bias, "evidence for" or "evidence against" a variable was only coded if such evidence was explicit in the text.

2.3. Operationalization

The IFM and BRM were operationalized into sets of 5 and 12 variables, respectively, for a total of 17 theoretical variables (see Tables 1a and 1b). Each variable was then evaluated in each record to determine if there was evidence for that variable (+1), evidence against that variable (−1), or no evidence (0). (We then recoded these 17 trichotomous variables into 23 binary variables; see below.)

Exact ages of victims were rarely available, so we assigned cases and cultural models to one of 4 age categories using textual clues (Table 2). For example, informants often evaluated the victim as "young", "old", or "a child." In other cases, details about the victim's life, such as a first marriage, indicated age. Some age categories could be reasonably excluded based on, e.g., mention of a spouse. Evidence for sex, marital status, and mental illness was coded as well.

To illustrate the coding process, including some of the challenges, we present the following example from the Central Thai (Sharp, 1978; p. 271):

> Disputes and grievances against kinsmen are frequently settled by suicide or attempted suicide: "Rim had two wives. About nine o'clock at night the second wife and husband slept together. Pum, the first wife, slept nearby. That night Rim heard noises where his first wife was sleeping. He found her trying to commit suicide by tying a blanket around her throat" – (LMH 6/29/53).A jealous husband was more successful in his effort to kill himself: "Before Wien died, he asked his wife, 'Do you love me?' Wife: 'Yes, I love you.' But Wien did not believe her. He took a razor and touched it to his neck. Wife cried and prayed to him. She then ran into the field to call her parents, who were working in the field. Suddenly she heard the sound of a gun" (LMH 6/30/53). Here the objective was apparently the indirect revenge of anguish and remorse, through assigning responsibility for one's death to another.

This report generated three records: one cultural model ("Disputes and grievances against kinsmen are frequently settled by suicide or attempted suicide"), and two cases involving adults, a female and a male. Although the coders agreed that there was no evidence for most

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Table 1a
Operationalization of the inclusive fitness model.

Variable	Example evidence
Low reproductive potential. The victim was unlikely to ever reproduce or invest in kin. Operationalized as old age, chronic illness, sterility, severe mental illness or similar conditions that, based on the evidence at hand, were unlikely to remit.	Old age: "And when she gets older, it is the custom for her to swim out to sea and commit suicide. Why? … She will stop and grow old, and there will be no son to look after her. So she commits suicide." Chronic illness: "Suicide is also very rare, though it is alleged that one man dying of tuberculosis killed himself some fifteen years ago." Sterility: "She also said she had by witchcraft damaged her own womb so that it had borne but one child." Impotence: "An impotent man may commit suicide because he will no longer have any control over his wives who might well leave him." Severe mental illness: "[The victim] at the last was reputed to have become melancholic and deranged."
Burdensomeness: costs victim imposed on others exceeded benefits he or she provided. Operationalized as severe chronic illness or physical impairment that burdened others, lack of contribution to the group, or causing harm to the group.	Severe physical impairment: "[The victim] was not only getting on in years, but her eyesight was fading and she couldn't sew anymore. …[E]verybody kidded her about being helpless." Low or no contribution to group: "A man…expelled his eldest son [the victim] who was a very unsatisfactory herdsman, and made his younger son the principal heir." Tremendous harm to group members: "Wakes-up-last [the suicide victim] murdered all of his children."
Motive: make others better off. Operationalized based on the cultural model or observations made by others.	Cultural model: "Not many years ago, if a man or woman became too old and feeble to run behind the dogs and could no longer contribute to the family, his or her death might become necessary. Usually in such cases the older people themselves asked a close relative to kill them." Observations made by others: "…she may have had a feeling, heightened by her friends' taunts, that it was time to get out of the way."
Motive: make kin better off. Operationalized based on cultural models or others' observations.	Cultural model: "…an elderly individual who viewed himself as an unnecessary and unproductive burden might request a kinsman to assist him in terminating his life."
Outcome: kin better off. Operationalized based on cultural models or others' observations.	Cultural model: "If in such a case the debt be not paid, and the creditor doth commit suicide, the debtor is bound to bear the funeral expenses in addition to paying the original debt and making substantial compensation to the family of the deceased creditor."

variables, they initially disagreed whether, in case 1, there was a threat to the fitness of the victim, and in case 2, whether there was conflict between the victim and his wife. During the consensus phase (described below), both coders agreed that in case 1, the husband sleeping with the second wife was evidence of a fitness threat to the first wife, and in case 2, that the husband's distrust of his wife was evidence of marital conflict.

We gave each record a quality score, with one point added for information on each of 9 categories: victim's sex, cause, method, motive, evidence of emotional states, evidence of cognitive states, accompanying behaviors, and information on the outcome. In addition, we coded more than 25 variables relevant to non-evolutionary models of suicide. These results will be reported in a future publication.

Interrater reliability was evaluated using several chance-adjusted statistics: Cohen's kappa, Gwet's AC1 (Gwet, 2001), and Bangdiwala's B (Muñoz & Bangdiwala, 1997). These statistics equal 0 when agreement equals that expected by chance and 1 when there is complete agreement. Although kappa is one of the most widely used statistics, it has several deficiencies, including paradoxically low values despite high agreement in certain situations, such as when some categories have low prevalence and there are few categories (e.g., Bakeman, McArthur, Quera, & Robinson, 1997; Feinstein & Cicchetti, 1990). Our data had few categories and was highly variable: the proportions of {−1,0,1}, were, respectively, 0.04, 0.83 and 0.14. Across all cells, kappa = 0.43. Entering the latter values into equation 2A in Bakeman et al. (1997), our rater accuracy was 86.3%. Gwet's AC1, which is the conditional probability that two raters will agree, given that no agreement will occur by chance, was 0.8; Bangdiwala's B was 0.79.

To produce a consensus dataset, the authors jointly re-coded every record for which there was disagreement, coming to agreement for all values in the data matrix.

There was very little evidence against variables: only 3.9% of the codings = −1. In order to use logistic regression, which requires dichotomous outcome variables, and non-negative matrix factorization (explained later), which requires values ≥0 we recoded the few -1 values to +1 as follows. Three variables had no negative values. Six variables were complimentary; for example, when "Low RP" = -1, "High RP" = +1, and when "Motive: make others better off" = -1, "Motive: harm others" = +1. For these variables, we set the negative values = 0 but retained the complimentary +1 values; thus, no information was lost. For five variables, we created five new complimentary variables. For instance, evidence against "Public suicidal behavior" was evidence for private suicidal behavior. We therefore created a new variable "Private suicidal behavior" whose values = +1 exactly when "Public suicidal behavior" = -1, and 0 otherwise. We then set all -1 values in "Public suicidal behavior" to 0. The four other variables were created similarly. Two variables had one -1 each. Rather than create complimentary variables that (almost) would not vary, we briefly discuss these two cases in the supplementary info.

Thus, our primary data set comprised an n × p matrix with values x_{ij} in {0,1}, where n = the number of records (474), and p = the number of variables (23), for a total of 10,902 cells.

2.4. Culture-level variables

The IFM and BRM both posit that their corresponding behavioral strategies evolved by natural selection. Hence, each model predicts that its strategy should be widespread across cultures (i.e., is a human universal). To determine if the evidence for and against each model instead differed by important cultural variables, we utilized the Standard Cross Cultural Sample (SCCS), which is independent of, and has different aims than, the HRAF. The SCCS comprises a sample of 186 cultures that have been assigned a single culture-level value for a large number of variables. There were 50 cultures in the SCCS that were either identical to, or very similar to, the cultures in the HRAF probability sample, which allowed us to characterize the cultures in our sample using the following SCCS variables: Descent system (e.g., patrilineal, matrilineal) (V70); Composite cultural complexity score (V158.1); Marital residence (e.g., matrilocal, patrilocal) (V69), and Polygyny (V79). For subsistence mode (e.g., hunter-gatherers, horticulturalists), we used the categories supplied by the HRAF.

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Table 1b
Operationalization of the bargaining model.

Variable	Example evidence
High reproductive potential. The victim had the *potential* to reproduce or invest in kin during the remainder of his or her natural life, operationalized as young age without evidence of ill health.	Young and no evidence of infirmity: "I also heard of a young man who shot himself because he was spurned by the girl he hoped to marry" Cultural model: "…suicide was not uncommon among young, heartbroken women."
Fitness threat. Events, such as loss of mate, loss of social status, loss of resources, and assault, that threaten high reproductive potential, but whose lifetime fitness consequences, if the victim lived, depended on the response of social partners.	Loss of mate: "Suicides and attempted suicides are rare but known, sometimes occurring over broken love affairs." Loss of status: "It is expected that people will despise a person of arrogance and that there will be much hostile gossip about him. The resulting shame has driven a number of persons to suicide." Rape: "There have been cases where the girl tries to commit suicide after that experience [gang rape]." Thwarted marriage: "One may still read stories in the newspapers of the suicide…of two lovers whose families forbade their marriage because they bore the same surname." Forced marriage: "She even attempted to commit suicide to escape his importunities [forced marriage]."
Powerlessness. Inability to unilaterally respond to fitness threat. Operationalized as explicit mention of powerlessness or low status.	Explicitly mentions powerlessness: "In desperation over their powerlessness to change things, some children decide that death is better than life." Imprisonment: "…George Traverse (d. 1914) committed suicide by hanging while in prison." Low social status: "women's suicides often signal acts of autonomy in a social and political context in which women are otherwise relatively powerless."
Conflict. Significant disagreements with social partners. Operationalized as marital, family, community, or political troubles or explicit mention of conflict.	Family conflict: "He criticized his father's brother's little boy for being a crybaby. His mother, who was caring for the child, became angry and struck Don, and he went off to the foothills and dug a pit in the sand. There he lay waiting for a cave-in to kill him." Community conflict: "In the recent past a man deserted his wife and children to live with another woman. Bound to the reserve, he faced daily social censure for his acts until he terminated his marginal position by suicide." Political conflict: "…Ming loyalists…committed suicide in protest against the Ch'ing dynasty"
Social partner fitness. Operationalized as social partners in conflict with the victim whose fitness was linked to the victim's, such as parents, offspring, and spouses. Excludes conflicts with, e.g., govt. agents	Kin: "A woman I had known in 1952 swam off to sea…because, it was said, she had a quarrel with her family." Spouse: "If…a man had committed suicide because his wife had treated him badly." Parent: "If a person struck his father, however, that would be too much. He would be expected to take a canoe and go out to sea, there to be lost–the favourite method of suicide."
Low Lethality. The method of suicide is not highly lethal. Operationalized as threat only, unsuccessful attempt, method that allowed rescue, or death only after several days.	Threat: "The threat of suicide is sometimes used as a bluff to get one's way." Method allows rescue: "A 22-year-old son who reportedly was dominated by his mother…ran out of the house, jumped into the water and started swimming out to sea. The screams of his sister finally alerted rescuers who went after him with a boat" Survival: "…in the earlier of these episodes the would-be suicide landed on soft ground, barely missing several rocks, and was only slightly injured."
Public suicidal behavior. Operationalized as suicide threats, presence of one or more witnesses, or explicit mention that attempts were typically conducted in public.	One or more witnesses present: "One evening she was seen standing on the edge of a high cliff in full view of the camp. The Indians heard her singing this same song to her dead lover, and then saw her jump to her death." Suicide threats: "Only threats of suicide by the couple finally forced the chief and the respective lineage heads reluctantly to give their consent…."
Angry SB. Suicidal behavior was motivated by anger. Operationalized as explicit mention that SB was motivated by anger, revenge, or similar emotions or motives.	Explicit mention: "Parents say they must be tolerant of defiance because they are afraid that, in his or her anger, the child might commit suicide to spite them." Revenge: "Young women…despairing at the cruelties of their mothers-in-law and desirous of revenge…drink poison or throw themselves off bridges or under trains…."
Motive: harm others. Operationalized as explicit mention of motive to harm others by killing oneself.	Explicit mention: "A powerless person unable to punish his enemy or obtain retribution for insults would often commit suicide, in order to force his own kin to carry out the punishment" Explicit mention: "I know some cases of boys and girls who were not yet twenty, and who killed themselves from spite...."
Outcome: others harmed. Operationalized as evidence of prolonged grief or similar negative impact on the family or community.	Prolonged grief: "[The young men's] deaths were a wrenching blow in a community still grieving for four youth who had hung themselves during the previous year." Guilt and regret: "…his only way for vengeance is to kill himself and let his tormentors suffer guilt thereafter." Social penalties: "If the man be false to his word, and the woman commits suicide, he is held responsible for the value of her life, and is very heavily fined…."
Motive: leverage. The victim seeks to influence the behavior of others. Operationalized as suicide threat to achieve desired outcome, or similar language	Threat: "After several years Theodore asked to be relieved of his duties as chief. He was refused but finally threatened in a public meeting to hang himself if his wish was not granted; at this he was permitted to resign and was replaced by Thomas." Threat: "…the man finally went to the Emir and said he was going to commit suicide…unless he could get his wife to return."
Outcome: victim better off. Operationalized as some tangible benefit to that could be linked to non-lethal SB.	"The boy was treated very harshly, so that he even tried to commit suicide. The[n] he was released in exchange for a new payment in live reindeer." "Only threats of suicide by the couple finally forced the chief and the respective lineage heads reluctantly to give their consent [to the marriage]."

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Table 2
Age categories, their assigned minimum and maximum ages, and the percent of text records referring to victims of that estimated age and sex.

Age category	Age range	Female	Male	Both sexes	Unknown sex	Total
Child	5-14	1.1	0.8	0.0	1.3	3.2
Adolescent	15-19	5.9	5.9	0.8	1.7	14.4
Adult	20-60	17.2	23.8	1.3	35.5	77.7
Elderly	61-90	1.7	1.7	0.0	1.3	4.7
Total		25.9	32.3	2.1	39.7	100.0

2.5. Statistical analysis

The data had a complex hierarchical structure: records were nested within documents, which were nested within authors, who were nested within cultures, which were nested within regions. Because, in the Probability Sample, one culture was selected to represent each culture area (i.e., cultures were putatively independent), we modeled the nested structure of the data as records grouped by author, and authors grouped by culture. We estimated parameters and their standard errors using either generalized linear mixed models (Bates, Mächler, Bolker, & Walker, 2014), or with a cluster bootstrap (Ren et al., 2010; Shotwell, 2014) using R (R Core Team, 2015).

3. Results

The data set consisted of 224 cases and 250 cultural models of suicidal behavior (474 total records), obtained from 228 ethnographic documents, written by 184 authors regarding 53 cultures whose geographic distribution and modes of subsistence are shown in Fig. 2. The number of records per culture ranged from 1 to 40, with a median of 4. Cultures with the largest number of records tended to contain multiple documents by the same author(s) who dedicated significant portions of their writings to the problem of suicide, as occurred among, e.g., the Chukchee, Tikopia, and Chuuk.

Case scores ranged from 0 to 8, with a median score of 4, which meant that half the cases had information on 4 or more of the following: age, sex, cause, method, motive, evidence of emotional states, evidence of cognitive states, accompanying behaviors, and information on the outcome.

We characterized the basic textual content of the records by removing all punctuation and English stop words (i.e., uninformative words such as *the, is, at*), and then stemming the remaining words (i.e., reducing inflections such as plurals and past tenses to the root, or stem, words). The word count of the records in the resulting corpus ranged from 2 to 3384, with a median of 33 and a mean of 65.1. There were fewer words, on average, in cultural models than in cases (39.2 vs. 93.9, $t = 3.3$, $p = 0.001$).

3.1. Age and sex

Most records involved adults of indeterminate age (Table 2). We had four sex categories (male, female, both, unknown). Most cultural models of SB did not specify a sex (67.6%), but if they did, it was more often female (19%) than male (13.4%). In contrast, most cases did specify the sex of the victim (91.07%), and it was more often male (53.1%) than female (33.5%). There were no major differences in the distribution of age by sex (Table 2).

Most SB involved completions (84.6%), and was usually an individual act (93.9%) with only a handful involving two or more persons. The one notable age pattern was the greater fraction of threats in juveniles compared to adults and elderly. See Fig. S1.

3.2. Theoretical variables

Each record was coded on 23 theoretical variables: 86.9% of the records were informative concerning at least one theoretical variable, 56.5% were informative concerning 3 or more variables (the mode), and 13.1% of the records provided no evidence on any of the variables. Thus, this data set was informative about the theoretical models under consideration.

Levels of evidence were largely similar in cases vs. cultural models. However, across variables, there were usually more cultural models with 'no evidence' than there were cases with 'no evidence'. This suggests that descriptions of cases in the ethnographic record are capturing theoretically important aspects of suicide that are often not captured in the cultural models. Nevertheless, given the similar levels of evidence in cases and cultural models, the two types of records will be combined in subsequent analyses, using author as a grouping variable.

For each of the 23 theoretical variables, we computed the percentage of records that provided support, estimating standard errors using a binomial generalized linear mixed effects model with a random intercept for author nested within culture. The most strongly supported variables – fitness threat and conflict – were supported by just under 50% of the records. See Fig. 3, blue bars.

To calculate the percentage of cultures that provided support for a particular theoretical variable, we deemed a culture to support a variable if at least one record from that culture supported that variable. We estimated standard errors using a cluster bootstrap. The most strongly supported variables – fitness threat and powerlessness – were supported in about 85% of the cultures. See Fig. 3, red bars.

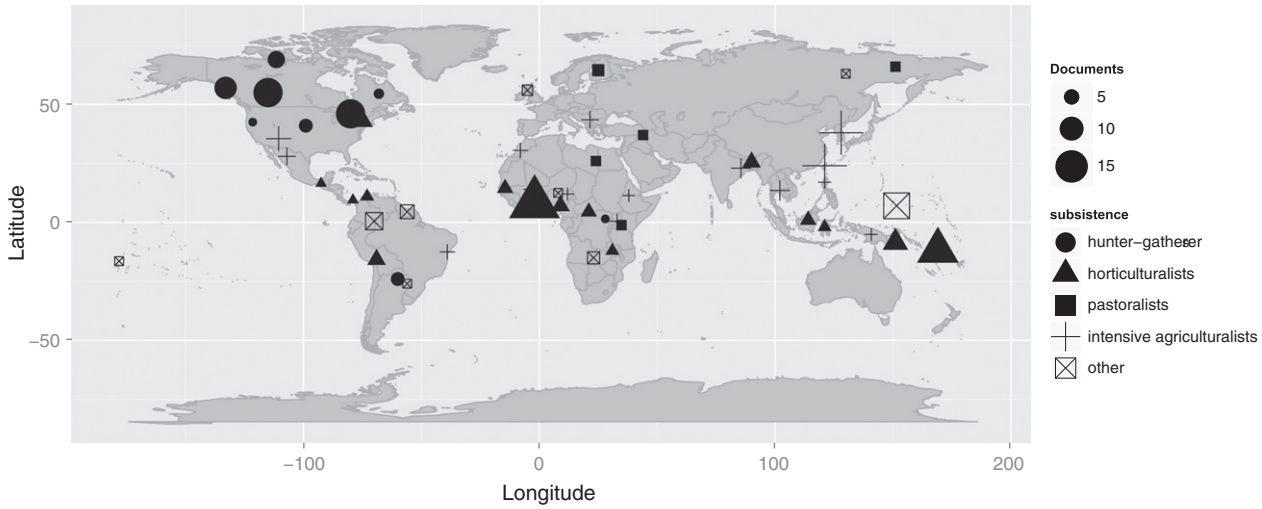

Fig. 2. Geographic location of cultures in the data set. Symbol size is proportional to the number of books, journal articles, and other documents from that culture.

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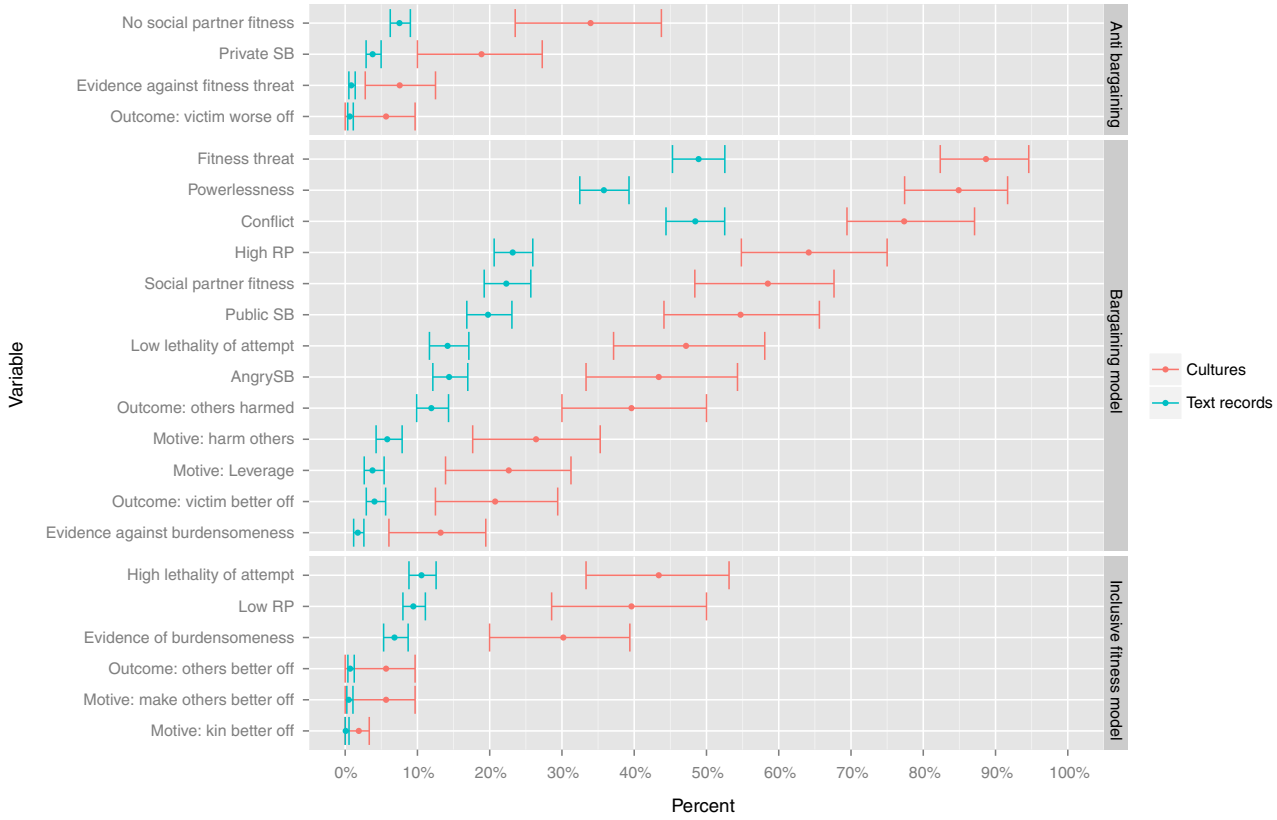

Fig. 3. Summary of the evidence for all theoretical variables, grouped by those that refute the bargaining model (top), support the bargaining model (middle), and support the inclusive fitness model (bottom). Blue bars represent the percent of records that support each variable (+/− 2SE). Means and standard errors estimated with a generalized linear mixed effects model with a random intercept for document authors nested within cultures. Red bars represent the percent of cultures for which at least one record supports that variable (+/− 2SE). Standard errors estimated with a cluster bootstrap.

A few text records (13.1%) provided no evidence for any theoretical variables. These uninformative records had significantly fewer words, on average, than did records providing evidence for at least one variable (25.9 vs. 70.9 words, $t = 4.7$, $p = 0$), and significantly lower case scores (1.8 vs. 3.8, $t = 5.2$, $p = 5.25 \times 10^{-5}$). This suggests that these text records were often simply too short to provide much information about SB. The following is the complete text of a typical uninformative record (Bogoraz-Tan, 1909; p. 46-47):

> At the head waters of the river Omolon I met a family four of whose members had taken their own lives within four years without any apparent reason. Their neighbors felt much afraid, and expressed the opinion that the spirits who wanted more prey had treacherously led them on to self-destruction.

The uninformative records included 40 cultural models (out of 250 total): 8 indicated whether or not suicide was a sin or socially sanctioned; 7 linked suicide to demons, spirits and other supernatural causes, as in the above quote; 7 linked suicide to vague, and probably social, situations involving, e.g., "frustration"; and 18 linked suicide to alcohol, mental illness, fealty to a master, or unknown crimes.

3.3. Co-occurrence of model variables

Whereas Fig. 3 shows the level of support for individual variables, it does not indicate the extent to which evidence for the model variables co-occurs within the text records. We investigate variable co-occurrence with cumulative distributions of evidence and non-negative matrix factorization.

3.3.1. Cumulative distributions of evidence

Fig. 4 shows, for each model, the cumulative fraction of records in which evidence for specific numbers of model variables occurs. For instance, over 25% of records had evidence supporting 4 or more variables of the BRM.

3.3.2. Non-negative matrix factorization

Our data comprised 474 text records that had been coded for the presence/absence of 23 "features" (the theoretical variables). These data were represented in a 474 x 23 matrix. A natural approach to identify structure in such data is to use a matrix decomposition method to produce a lower rank approximation of the original matrix. Non-negative matrix factorization (NMF) (Lee & Seung, 1999) is an increasingly popular decomposition method that is widely used in document classification, text mining, signal processing, and pattern recognition. Similar to principal components analysis (PCA), NMF identifies a limited number of basis components that, when combined, approximate the original matrix. More formally,

$$X \approx WH$$

where X is an $n \times p$ matrix, and W and H are $n \times k$ and $k \times p$ matrices, respectively; all elements of X, W and H are ≥ 0; and, typically, $k \ll min(n, p)$. NMF estimates W and H by minimizing a measure of distance between X and WH:

$$\min[D(X, WH) + R(W, H)]$$

where D is a loss function, typically the Frobenius norm or the Kullback-Leibler divergence, and R is an optional regularization function that

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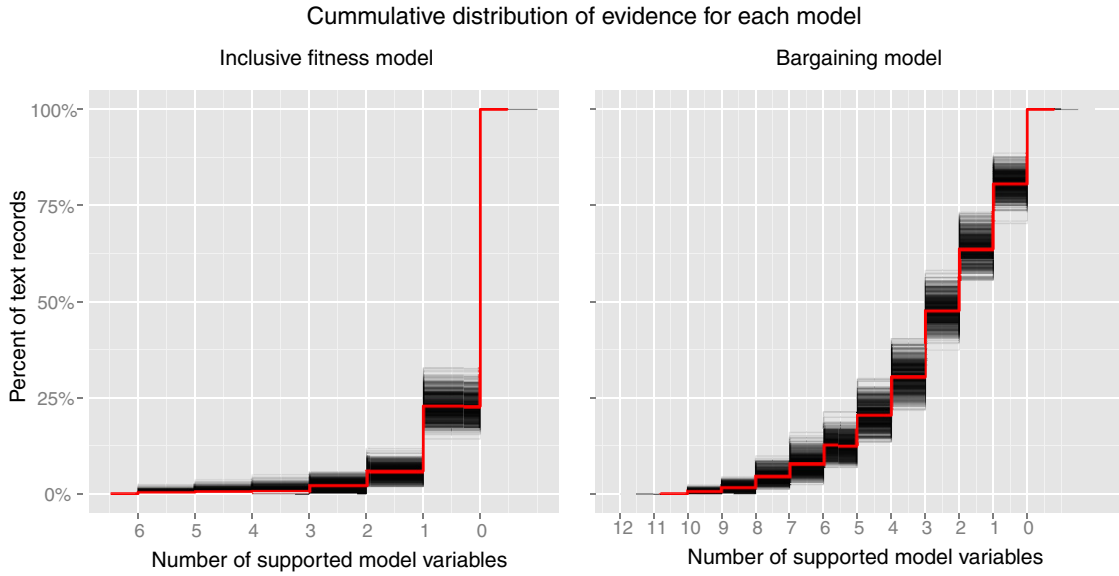

Fig. 4. Summary of support for each model. The stepped lines represent empirical cumulative distribution functions (ecdf): the cumulative fraction of records that support *at least* that number of variables in the inclusive fitness model (left) and bargaining model (right). The bands are overplotted ecdfs from 500 bootstrap replications, which indicate the estimated sampling variation.

enforces desirable properties on W and H, such as smoothness or sparsity (Gaujoux & Seoighe, 2010).

Compared to PCA, NMF has a number of advantages. First, by definition, the matrix factors are non-negative. Each observation can therefore be interpreted as a sum of the positive basis components. The mix of positive and negative values in the eigenvectors of PCA, in contrast, can make their interpretation difficult. Second, the NMF representation is usually sparse (i.e., mostly zeros), which aids interpretation of the basis components, and also provides a natural clustering of the observations. Thus, NMF simultaneously clusters rows and columns of the input matrix. Finally, unlike PCA, there is no orthogonality constraint on the basis vectors. Basis components can therefore overlap. NMF is an "unsupervised" technique; there is no prespecification of basis components or observation classes.

In document classification applications, such as ours, the basis components, W, are interpreted as "topics," and each document is represented as a combination of topics, H. Here, topics might be types of SB, and each text record might discuss one or more types of SB.

We used the NMF package (Gaujoux & Seoighe, 2010) with its default settings, which estimate the factorization by minimizing the Kullback-Leibler divergence according to the algorithm from Brunet, Tamayo, Golub, and Mesirov (2004). To choose the optimal rank, k, we plotted several quality measures, including the cophenetic correlation coefficient and RSS. These plots, which function somewhat like scree plots in PCA, suggested that the optimal rank was between 3 and 5. We chose to estimate NMF with $k = 4$. Unlike PCA, the factorization of X is typically not unique. A standard procedure is to optimize the factorization from different random starting conditions. We chose the best solution from mulitple runs (1000), as recommended by Gaujoux & Seoighe, (2010).

Fig. 5 displays heatmaps of the results. The four basis components (W, Fig. 5, top) formed two clusters (dendrogram, left hand side). The first cluster (component 3) comprised the 6 IFM variables plus Private SB. The second cluster comprised the 13 BRM variables plus the two remaining anti-bargaining variables. This cluster included three basis components (1, 2, 4), which is evidence that the BRM might encompass subtypes of SB.

A heatmap of the coefficient matrix H (Fig. 5, bottom) showed that most text records (matrix columns) focused on one type of SB, with some mixture from other types of SB.

3.4. Suicide models by culture and continental region

To determine if evidence for against each model of SB varied by culture-level factors, we first estimated a raw model score for each culture as the proportion of model variables scored as +1 for all records in a culture. For example, there were 25 records on the Tlingit, and there were 13 variables in the BRM. The total number of +1 in these 25 x 13 = 325 cells was 88. Thus, the Tlingit raw model score for the BRM was 88/325 = 0.27. For cultures with few records, the raw model scores might be misleading. For example, there were 9 cultures with only one record; a model score of zero in these cultures is not convincing evidence for the absence of that type of suicide in that culture. We therefore estimated an adjusted model score and its associated standard error for each culture using a binomial generalized linear mixed effects model, with cultures as a random effect, thus taking advantage of partial pooling across cultures (as recommended by Gelman & Hill, 2007), which moves the estimates for cultures with few records toward the cross-cultural mean. The raw and adjusted model scores for the two models are plotted for each culture in Fig. 6.

We then fit generalized linear mixed effects models of these scores as functions of the culture-level variables (using the binomial family and logit link, with weights equal to the number of variables in the model and number of records per culture, as described above, and culture and document author as grouping factors). We had no *a priori* hypotheses regarding cross-cultural variation in support for either model. Hence, these results should be regarded as exploratory.

Support for the IFM increased with increasing latitude. For model coefficients and indices of fit, see Fig. S2 and Table S1. There was no significant variation in support for the IFM on the remaining variables, or for the BRM by any of these variables (results not reported).

3.5. Suicide models vs. age and sex

To examine the relationship of age to evidence for the BRM and IFM, we first recomputed model scores omitting the reproductive value variables, which were strongly influenced by the age of the victim (and hence might inflate any correlation with age). There was a negative correlation between age and support for the BRM, and a significant

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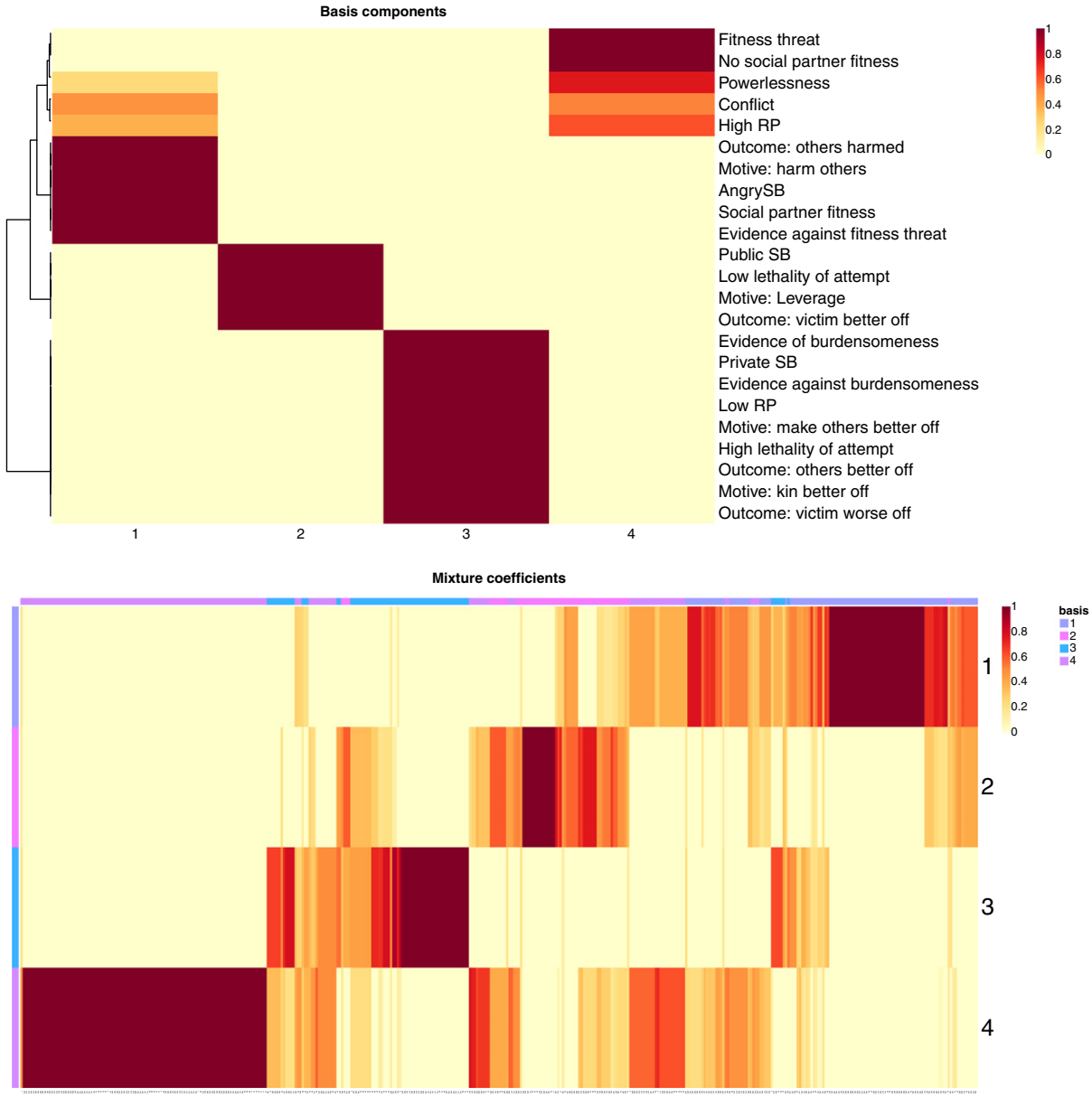

Fig. 5. Non-negative matrix factorization (NMF) analysis of the theoretical variables. Top: Heatmap of the basis matrix (W). Brown indicates variables that contributed to only one component; lighter shades indicate variables that contributed to multiple components. The four components clustered into two groups (left hand dendrogram). Bottom: Heatmap of the coefficient matrix (H). Each column represents one text record. Color represents the extent to which each of the four basis components contributed to that record. Brown indicates only one component contributed to that record. Lighter shades indicate the proportionate contribution of multiple basis components. The basis annotation track indicates the most-contributing basis component. See text for details.

positive correlation between age and support for the IFM. See Fig. 7 and Table S2.

There was no significant difference in support for either model by sex (results not reported).

3.6. Mental illness

Although not an explicit feature of the models tested here, mental illness is a strong predictor of SB in Western populations. The presence of debilitating mental illness could support the IFM. There was evidence of mental illness in only about 10% of the records, about a third of which (3%) appear to involve affective disorders (i.e. depression and anxiety). Close to half of the mental illnesses were categorized as 'unknown', however, due to lack of information. The severity of the mental illnesses and the extent to which these caused the victim to be a severe burden on kin could usually not be determined. Overall, there was little evidence for or against mental illness as an etiological factor in SB.

4. Discussion

SB appears frequently in the ethnographic record: 53 of 60 cultures in the HRAF probability sample had a case or cultural model of SB in our data set. Six of the seven inhabited continental regions were represented (the exception was Australia), as were all major modes of subsistence, such as hunter-gatherers, horticulturists, pastoralists, and intensive agriculturists (see Fig. 2). Nearly half the records involved a pre-existing threat to the victim's fitness and conflict with others; powerlessness was also common (Fig. 3). Any model of suicide must account for this widespread pattern.

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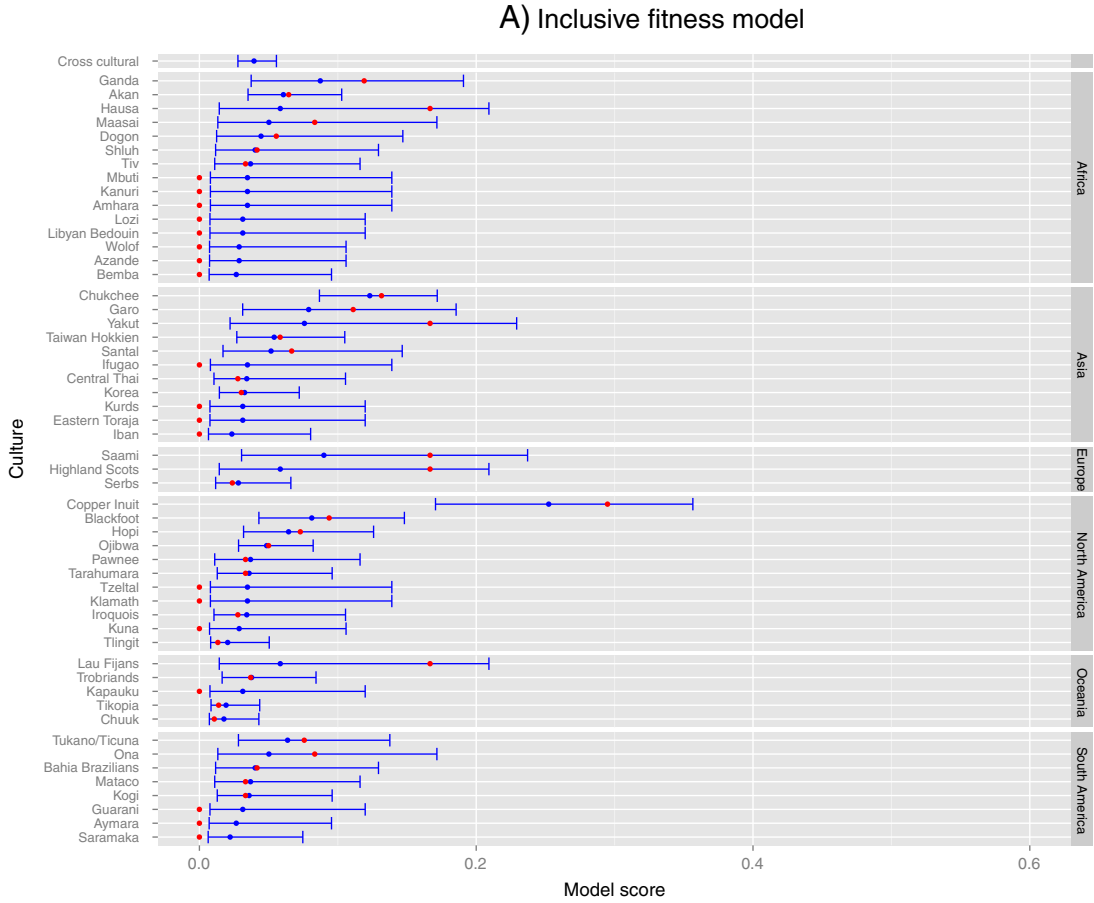

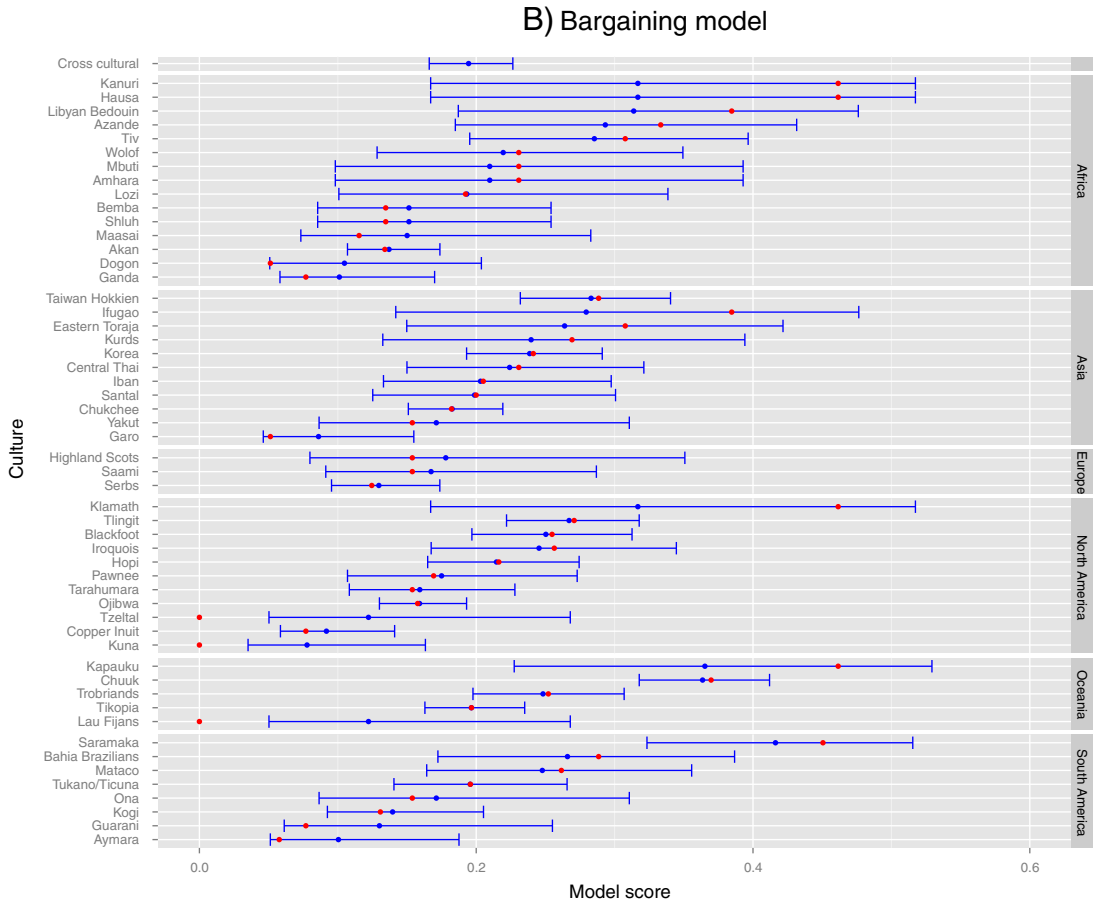

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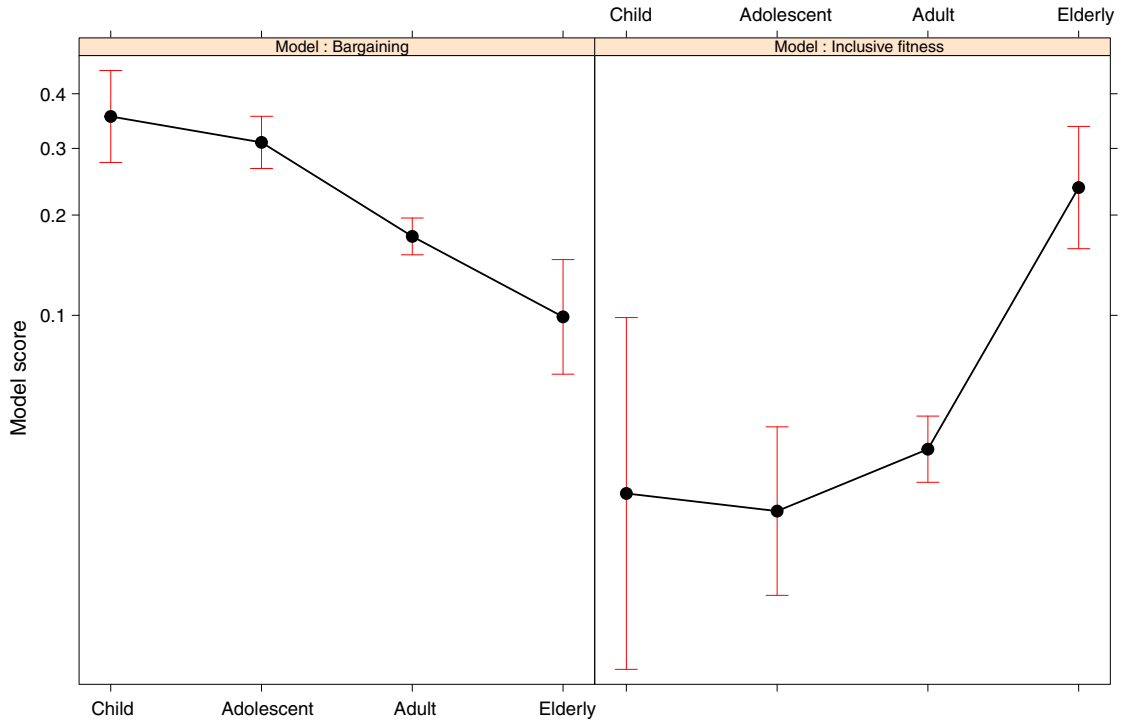

Fig. 7. Evidence supporting each model vs. age of the victim. Model score is the proportion of variables from that model that were coded +1. Model scores were fit using a binomial generalized linear mixed effects model with culture and author as grouping variables. For model parameters, see Table S3.

4.1. Inclusive fitness model

About one fifth (22.8%) of records had evidence supporting at least one variable of the IFM (Fig. 4). However, this value depended heavily on counting "High lethality of attempt" as supporting the IFM. If this variable was omitted, only 13.9% of text records had some support for the model. For the key variable of burdensomeness, 30.2% of the cultures had evidence that at least one victim was a burden on others.

There were five lines of evidence in support of this model. First, NMF found that the IFM variables formed a single component, distinct from all BRM variables except 'Evidence against burdensomeness', and there was a group of records comprised solely of this IFM component (two anti-bargaining variables also clustered with this component: 'Outcome: victim worse off' and 'Private SB'). See Fig. 5. Second, the mean level of 'evidence for' the IFM was greater among records describing older individuals (see Fig. 7). Third, about as many cases involved methods with high lethality as involved low lethality. Fourth, support for the model increased with increasing latitude, which indicates that in societies living in harsh environments, in which elderly or infirm individuals would be more likely to impose a severe burden on kin, completed suicides might increase inclusive fitness. And fifth, there was evidence of some support in every major continental region (see Fig. 6).

More problematic were the facts that only 5.7% of cultures had any evidence that suicide completions improved outcomes for others, compared to 39.6% of cultures that had evidence that suicide completions worsened outcomes for others, and that more victims had high RP than low RP (25.9% vs. 15.2%), contrary to the hypothesis. Conflict between the victim and his or her social partners was also common, whereas in this model the fitness interests of the victim and social partners are aligned. Moreover, there was little evidence for or against motives of making others or kin better off (Fig. 3).

In our view, the IFM has yet to answer the following theoretical question: why wouldn't a burdensome individual simply leave their kin, or kin simply abandon a burdensome individual? Both options would eliminate the burden on kin while leaving open some possibility of survival and reproduction. Perhaps suicide by older, burdensome individuals is better explained as a byproduct of, e.g., pain avoidance, than by natural selection. Alternatively, given the complex politics of kin-based societies in which older individuals often play central roles, it is possible that there is some additional strategic advantage to one's kin, beyond simply relieving burden on them, to choosing the time of one's death. Suicide might be a commitment device, for example. Nevertheless, our results suggest that the IFM describes a genuine pattern of SB whose low frequency might simply reflect the dwindling number of societies, such as arctic foragers, in which a burdensome individual genuinely threatens the well-being of close kin.

A 'paradigmatic' example of the IFM was identified by selecting a concise text record that supported all model variables (from the Copper Inuit, an arctic foraging population; Pryde, 1972, p. 49):

> Not many years ago, if a man or woman became too old and feeble to run behind the dogs and could no longer contribute to the family, his or her death might become necessary. Usually in such cases the older people themselves asked a close relative to kill them, a sort of assisted suicide. The garrotting or strangling was accomplished with a loose loop in a sealskin rope dropped around the neck and breaking it.

4.2. Bargaining model

There was considerable evidence for the BRM: 80.6% of records had evidence supporting at least one variable of the model (Fig. 4). The

Fig. 6. Model support by culture. A: inclusive fitness model. B: bargaining model. Model scores are the proportion of data matrix cells that were coded +1 for each model in each culture. Red points are the raw model scores. Blue points and confidence intervals are model scores adjusted via partial pooling across cultures (see text for further explanation). Within continental regions, cultures are sorted by decreasing evidence for each model. Bars represent +/- 2SE.

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evidence was similar at the cultural level: Fitness threat, Powerlessness and Conflict were supported in 88.7%, 84.9%, and 77.4% of cultures. Low lethality characterized SB in about 47.2% of the cultures, consistent with the hypothesis, but contrary to the hypothesis, high lethality characterized SB in a similar percentage of cultures (43.4%). Although outcome change in the victim's favor, the goal of SB under the BRM, characterized SB in only 20.8% of the cultures, evidence that SB harmed a surviving victim was present in merely 5.7% of cultures (Fig. 3). Of the 84 records involving non-lethal SB, 30 noted a consequent benefit to the victim, such as swaying parents and other authority figures, often in conflicts over marriage, punishment, or abuse; getting one's way; and mitigating anger or punishment from social transgressions (for a complete list of benefits, see Table S3).

The NMF analysis grouped the BRM variables in one cluster distinct from the IFM variables. Unlike the IFM, however, the NMF identified substructure among the BRM variables (Fig. 5, left hand dendrogram), grouping them in three components, 1, 2, and 4 (Powerlessness, Conflict and High RP contributed to two components). Component 1 comprised variables related to conflict, aggression and harm to others. Component 2 comprised variables related to the signaling aspects of SB, such as Public SB and Low lethality of attempt, as well as a leverage motive. Component 4 comprised variables related to a fitness threat to the victim, conflict with social partners, and her powerlessness.

There are at least two interpretations of the substructure among the BRM variables. The first is that the three components, or "topics," represent distinct types of SB. In the game theoretical literature on bargaining, different conditions can lead to different bargaining strategies. In an empirical study of SB, Andrews (2006) found evidence for distinct leveraging vs. signaling strategies. The second interpretation is that component 1 (Angry SB and harming others) corresponds mostly to the emotional response to conflict; component 2 (low lethality, public SB, and leverage) corresponds mostly to the use of SB to attain a desired outcome; and component 4 (conflict, fitness threat, and powerlessness) corresponds mostly to the social context. Different ethnographers have emphasized these different aspects of SB. Some ethnographers, such as Hezel (1987), have emphasized SB as a form of anger (component 1); others, such as Giddens (1964), have emphasized SB as a form of social pressure (component 2); and still others, such as Counts (1980), have emphasized the powerlessness of suicide victims (component 4).

Two anti-bargaining variables contributed to the BRM components. "Evidence against fitness threat" contributed to component 1, and "No social partner fitness" contributed to component 4. Less than 1% of records had evidence for the former, but 7.6% records had evidence for the latter. The relatively high frequency of this variable is evidence against the BRM. It mainly reflects SB involving conflict with an enemy group or powerful institutions, such as a colonial government, that were not invested in the victim's fitness. The latter might represent a mismatch between a psychological mechanism that evolved to influence members of small groups, and the large autonomous communities often encountered in modern environments.

The variables for the BRM were reasonably well represented in each major continental region (see Fig. 6) and support did not vary significantly by the cultural variables, such as mode of subsistence and social complexity, suggesting this type of SB is a human universal. Levels of support for the BRM were highest among records involving teenagers and young adults and lowest among the elderly (Fig. 7), a pattern that parallels the age-related decrease of attempts in the US (Fig. 1).

The high levels of support for Fitness threat, Powerlessness and Conflict (see Fig. 3) suggests that victims tend to be in situations that threaten their otherwise high RP, cannot unilaterally improve their circumstances, and, due to interpersonal conflict, cannot obtain help. These are exactly the conditions where the benefits of a costly bargaining strategy might be worth the risk. This view also corresponds closely to anthropological analyses of suicide that find that in conflicts, powerless individuals employ SB to strike back at powerful others in anger, protest, or revenge (e.g., Billaud, 2012; Brown, 1986; Counts, 1980; Fenton, 1941; Firth, 1936, 1939; Giddens, 1964; Hezel, 1987; Johnson, 1981; Malinowski, 1926).

A 'paradigmatic' example of the BRM was identified by selecting a concise record with one of the highest levels of support (9 of 13 model variables) (from the Kapauku, intensive agriculturalists from Papua New Guinea; Pospisil, 1958, p. 154):

> Attempted suicide is punishable by a beating administered by the woman's owner. Facts: The girl was being forced to marry a man she did not like. She attempted suicide several times in order to prevent the marriage. She was always saved from the river or captured on its bank. Outcome: Every time she attempted a suicide, she was beaten severely afterwards. Since she did not stop, her brother and father consented to her marriage with Jok whom she loved.

4.3. Limitations

Most of the ethnographers, with several notable exceptions (e.g. Hezel, Firth), were not specifically focusing on the topic of suicide. Thus, pertinent details such as victims' motives and cognitions, and familial and social outcomes of suicide were often unavailable. Furthermore, the ethnographic is biased towards events and behaviors of interest to Western ethnographers, which might not accurately reflect circumstances in the populations under study. Finally, the coders were not blind to the hypotheses.

The demographic profile of SB in our data differed in important ways from that seen in systematic cross-national surveys of SB. Whether this indicates differences in SB between the societies usually studied by anthropologists and the nation states studied by psychiatrists, or whether it instead indicates a bias in the ethnographic record, is unclear. In accordance with most national rates on suicide and sex, the number of cases of male suicide completions outnumbered female suicide completions (89 male, 56 female). The attempt rate was also greater for males (15 male, 8 female) unlike Western and post-industrial nations where female attempts outnumber male attempts (Murphy, 1998).

More striking, whereas suicide attempts typically outnumber completions by large margins (e.g., Fig. 1; Weissman et al., 1999), completions substantially outnumbered attempts in our data set (Fig. S1). This could be because ethnographers and their informants were more likely to remember and make note of completions than unsuccessful attempts. A lack of modern medical care in many of these societies might also contribute to higher rates of completions. Despite the low attempt rate, evidence of low lethality SB (16%) equaled evidence of high lethality SB (12%) (the lethality of attempts in the remaining records was unknown).

Suicide rates generally increase with age (Shah, 2007), but in our data elderly adults were a distinct minority (Fig. S1). This might be due to the age distribution in the populations in the data set, which comprises many populations with high fertility and mortality rates, and thus higher absolute numbers of younger individuals.

In contrast to the high rate of suicidal ideation seen in cross-national surveys (e.g., Nock et al., 2009), the rate in this data set was low (Fig. S1), probably because individuals not personally acquainted with the victim recorded many of the cases long after the event took place. Likewise, the low rates of mental illness, again contrary to cross-national surveys (e.g., Nock et al., 2009), is probably explained by the lack of rich information on the behaviors and cognitions of the victims leading up to the SB. Therefore, mental illness is certainly underrepresented.

We only tested two theoretical models but there are numerous other non-evolutionary models, one or more of which might better explain the data. In addition, there were several cultural models that did not correspond to Western scientific conceptions of suicides, such as those involving demons and spirits, or fealty to a master. Nevertheless, in our data, lack of evidence for the IFM or BRM could usually be ascribed

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to the brevity of the account, not the irrelevance of these models. There was one possible exception. In a substantial number of records, SB followed a severe violation of a social norm, such as engaging in taboo behavior or harming family members. These cases often involved shame, and, if the victim survived, the SB sometimes served to expiate the sin. We therefore propose a compliment to the BRM: following a severe violation of a social norm, SB might serve as a costly, and therefore credible apology (for a game theoretic model of costly apologies, see Ohtsubo & Watanabe, 2009).

Finally, it is important to keep in mind that 94% of the documents were published in the Twentieth century, by which time many of these populations were undergoing or had undergone profound cultural, demographic, and socioeconomic changes. Such changes might have substantially altered patterns of SB relative to pre-contact periods. We cannot rule out the possibility that the societies described in the ethnographic record diverge so dramatically from ancestral societies that they provide little evidence relevant to evolutionary models of behavior.

5. Conclusions

The IFM and BRM are complimentary. Committing suicide to reduce burden on kin, although less common in the ethnographic record, is reasonably well documented among older or infirm individuals, especially those living at high latitudes.

Suicidal behavior by younger, healthy adults in the context of fitness threats, such as forced or thwarted marriages, physical or sexual abuse, or loss of a mate; social conflict, such as severe disagreements with parents and other authority figures; and powerlessness to improve one's situation, is ubiquitous in the ethnographic record. There is also consistent evidence that non-lethal SB can improve outcomes for victims (Table S3). These findings closely parallel those for deliberately self-harmful behavior in Western societies (e.g., Hagen et al., 2008). Much suicide mortality in the ethnographic record was therefore probably a consequence of particularly dangerous forms of deliberate self-harm, perhaps in combination with a lack of modern medical care, whose aim was to improve victims' circumstances if they survived. These results support the BRM (Andrews, 2006; Hagen, 2002, 2003; Hagen et al., 2008; Nock, 2008; Rosenthal, 1993; Stengel, 1952; Watson & Andrews, 2002) and the venerable idea that much SB is a 'cry for help' (e.g., Farberow & Shneidman, 1961). In particular, they support the view, perhaps first and most clearly expressed by the anthropologist Raymond Firth, that SB is often a gambit to improve one's situation (e.g., Firth, 1936).

Because close to half of the global disease burden of suicidality can be attributed to major depressive disorder (Ferrari et al., 2013), these results also support the bargaining model of depression (Hagen, 1999, 2002, 2003; Rosenström, 2013; Watson & Andrews, 2002).

If one or both models of SB are correct, this undermines the mainstream view that most suicidal behavior is a consequence of neurophysiological, cognitive, or emotional dysfunction. It also implies that, rather than altering victims' neurophysiology, psychology, or behavior, the most effective response to SB would be to substantially improve victims' lives, which in many cases would involve changing the attitudes and behaviors of their social partners. In particular, if the BRM is correct, victims of physical or sexual assault – perhaps the strongest risk factors for SB (Devries et al., 2011; Stein et al., 2010) – require protection from an assailant, not treatment for their putative emotional or cognitive dysfunctions.

Supplementary Materials

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.evolhumbehav.2015.10.005.

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