Why warmth matters more than competence: New evolutionary models

Adar B. Eisenbruch^{1,2*} & Max M. Krasnow¹

¹ Department of Psychology
Harvard University
Cambridge, MA, 02138

² Present address:
Department of Psychology
State University of New York at Purchase
Purchase, NY 10577

*Corresponding author:
adar.eisenbruch@gmail.com
(917) 528-0844

Abstract

Multiple lines of evidence suggest that there are two major dimensions of social perception, often called warmth and competence, and that warmth is prioritized over competence. Existing explanations for this prioritization argue that it is more consequential for an observer's welfare than is competence. We develop a new explanation for the prioritization of warmth, based on cooperative partner choice. A review of the anthropological literature suggests that, over the course of human evolution, there was greater variance in the warmth than competence of potential cooperative partners, but greater variance in competence over time within cooperative relationships. We present agent-based models showing that these features of the ecology promote the evolution of the prioritization of warmth over competence, suggesting that this prioritization is due to an asymmetry in their *distributions*, not in their necessary *consequences*, per se. Future directions for the study of social perception and preferences more broadly are discussed.

Why warmth matters more than competence: New evolutionary models

A wide literature in social psychology has robustly shown that people care more about another person's disposition to help or harm than about their ability to do so. The dominant explanation for this primacy of "warmth" over "competence" is that another person's warmth is more consequential for an observer than their competence (e.g. Abele & Wojciszke, 2007, 2014; Cuddy, Fiske, & Glick, 2008; Fiske et al., 2007; Wojciszke et al., 1998). This explanation, however, merely shifts the explanatory burden back one step. Why is warmth more consequential than competence? Here, we hope to show a more satisfactory explanation for this asymmetry in priorities can be found in an asymmetry in the natural ecology of partner choice in our species. In addition to describing the relevant features of our ancestral ecology, we present agent-based models that demonstrate that these features can in fact lead to the evolution of prioritizing the disposition to help over the ability to do so. This paper will proceed as follows: first, we describe the social psychological evidence that people are more sensitive to an other's 'warmth' than to their corresponding 'competence'; second, we present the existing explanations for this phenomenon and describe their shortcomings; third, we offer a novel explanation based on the dynamics of partner choice, and describe the features of the ancestral ecology that make this account plausible; fourth, we present new agent-based models that simulate the evolution of partner choice psychology, and demonstrate that the ecological features we identified in fact lead to the observed psychological design. Finally, we discuss the state of the evidence for our new explanation, and implications for the field.

1. Caring more about dispositions than ability

Multiple lines of research indicate that that people care more about another person's intentions to harm or benefit others, than about the extent of their ability to effectively do so (or the extent to which they have actually done so). The subsections below will review key findings from three fields of inquiry that all point to this conclusion. Though these research programs use different terms for these two dimensions (e.g. warmth/generosity/morality/communion vs. competence/productivity/agency), they are all referring to the same fundamental concepts: a person's disposition towards the interests of another, and a person's ability to effectively create harms or benefits for themselves and others.

Social Cognition

Multiple approaches in social cognition have shown that there are two main dimensions along which people are perceived (see e.g. Abele & Wojciszke, 2014; Fiske, 2018; Fiske, Cuddy, & Glick, 2007; Wojciszke, 2005 for reviews). For example, in a study in which participants were asked to sort personality traits into categories of traits that typically go together in people they know, multidimensional scaling of the sorting decisions suggested that people grouped personality traits along two dimensions (Rosenberg, Nelson, & Vivekananthan, 1968). The first dimension is the disposition of an individual to positively incorporate the interests of another into their behavior (e.g. the disposition to be generous, helpful, trustworthy, etc., as opposed to selfish, harmful, etc.). This dimension is variously referred to as warmth, morality or communion; for convenience, we will use "warmth." The second dimension is the ability of an individual to successfully achieve their goals, whatever those goals may be. This dimension is

often called agency or competence; for simplicity, we will use “competence”. This basic structure of social perception has been observed cross-culturally (Abele, Uchrowski, Suitner, & Wojciszke, 2008; Cuddy et al., 2009; Fiske & Durante, 2016; Ybarra et al., 2008). These dimensions, although reliably emerging, are not of equal importance: warmth has been shown to be the primary component of person perception, with warmth information both having a stronger effect on the overall impression of a person (e.g. positive vs. negative) and being preferentially sought when people choose what traits to learn about a person (e.g. Abele & Bruckmüller, 2011; Goodwin, Piazza, & Rozin, 2014; Wojciszke & Abele, 2008; Wojciszke, Bazinska, & Jaworski, 1998).

The general asymmetry of warmth being prioritized over competence is also qualified by several interactions that may be relevant to the current argument. First, the asymmetry varies depending upon the target of evaluation (e.g. Abele & Brack, 2013; Abele & Wojciszke, 2007; Cottrell, Neuberg, & Li, 2007; Wojciszke, 1994; Wojciszke & Abele, 2008). People care more about warmth than competence when thinking about others, but more about competence than warmth when thinking about themselves (e.g. Abele & Wojciszke, 2007; Wojciszke, 1994; Wojciszke & Abele, 2008). Even when considering only other people, the relative importance of competence increases as social distance decreases (e.g. going from a peer to a close friend; e.g. Abele & Brack, 2013; Abele & Wojciszke, 2007). This effect is mediated by perceptions of outcome interdependence with the other person, suggesting that people care about another person’s competence to the degree that they think that they themselves will be materially affected by the other person’s ability to achieve their goals (Abele & Wojciszke, 2007).

Second, the prioritization of warmth over competence in perceiving other people is stronger for women than men. Women are commonly perceived as warmer than men, and men

are perceived as more competent than women (e.g. Fiske, Cuddy, Glick, & Xu, 2002). Female perceivers also rely on warmth information in forming impressions of others to a greater degree than males do (Wojciszke et al., 1998). This has important effects in several domains. For example, letters of recommendation for female job applicants use fewer agency-related words than do letters for male applicants, especially when written by females (Madera, Hebl, & Martin, 2009). Likewise, evidence suggests that men choose friends more on the basis of competence-related traits than women do, while women choose friends more on the basis of warmth-related traits than men do (e.g. Eisenbruch, Grillot, & Roney, under review; Eisenbruch & Roney, under review; Hall, 2011). Some researchers have attributed this sex difference to contemporary social roles, such that males are socialized for roles that place comparatively more emphasis on agency and competence-related traits, and women are socialized for roles that place relatively more emphasis on warmth-related traits (e.g. Eagly & Wood, 2016; Madera et al., 2009; Wojciszke et al., 1998). We will return to these interactions following the presentation of our agent-based models.

Cooperative partner choice

Recently, researchers have used economic tasks to examine people's choices between potential cooperative partners who vary in both generosity (the proportion of a resource that they are likely to offer) and productivity (the magnitude of the resource they have access to). Participants consistently exhibit a stronger preference for generosity than productivity, choosing partners more on the basis of their warmth than their competence, effectively caring more about the relative size of the slice they are offered than the size of the pie it comes from (Eisenbruch & Roney, 2017; Hackel, Doll, & Amodio, 2015; Raihani & Barclay, 2016; Robertson, Krasnow, &

Lim, 2017; see also Delton & Robertson, 2012). Importantly, these effects obtain even when the choice violates the incentive structure of the experiment. That is, participants will still choose the generous over the productive partner even when it costs them money to do so. Similarly, participants given the ability to exclude partners from subsequent rounds of a public goods game did so more on the basis of the partners' intended than actual contributions to past rounds (Liddell & Kruschke, 2014). Similar effects have been observed in the real world as well; workers choose colleagues to collaborate on a task based on how much they like their various coworkers (which is largely based on warmth), rather than their coworkers' task-relevant competence (Casciaro & Lobo, 2008). These results suggest that people prioritize a cooperative partner's disposition to confer benefits on them over their ability to actually do so, even when this is materially costly.

Moral judgments

Human moral judgment is largely nonconsequentialist, in that moral judgments of actions are informed more by the intended rather than actual consequences of the action (e.g. Cushman, 2008). For example, an identical harm is widely seen as unacceptable if it is intentional, but acceptable if it is merely foreseen (Cushman, Young, & Hauser, 2006; Greene et al., 2009; Greene, Sommerville, Nystrom, Darley, & Cohen, 2001). Children also distinguish between harms caused intentionally versus accidentally, and may be more sensitive to intention than harm magnitude in making condemnation decisions (Grueneich, 1982). The psychology of detecting defection on a social contract or exchange – important for the evolution of cooperation – appears to be specialized for detecting *cheaters* rather than instances of *cheating* (Cosmides, Barrett, & Tooby, 2010), and the same result obtains for detecting free-riders on n-person collective actions

(Delton, Cosmides, Guemo, Robertson, & Tooby, 2012; Delton, Nemirow, Robertson, Cimino, & Cosmides, 2013). Observations such as these have led some scholars to conclude that human moral judgment is fundamentally focused on people rather than actions; that is, the goal of moral judgment is not to assess the extent to which harm was caused or rules were broken, but to assess – and possibly recalibrate – the actor’s intentions to help or harm in the future (e.g. Delton & Krasnow, 2015; Krasnow, 2017; McCullough, Kurzban, & Tabak, 2013; Uhlmann, Pizarro, & Diermeier, 2015; see Jara-Ettinger, Tenenbaum, & Schulz, 2015 for evidence of early emergence of this tendency).

2. Existing explanations

Social cognition researchers explain the observed primacy of warmth over competence in person perception based on the relevance of these traits to the observer’s self-interest (e.g. Abele & Wojciszke, 2007, 2014; Cuddy, Fiske, & Glick, 2008; Fiske et al., 2007; Wojciszke et al., 1998). The argument is that another person’s warmth (or morality, or generosity) is more consequential for the observer’s self-interest than is that other person’s competence; in other words, a person’s intention to help or harm is more important to an observer’s welfare than their ability to do so. This may be especially true since humans evolved in cooperative groups and depended on reciprocal altruism, and warmth-related traits may have been a stronger indicator that another person abides by group norms and will be a good reciprocator (e.g. Abele & Wojciszke, 2014; Ybarra et al., 2008). This asymmetry of consequence – in which an observer’s outcomes are more affected by another person’s warmth than their competence – created a selection pressure for prioritizing warmth in person perception. This explanation is neatly captured by the terms often used to describe warmth- and competence-related traits (e.g. Abele &

Wojciszke, 2007, 2014; Fiske et al., 2007): competence-related traits are described as “self-profitable,” because they principally affect the possessor’s own outcomes, while warmth-related traits are described as “other-profitable” because they principally benefit people other than their possessor. On this account, it seems intuitive that observers should care more about another person’s warmth than competence simply because it affects them more.

There are several reasons that, we believe, this does not fully explain the phenomenon. First, the self-profitable vs. other-profitable dichotomy breaks down in the cooperative ecologies in which humans evolved (and live currently). Cooperation makes the fruits of one person’s competence available to others (e.g. many people may benefit from a good hunter’s success), such that competence is “other-profitable,” and individuals in a cooperative ecology benefit from being known for warmth-related traits like trustworthiness and generosity (e.g. Barclay & Willer, 2007; Roberts, 1998), such that warmth is “self-profitable.” This point is consistent with the evidence that competence matters more when the observer is outcome-interdependent with the actor (e.g. Abele & Brack, 2013; Abele & Wojciszke, 2007), but we argue that previous researchers have underappreciated how pervasive these outcome-interdependent relationships were in the environment in which humans evolved. In fact, true strangers were likely a rarity for our ancestors (Krasnow, Delton, Tooby, & Cosmides, 2013), and there is some evidence that valuable resources are shared widely throughout hunter-gatherer groups, not merely with the producer’s preferred partners (e.g. Hawkes, 2001; Hawkes, O’Connell, & Jones, 2001), suggesting that some degree of dependence on another’s ability to produce resources may be the default relationship structure. Therefore, it is not obvious that warmth would have been consistently more “other-profitable” than competence in the ecologies in which humans evolved.

Second, considering warmth as more “other-profitable” than competence assumes that another person’s intentions are more indicative of the impact that they will have on an observer than that person’s competence is, but there is no principled reason why this must be true. In principle, the impact of a person’s behavior is the product of their intentions and their ability to carry out their intentions, much as a serving of pie is a product of both the size of the entire pie and the relative share of the slice being served. For example, a generous but unskilled hunter might provide 2lbs of meat after a hunt (50% of their 4lbs total yield), while a skilled but less generous hunter might provide 5lbs of meat after a hunt (10% of their 50lbs total yield). Rather than suggesting that warmth should be prioritized because it has a greater effect on the welfare of others, this reasoning indicates that warmth and competence equally co-determine one person’s effect on the welfare of others. It could even be argued that prioritizing competence in social perception may be a reasonable heuristic, since an individual’s competence affects others regardless of their warmth (i.e. a competent person is helpful if kind and dangerous if malicious), but their warmth is only consequential if they clear a threshold of competence (i.e. an incompetent person is unlikely to affect an observer’s outcomes regardless of their intentions). The point here is merely that it is not obvious that a person’s intention to help or harm affects an observer’s welfare more than their ability to do so effectively, so a satisfactory explanation for the prioritization of warmth over competence cannot rest on this assumption.

3. A new explanation

We start from the same premise as the dominant theories, that the prioritization of warmth over competence stems from adaptations crafted by the ancestral social ecology. In particular, given the extreme importance of cooperative relationships to humans (e.g. Sugiyama,

2004), and the large effects that this evolutionary history of cooperation has had on our social psychology (e.g. Barclay, 2016; Cosmides & Tooby, 1992, 2005), we expect that human social cognition will contain design features for effectively choosing cooperative partners that would have yielded fitness benefits, on average, in ancestral social environments. As the section above argues, a person's warmth need not necessarily have more of an effect on an observer's welfare than does their competence. However, if the ways in which warmth and competence are distributed throughout the population differ, these asymmetrical distributions could create selection pressures for prioritizing warmth over competence in partner choice.

In order to make this argument, we now introduce terminology that maps onto the concepts of warmth/communion/morality and competence/agency, but that we believe more usefully conveys intuitions about resource divisions between social partners. We will refer to person A's disposition to help or harm person B at the expense of their own welfare as A's welfare tradeoff ratio towards B (WTR; Delton & Robertson, 2016; Tooby & Cosmides, 2008; Tooby, Cosmides, Sell, Lieberman, & Sznycer, 2008). WTR captures the degree to which someone is motivated to help or harm someone else by measuring how the actor weighs the utility of the other person relative to their own. For example, if Jack would choose to forgo up to \$1.00 so that Jill can receive \$2.00, Jack's WTR towards Jill is 0.5. If Jack is willing to forgo up to \$1.00 in order to *prevent* Jill from receiving \$2, Jack's WTR towards Jill is -0.5. WTR conveniently captures both positive and negative valuations of another's welfare, and likely underlies social treatment across a range of situations (Delton & Robertson, 2016; Tooby & Cosmides, 2008; Tooby et al., 2008). We will refer to a person's ability to create material benefits as their productivity. This is conceptually overlapping with competence and agency, but

more clearly primes intuitions about a person's ability to create resources, which can then be divided with others according to WTRs.

We propose that differences in the distributions of WTR and productivity throughout the ancestral population of partners to be chosen created selection pressures that favored the prioritization of WTR over productivity in partner choice. Specifically, in the cooperative ecology in which humans evolved, (1) target-specific WTR varied more than productivity between potential partners, while (2) productivity varied more than WTR between interactions with a given partner.

Hypothesis 1 is that greater between-person variance in WTR made it the more important criteria of partner choice. To understand this, imagine having to choose cooperative partners while blind to either their productivity or their WTR. Imagine that two partners are drawn randomly from a population where the range of WTRs is wider than the range of productivity values. In expectation, the difference between the WTRs of the two candidates is larger than the difference between their productivities, such that being blind to WTR would result in worse mistakes (missing out on the highly generous partner, or inadvertently choosing the malicious one) than would being blind to productivity.

Hypothesis 2 is that WTR is more stable across time within a given relationship than productivity is, which makes it more predictive of the flow of future benefits from that relationship, and therefore a more important criteria of partner choice. We can imagine WTR and productivity estimates as being forecasts of the benefits that will accrue over the future course of a relationship. If a person's WTR towards someone else is more stable over multiple interactions than their productivity is, then their WTR at time 1 is more predictive of their WTR at times 2, 3 and 4 than their productivity at time 1 is predictive of their productivity at times 2, 3 and 4. This

makes WTR the better forecast of future benefits within a relationship; if the point of partner choice is to maximize the expected future benefits of a relationship, then WTR should be prioritized over productivity.

In sum, while the standard explanation for the prioritization of warmth over competence assumes an asymmetry in their *consequences* for an observer, we are positing asymmetries in their *distributions* within and between potential relationship partners. In order to substantiate these arguments, below we will describe the likely variances of WTR and productivity, both within and between relationship partners, in the environment of our ancestors. These sketches draw on the psychological, anthropological, economic, criminological and zoological literatures.

3.1. Variance between partners

3.1.1. How much did WTR vary between people in the ancestral environment?

The clearest way to address this question may be to consider the range of possible WTRs that one may receive from others in the social environment. On the high end, individuals commonly receive great solicitude and care from kin, such as parents, siblings and spouses (e.g. Hrdy, 2011). On the low end, individuals sometimes have such divergent interests that one is willing to bear substantial costs and risks in order to harm the other, potentially culminating in homicide (e.g. Daly & Wilson, 1988b; Duntley & Buss, 2011). We argue that the frequency and import of relationships characterized by these extremely different WTRs created a selection pressure for ascertaining and monitoring the WTR that one is likely to receive from an actual or potential relationship partner going forward, and for prioritizing this dimension of social cognition.

Across the lifespan, humans rely on the care of others for survival. The most obvious example of this comes from the parenting and alloparenting required by young children (e.g. Hrdy, 2011). Human young are remarkably altricial, and require near-constant care. Among hunter-gatherers, young children are nearly always in close proximity – if not physical contact – with a caretaker, most frequently their mother (e.g. Konner, 2017). The demands of childcare place a substantial (often literal) burden on the mother, which likely interferes with her ability to do other things like gather food (e.g. Hurtado, Hawkes, Hill, & Kaplan, 1985). Lactation is energetically costly as well (Thomson, Hytten, & Billewicz, 1970). That mothers (and, to a lesser extent, fathers and other kin) bear these costs for the welfare of their children over long periods of time (note that individuals do not become calorically self-sufficient until approximately age 15; Hill & Hurtado, 2009; Kaplan, Hill, Lancaster, & Hurtado, 2000), suggests the extremely high WTR that children receive from their caretakers.

Adults also benefit from the extremely high value that select social partners place on their welfare. Humans are vulnerable to temporary shortfalls in food production, for example due to injury, illness, or bad luck, leading to the evolution of reciprocal provisioning relationships (Trivers, 1971). Sugiyama (2004) estimates that 64.7% of members of one forager-horticulturalist population have experienced a disability of 30 days or longer, and therefore would probably have died if not for provisioning from other community members. Even the best food producers in a group are prone to periods of very low production (Hill & Hurtado, 2009), and therefore likely depend on help from others. These relationships of mutual interdependence are expected to lead individuals to place extremely high valuations on the welfare of their partner, since their fitness outcomes are positively correlated (e.g. Aktipis et al., 2018; Tooby & Cosmides, 1996). Similarly, monogamous couples have highly correlated genetic outcomes

(Alexander, 1987), typically leading to great concern for each other's welfare and relatively low levels of conflict. Along with parent-child relationships, these relationships of prolonged interdependence and positively-correlated outcomes may represent a high water mark of WTRs available in the social environment.

The low water mark of available WTRs is perhaps more obvious: people are sometimes so determined to harm another's welfare that they kill that person (Daly & Wilson, 1988b; Duntley & Buss, 2011). This possibility may seem remote in affluent, state-based societies, but it was far more common over the course of human evolution (Pinker, 2011). Knauft (1987) has compiled homicide rates in a variety of societies, and found that small-scale societies often have very high murder rates. The Hewa of New Guinea had an annual homicide rate of 778 per 100,000 people in 1959-1968, and even the !Kung – a hunter-gatherer group often described as peaceful – had a homicide rate of 41.9 per 100,000 (1920-1955). For comparison, the homicide rate in the United States in 2016 was 5.3 per 100,000 people (FBI, 2017). As suggested by these statistics, the potential for a social actor's WTR to be sufficiently low to motivate severe harm or homicide was likely a common ancestral concern. Among the Central Eskimos, 60% of adult men had committed at least one homicide, and another 13% had attempted it (Knauft et al., 1987). Among the Yanomamo, 44% of adult men had committed homicide, and 39% of those had participated in two or more killings; as a result, two-thirds of people age 40 and older had lost at least one close relative to interpersonal violence (Chagnon, 1988). People know that committing homicide exposes them and their families to revenge, suggesting that individuals are sometimes so determined to harm their victim's welfare that they are willing to do so at substantial personal risk and cost (Chagnon, 1988). Even within families, interests sometimes diverge so strongly that relatives kill each other (Daly & Wilson, 1988a). Committing homicide

is an indicator of an extremely negative WTR, and its prevalence suggests that our ancestors had to be alert to the possibility that they might receive such a low WTR from someone else.

These two extremes – mothers and murderers – suggest the vast range of the WTRs that an individual might have received in the social ecology of our ancestors. On the low end, some individuals are willing to bear substantial costs to inflict harm; on the high end, some individuals are willing to bear substantial costs over long periods of time to provide benefits. Between these extremes lies a diversity of dispositions – apathy for strangers, concern for acquaintances, deeper concern for friends, etc. – that populate the social world to which we can surely all relate. We argue that this extreme variance in available WTRs selected for preferential attention to the WTRs that we expect to receive from others, since failing to monitor these WTRs could result in overlooking important threats and opportunities. But how does this compare to the variance in productivity between potential social partners in the ancestral ecology?

3.1.2. How much did productivity vary between people in the ancestral environment?

In contemporary industrialized economies, individual differences in the ability to create material benefits are enormous. For example, Amazon founder and CEO Jeff Bezos earned \$35 billion in 2017 (Guarnieri, 2017), while a person working 40 hours/week at the US federal minimum wage of \$7.25/hour earned \$15,080/year. This equates to a roughly 2.32 million-fold difference in the incomes of the top vs. bottom earners. Differences in the ability to create material benefits in the environment of our ancestors, while appreciable and important, were far more moderate.

To estimate the variance in productivity in the ancestral environment, we will examine variance in hunting returns. Because hunting has greater variance of outcomes than gathering

plant foods (e.g. Kaplan et al., 1985), focusing on hunting should yield a higher estimate of productivity variance than focusing on gathering or both hunting and gathering would, and is therefore more conservative with respect to our hypothesis. Hill and Kintigh (2009) analyzed the outcomes of 14,364 hunting days among the Aché hunter-gatherers of eastern Paraguay, including data from 147 men over 27 years. They found that there is a five-fold difference in mean return rates between the best and worst hunters, among men who were sampled at least 100 times within a five-year period. Reanalyzing the same data set, McElreath and Koster (2014) found that success rates (i.e. the percentage of hunts yielding any meat) range from 15-70% among men age 33-46, which is approximately the age of peak hunting productivity. During peak hunting years, the best hunters return 8kg of meat per hunt, on average, compared to 4kg for the worst hunters. Thus, there is approximately a two-fold difference in average total returns, and a 4.67-fold difference in success rates, between the best and worst hunters during the years of peak productivity. Other estimates may indicate slightly higher variance. For example, one study of 10 !Kung hunters found a 10-fold difference in mean meat obtained per day between the best and worst hunters (Yellen, 1977). Some of this additional variance likely comes from the fact that the !Kung hunt larger, rarer animals than the Aché do, but it may also be inflated by the small sample size (Hill & Kintigh, 2009). Viewing this evidence as a whole, an estimate of a 2- to 10-fold difference in productive ability between the best and worst hunters appears reasonable.

Anthropologists have also attempted to characterize the degree of inequality among hunter-gatherers using the Gini index, a metric typically used to measure income inequality within modern economies. Gini values can range from 0 (total equality) to 1 (virtually all wealth held by one individual or family); for reference, the Gini value for income inequality was 0.28 in Denmark in 2015, 0.42 in the US in 2016, and 0.63 in South Africa in 2014 (World Bank, 2017).

Gini estimates in small-scale societies consider material wealth (e.g. land rights, livestock, household goods), embodied wealth (e.g. physical strength, knowledge and skills) and relational wealth (e.g. number of exchange partners), which together provide an assay of the ability of a person to create benefits for themselves or another person. Pooling across wealth types and 5 hunter-gatherer populations, Ginis are approximately 0.25 in hunter-gatherer societies, which is lower than in pastoral or agricultural societies (0.4 - 0.5) or modern economies (0.25 - 0.6). Ginis among hunter-gatherers are lowest for embodied and relational capital (means = .22 and .23, respectively), and higher for material wealth (mean = .36), suggesting that there is less inequality in the traits that contribute to the ability to produce benefits than in actual wealth achieved (Smith, Borgerhoff Mulder, et al., 2010; Smith, Hill, et al., 2010). Collectively, this method suggests that variance among hunter-gatherers in the ability to produce material benefits is low-to-moderate.

It is difficult to directly compare variance in WTRs to variance in productivity among available social partners in the environment of our ancestors, since they do not exist in a common metric. However, the above evidence strongly suggests that between-person variance in expected WTR was likely far greater than between-person variance in productivity. The WTRs that a person might have received in the social environment had extreme range, from individuals who were determined to sustain one's life to those who were determined to end it. It seems clear that the productivity levels of possible social partners existed within a much smaller range. To take a high estimate, the best producer may be ten times as valuable as the worst producer over a short period of time (Hill & Kintigh, 2009; Yellen, 1977); it seems safe to assume that the most helpful possible social partner (e.g. a mother) is far more than ten times as valuable as the most harmful possible social partner (e.g. a murderer). Stepping back, productivity is expected to have

lower variance in a naturally selected population than is WTR because WTR is target specific and personal interests vary. One person's mother is another person's potential mate is another person's potential enemy. Thus, a single person represents a range of WTRs across individuals considering them, and this is by design. In contrast, there is no similar design feature selecting for low productivity in certain relationships. We argue that the greater variance in available WTRs, relative to productivity levels, in the ancestral social ecology – including the possibility of harm – created a selection pressure for greater attention to and preference for the WTRs of others than their productivity levels.

3.2. Variance within partners

3.2.1. How much did WTR vary between interactions in the ancestral environment?

To this point, we have reviewed the different amounts of variation in WTR and productivity that existed between potential cooperative partners in the environment of our ancestors. Now, we turn our attention to the within-partner variation in these variables. How stable across interactions, spanning time and different cooperative activities, were the WTR and productivity levels that an individual could expect from a social partner? WTR – essentially, the quality of treatment that one can expect from another person – was likely largely stable across time and interaction types within relationships. In other words, if a person was generous towards you on Monday, they are likely to be generous on Tuesday and Wednesday as well, and if they were generous towards you in dividing meat, they are likely to be generous to you when providing childcare or social capital as well. Similarly, someone who displays a low regard for your welfare in one interaction is unlikely to be highly caring in the next interaction, barring intervening events that warrant a WTR revision (e.g. a feud, a betrayal, a gift, a reconciliation, a

dramatic change of circumstance, etc.; see e.g. McCullough et al., 2013; Sznycer & Lukaszewski, 2019; Sznycer, Xygalatas, Agey, et al., 2018; Sznycer, Xygalatas, Alami, et al., 2018). The clearest example of this may come from the extremely high WTR that individuals receive from parents and alloparents over the course of decades (see above), but WTRs are likely to be stable in other relationship types as well. This assumption is supported by the theory underlying WTR, evidence of stability in human friendships, and evidence of stability in non-human social relationships.

Decisions about how to allocate resources between the self and another person are likely made by specialized cognitive machinery that evolved for the task (Cosmides & Tooby, 2013; Delton & Robertson, 2016; Tooby et al., 2008). This cognitive mechanism produces a WTR by integrating a variety of variables pertaining to the other person (e.g. degree of relatedness, value as a cooperative partner, formidability) and a variety of variables pertaining to the situation (e.g. the size of the resource to be divided, the audience to the decision). The WTR therefore describes the weight given to another's welfare, relative to the self's, for a given person in a given situation. A wide body of evidence (including from the conceptually-similar approach of "social discounting") has shown that people make WTR judgments in highly sophisticated, consistent, and predictable ways, for example privileging kin over friends, and friends over acquaintances (e.g. Delton, 2010; Jones & Rachlin, 2009; Jones & Rachlin, 2006; Osiński, 2009, 2010; Rachlin & Jones, 2008; Safin, Locey, & Rachlin, 2013; Stewart-Williams, 2007; see Delton & Robertson, 2016 for review). Importantly, the WTR extended from one person to another is predicted to be autocorrelated across interactions, because the person-level features that it integrates are largely stable. For example, kinship is static, and traits like formidability, social status and skill level typically change slowly and predictably. Specific events that dramatically

recalibrate WTR, such as defections or reconciliations, are emotionally salient precisely because they represent discontinuities or expectation violations within the relationship (e.g. McCullough, Kurzban, & Tabak, 2013; Tooby et al., 2008; see also Sznycer & Lukaszewski, 2019; Sznycer, Xygalatas, Agey, et al., 2018; Sznycer, Xygalatas, Alami, et al., 2018). In sum, then, WTRs are likely to be stable across time and interaction types because the inputs to their calculation are largely stable. Another theoretical approach, based on the stability of social incentives, also suggests that solicitousness is likely to be largely stable within relationships (André, 2010). There is evidence that people may perceive this stability; moral traits are considered to be the most essential to a person's identity (vs. their personality, their desires, etc.), such that if their moral character changed, they would no longer be "themselves" (Strohming & Nichols, 2014). This prediction is borne out by the observation that the nature of relationships is typically stable across even large spans of time; that is, relatives stay related, and friends stay friends.

While friendships sometimes change in nature or dissolve over time, they are generally a stable relationship. It is common for friendships to persist for years, with closer friendships having greater longevity than more casual relationships (Hiatt, Laursen, Mooney, & Rubin, 2015; Yaniklar, 2012). Friendships tend to be less stable early in life, and become more stable as individuals age (Poulin & Chan, 2010; Yaniklar, 2012). For example, 41% of early adolescents (mean age = 12.4 years) and 44% of middle adolescents (mean age = 16.7 years) had a stable best friendship over the course of a year (Branje, Frijns, Finkenauer, Engels, & Meeus, 2007). In contrast, among a sample of adults, 75% of the men and 81.1% of the women reported a best friendship that persisted for five years, and second- and third-best friendships were also more likely than not to survive this period (Yaniklar, 2012). Mollenhorst et al (2014) found that approximately half of personal relationships among adults persisted over the course of 7 years.

Note that the underlying feelings of caring and regard towards a friend (e.g. WTR) may be more stable than the relationships themselves. The majority of relationships that dissolved over 7 years did so for lack of opportunity to spend time together (e.g. due to a job change), and only 12.2% dissolved due to a change in the emotional character of the relationship itself (e.g. having a fight; Mollenhorst et al., 2014). Research on antipathetic relationships is less plentiful and mostly conducted in children and adolescents (reviewed by Card, 2010), but there are reports of feelings of enmity lasting years or decades (Wiseman & Duck, 1995).

Many non-human animals also form social relationships that range from alliances to reciprocal grooming partnerships to a simple tendency to be near each other. These relationships are similar to human friendships, in that they entail preferential treatment of particular individuals in multiple interactions over time, and may rely on similar cognitive and physiological mechanisms (Massen, Sterck, & Vos, 2010; Seyfarth & Cheney, 2012; Silk, 2002). The stability of these relationships – that is, that the quality of treatment at time A predicts the quality of treatment at time B – has been observed in horses, mice, macaques, capuchins, chimpanzees, baboons, and dolphins, with some dyads experiencing relationships that are stable over the course of years to a decade (Cameron, Setsaas, & Linklater, 2009; Kalbitz, Ostner, & Schülke, 2016; Koski, de Vries, van de Kraats, & Sterck, 2012; Langergraber, Mitani, & Vigilant, 2009; Massen & Sterck, 2013; Mitani, 2009; Perry, 2012; Silk, Alberts, Altmann, Cheney, & Seyfarth, 2012; Silk et al., 2010; Weidt, Hofmann, & König, 2008; Wiszniewski, Brown, & Moeller, 2012).

3.2.2. *How much did productivity vary between interactions?*

Humans form long-term cooperative relationships that span across interactions and activity types, and aide provided in one domain (e.g. childcare) may be reciprocated in another domain (e.g. other labor; Jaeggi, Hooper, Beheim, Kaplan, & Gurven, 2016). Above, we argued that the generosity received from a partner at one time is likely to be predictive of their generosity at another time (even in a different cooperative domain), because WTR judgments are stable by design. But what about the ability to create benefits? Here we argue that productivity is less stable across interactions; in other words, how good someone is at creating benefits in interaction A is less predictive of their ability to create benefits in interaction B, compared to the stability of generosity. This is because the skills and knowledge that hunter-gatherers rely on are domain-specific and take time to acquire, and because even highly skilled foragers experience high variance in their outcomes over time.

Turning first to the question of intra-individual variance in productivity across time, evidence suggests that foragers commonly experience semi-random episodes in which they are unable to produce resources, owing largely to injury and illness (Sugiyama, 2004). Of 215 recorded health insults among a forager group (e.g. infections, lacerations, bites, etc.), 40% disabled the victim for at least one day, 30.7% for at least one week, and 14.9% for at least one month. As a result, Sugiyama (2004) estimates that 64.7% of foragers have experienced a disability of at least 30 days, and 94% have experienced a disability of at least 7 days. Compared to a modern economy, “sick days” among our ancestors were far more common and far more serious. Even when foragers are healthy enough to produce, there is wide intra-individual variance in outcomes, particularly in the domain of hunting. Even the best hunters in a group experience large fluctuations over time in their hunting returns, including periods of very low

yields, such that small numbers of observations are unrevealing of future returns (Hill & Hurtado, 2009; Hill & Kintigh, 2009). Approximately half of hunts among the Aché fail to produce any meat at all, and this is largely due to factors outside of the hunter's control, such as weather and animal movements (McElreath & Koster, 2014).

There is less research directly comparing productivity across domains than productivity over time within a single domain, but we can nonetheless develop a rough estimate of the domain-specificity of productivity. There is reason to believe that productivity in one domain will have some limited power to predict productivity in another domain, because there are traits that contribute to multiple types of productive ability. For example, physical size among males simultaneously predicts the ability to produce food, win fights, and influence the community (von Rueden, Gurven, & Kaplan, 2008), and the general factor of intelligence predicts ability in a wide range of tasks (Gottfredson, 2002). In addition, health likely predicts ability across domains since most tasks cannot be completed without a threshold level of strength and energetic availability, but it is not clear that health should be predictive above these thresholds.

Despite the existence of these traits that contribute to productivity in multiple domains, productivity in the environment of our ancestors was likely largely domain-specific, because it relied on deep, specialized knowledge acquired over time. The clearest example of this is large-game hunting. Men do not reach their productive peak as hunters until approximately age 40, well after achieving adult size and even after physical strength has begun to decline (Gurven, Kaplan, & Gutierrez, 2006; see Lew-Levy, Reckin, Lavi, Cristóbal-Azkarate, & Ellis-Davies, 2017 for review of similar findings). This is because hunting success is heavily dependent on experience and specialized knowledge, such as the ability to identify animal species from their tracks, which take decades to acquire. Though not as extreme an example as large-game hunting,

efficiently gathering and extracting plant foods also depends on expertise which takes years or decades to develop (Kaplan et al., n.d.). Other skills, such as the ability to manufacture complex tools, musical ability, and knowledge of medicinal plants, also require a long time to acquire and continue developing well into adulthood (e.g. Begossi, Hanazaki, & Tamashiro, 2002; Lew-Levy et al., 2017; Schniter, Gurven, Kaplan, Wilcox, & Hooper, 2015). Schniter et al (2015) observe that foragers' skill levels in different domains typically shift across the lifespan, from domains that require more strength and towards those requiring more expertise, as individuals' physical capacities and knowledge bases change. Since time and experience are finite and exclusive, there are tradeoffs to developing any particular skill. Therefore, expertise in one area is unlikely to strongly predict expertise more generally. In other words, seeing that a person excels in domain A does not reveal that they will excel in domain B, at least not nearly to the degree that generosity generalizes.

4. Agent-based models testing these hypotheses

We have identified two novel hypothesis for why people care more about generosity (and related traits) than about productivity (and related traits), based on an evolutionary history of selecting social partners: (1) Generosity is prioritized over productivity because it varied more between possible partners, and (2) Generosity is prioritized over productivity because it varied less between interactions with a given cooperative partnership (i.e. it was less domain-specific than productivity). As the above literature review shows, these assumptions about the ancestral social ecology are justified by the anthropological literature. We argue that these features of the social ecology created selection pressures promoting the prioritization of generosity in cooperative partner choice, and therefore in social perception more broadly, but the question

remains as to the mechanistic plausibility of these selection pressures. That is, if generosity really did vary more between individuals but less within relationships relative to productivity, would that actually cause the prioritization of generosity to evolve?

To address this question, we constructed agent-based models (Smith & Conrey, 2007) in which we varied features of the ecology relevant to our hypotheses. This allows us to simulate how partner selection heuristics – specifically, the relative weight given to generosity vs. productivity – would evolve in different social ecologies. Effectively, we can observe evolution in a simulated population in order to test whether the hypothesized selection pressures are likely to actually produce the psychological trait we seek to explain.

4.1. Design of agent-based models

We simulated populations of agents who chose each other for relationships, cooperated within those relationships, reproduced in proportion to the resources they received as a result, and died. Each agent had three traits: productivity, generosity, and the degree to which they prioritize generosity over productivity in partner choice (with 0.5 indicating an equal preference for generosity and productivity). Productivity and generosity values were randomly drawn from normal distributions with a mean of 0.5 and standard deviations which were varied parametrically in order to model differing levels of individual differences in these traits. The degree to which an agent prioritized generosity in the first generation was randomly drawn from a normal distribution with a mean of 0.5 and a standard deviation of .05, and then evolved over subsequent generations. These populations evolved over 3,000 generations.

Each generation consisted of 100 agents. In order to pair up for cooperative relationships, we lined up the agents in a random order. The first agent chose from the next two in line (choice

algorithms will be described below); it was paired with the agent it chose and both were removed from the line. The rejected agent was moved to the end of the line, and this process was repeated until all agents were paired.

Each pair of agents then cooperated in what can be thought of as digital foraging task. One agent in the pair was randomly chosen to forage, and their productivity was tested against a random number drawn on the uniform interval $[0,1]$. If the agent succeeded (i.e. their productivity exceeded the random draw), that agent produced a resource of value 1, shared a portion of their earnings with their partner proportional to their generosity and kept the rest. That is, imagine that ‘Bob’ is chosen to forage, and ‘Bob’s productivity = 0.6 and generosity = 0.45. Imagine the random draw = 0.5, in which case ‘Bob’ succeeds (because $0.6 > 0.5$), produces 1 unit of resources, and sends 0.45 units to his partner and keeps 0.55 units for himself. Note that these are realistic operationalizations of individual differences in productivity and generosity; among hunter-gatherers, good hunters are distinguished more by their frequency of success than by the size of a typical kill (e.g. McElreath & Koster, 2014), and the proportion of a resource given to a partner matches the intuitive meaning of generosity. After each interaction, whether or not the agents interacted again was probabilistically determined by a parameter, w , which we varied parametrically in order to model ecologies of longer and shorter relationships. Therefore, agents accumulated benefits over some number of rounds of digital foraging with their partner, such that agents with more productive and more generous partners would be expected to accumulate more benefits.

If the agents engaged in another interaction, their productivity and generosity levels were updated using a random walk procedure in order to model the domain specificity of these traits. That is, we model the multiple interactions that can occur across a relationship as potentially

involving multiple domains. We added to their prior trait levels a value drawn randomly from normal distributions with mean = 0 and a SD that we varied parametrically and separately for each trait. This SD therefore dictates how well productivity and generosity in the first interaction predict productivity and generosity in subsequent interactions. When this SD is comparatively small, that yields a straighter random walk, meaning that the trait value generalizes better across interactions, and the trait is therefore less domain specific. When this SD is comparatively large, that creates a more variable random walk, which means that trait values in the initial interaction are less predictive of their values in subsequent interactions, i.e. the trait is more domain-specific.

After all of the rounds of interaction within a population were concluded, the agents reproduced asexually in proportion to the resources that they had accumulated, such that the more successful agents were more likely to leave offspring in the next generation. Offspring inherited the degree to which they prioritized generosity from their parent agent, modified by a 5% mutation rate. Following previous models (e.g. Delton, Krasnow, Cosmides, & Tooby, 2011), each offspring had a 0.05 probability of a mutation, in which case we added a random value from a normal distribution with mean = 0 and SD = 0.025 to the degree to which their parent prioritized generosity. The offspring then engaged in the same process of pairing, cooperation, and reproduction, and this was repeated for a total of 3000 generations.

We varied the algorithm by which agents chose their partners, in order to model the prioritization of generosity under different types of social cognition. When the cognition type was “information choice,” the agent choosing between two different partners was initially blind to all of their traits, and then had to choose whether to learn either the productivity levels or generosity levels of the two potential partners. In this case, the degree to which the agent

prioritized generosity equaled the probability that they would choose to learn the generosity levels of the two potential partners. Once the choosing agent learned the information that they chose, they chose the partner who was higher on that dimension. When the cognition type was “information weighting,” the choosing agent could see both the generosity and productivity levels of their potential partners, and computed a weighted average of those two values to create a composite partner value score for each potential partner. In this case, the degree to which the agent prioritized generosity equaled the weight applied to generosity in computing these partner value scores, with productivity given the complementary weight (e.g. if generosity was weighed by 0.6, productivity was weighted by 0.4). The agent then chose the partner with the higher composite partner value score. We expect the prioritization of generosity to evolve under both cognition types; we tested both cases as a robustness check to demonstrate that this evolutionary process is not dependent on any particular partner choice heuristic.

In total, there were six parameters that we varied using a factorial design: generosity individual differences (i.e. population SD), productivity individual differences (i.e. population SD), generosity domain specificity (i.e. random walk SD), productivity domain specificity (i.e. random walk SD), w (probability of a pair having another interaction), and cognition type. The values we used for individual differences and domain specificity for productivity and generosity were 0.0, 0.1, 0.2, 0.3, 0.4, and 0.5. W was varied to create three expected relationship lengths: 1 interaction, 10 interactions, and 50 interactions (group by group, the number of interactions was drawn from a normal distribution with mean w , $SD = w/5$, rounded to the nearest whole number). There were two cognition types: information choice (agents choose to learn either the generosity or productivity values of their two potential partners), and information weighting

(agents create a weighted average of productivity and generosity to evaluate their potential partners). The model was run 50 times at every possible combination of parameter settings.

We have two main hypotheses:

H1: The evolution of the prioritization of generosity will be positively related to the degree to which individual differences in generosity exceed individual differences in productivity; when individual differences in generosity and productivity are equivalent, the prioritization of generosity will not evolve.

H2: The evolution of the prioritization of generosity will be positively related to the degree to which the domain specificity of productivity exceeds the domain specificity of generosity; when generosity and productivity are equally domain specific, the prioritization of generosity will not evolve.

There are also more nuanced predictions that serve to verify the precision of the hypothesized selection pressures. First, we expect an asymmetry in domain specificity to select for the prioritization of generosity only in an ecology of long-term relationships. Conceptually, the domain specificity of a trait is meaningless if agents interact only in one domain (i.e. have only one interaction). Mechanistically, if agents interact only once, there is no opportunity for the profile of the random walk to affect their fitness. As relationships get longer, however, the asymmetry in domain specificity is expected to exert a stronger selection pressure. Second, we expect an asymmetry in individual differences to select for the prioritization of generosity only under the information choice cognition type. This is because an agent with the information

choice cognition type is choosing their partner under uncertainty (i.e. they only know half of the information about their potential partners); the magnitude of the uncertainty is the magnitude of individual differences in the trait that they have chosen not to see. Under these conditions, choosing to learn about the more variable trait is a way to reduce this uncertainty as much as possible, and therefore reduce the scale of possible mistakes. On the other hand, an agent with the information weighting cognition type has complete information about its potential partners; there is no reason that the distributions from which those trait values were drawn would affect its fitness.

4.2. Analysis

After running 50 iterations of the model at each combination of parameter settings, we averaged the degree to which generosity was prioritized in the last 500 generations of each population. This yields one data point for each of the 50 model runs at each parameter setting. We used these means as an estimate of the outcome of this evolutionary process.

In order to test the outcomes of these simulations, we first ran a multiple regression testing the main effects of productivity individual differences, generosity individual differences, productivity domain specificity and generosity domain specificity on the mean prioritization of generosity across all values of w and cognition type. Next, we added the main effects of cognition type, and each of the two-way interaction terms between cognition type and the productivity and generosity parameters. Finally, we added to the original main effects model the main effect of w and the two-way interactions between w and the productivity and generosity parameters. This allows us to test whether relationship length and cognition type moderate the effects of within- and between-partner variance in productivity and generosity as we expect.

Note that we are not particularly interested in conventional significance testing in this case, since the number of agents per population, number of model runs per parameter setting, etc. are essentially arbitrary. Rather, we are using these regressions primarily to confirm the patterns revealed by graphing the data.

Plots of the mean prioritization of generosity across all 3000 generations at every parameter setting are presented in SI. In order to present the outcomes of these simulations in a more condensed way, we computed the difference between productivity and generosity for both domain specificity and individual differences for each model run. We then plotted the mean prioritization of generosity in the last 500 generations against these difference scores, which we present here. We predict that the prioritization of generosity will be greater at parameter settings when individual differences in generosity exceed those in productivity, and when the domain specificity of productivity exceeds that of generosity.

4.3 Results

Table 1 presents the results of the three regression models described above. As predicted, increasing individual differences in generosity promote the prioritization of generosity, and individual differences in productivity have a symmetrical negative effect; simultaneously, increasing domain specificity of productivity promotes the prioritization of generosity, and domain specificity in generosity has a symmetrical negative effect (Model 1). Figure 1 shows the effect of the degree to which generosity individual differences exceed productivity individual differences. As predicted, the prioritization of generosity is selected for to the degree that generosity is more variable between agents than productivity; when individual differences are equal generosity and productivity are equally valued, and productivity is prioritized when it is

more variable between individuals than generosity. Figure 2 shows the effect of the degree to which productivity domain specificity exceeds generosity domain specificity. As predicted, the prioritization of generosity is selected for to the degree that productivity is more domain specific than generosity; when they are equally domain specific productivity and generosity are equally valued, and productivity is prioritized when it is less domain specific than generosity.

Table 1

Main effects and interactions predicting the evolution of the prioritization of generosity.

	Model 1		Model 2		Model 3	
	<i>b</i>	95% CI	<i>b</i>	95% CI	<i>b</i>	95% CI
Generosity ID	0.25	(0.24, 0.25)	0.05	(0.04, 0.05)	0.31	(0.30, 0.32)
Productivity ID	-0.25	(-0.25, -0.24)	-0.05	(-0.06, -0.05)	-0.32	(-0.33, -0.31)
Generosity DS	-0.25	(-0.25, -0.24)	-0.21	(-0.22, -0.21)	-0.12	(-0.13, -0.11)
Productivity DS	0.25	(0.24, 0.25)	0.21	(0.21, 0.22)	0.12	(0.11, 0.13)
Cognition type (information choice)			-0.01	(-0.01, 0.00)		
Cognition type (information choice) *			0.40	(0.39, 0.41)		
Generosity ID						
Cognition type (information choice) *			-0.39	(-0.40, -0.38)		
Productivity ID						
Cognition type (information choice) *			-0.07	(-0.08, -0.06)		
Generosity DS						
Cognition type (information choice) *			0.07	(0.07, 0.08)		
Productivity DS						
w (relationship length)					0.00	(0.00, 0.00)
w * Generosity ID					-0.00	(-0.00, -0.00)
w * Productivity ID					0.00	(0.00, 0.00)
w * Generosity DS					-0.01	(-0.01, -0.01)
w * Productivity DS					0.01	(0.01, 0.01)

ID = individual differences. DS = domain specificity. For cognition type, the reference class is “information weighting.” All terms in the table are statistically significant at $p < .001$ except for the main effects of cognition type ($p = .001$) and w ($p = .516$).

Figure 1. Evolution of the prioritization of generosity under different asymmetries between generosity individual differences and productivity individual differences. On the left of the graph, generosity varies more between agents than productivity does; on the right of the graph, productivity varies more between agents than generosity does. Error bars = 95% CI.

Figure 2. Evolution of the prioritization of generosity under different asymmetries between generosity domain specificity and productivity domain specificity. On the left of the graph, generosity is more domain specific than productivity is; on the right of the graph, productivity is more domain specific than generosity is. Error bars = 95% CI.

We next turn to the moderation of these main effects by cognition type and expected relationship length. Figure 3 shows how the asymmetry in individual differences interacts with cognition type and relationship length, and Figure 4 does the same for domain specificity. As expected, there is no effect of the asymmetry in individual differences in populations with the information weighting cognition type, but there is a consistent effect when the cognition type is information choice. Also as predicted, the asymmetry in domain specificity has no effect in an ecology of one-shot interactions, but exerts a stronger selection pressure as relationships become longer. Models 2 and 3 in Table 1 confirm these interactions.

Figure 3. Effect of the asymmetry in individual differences on the evolution of the prioritization of generosity, split by cognition type and expected number of interactions. On the left of each graph, generosity varies more between agents than productivity does; on the right of each graph, productivity varies more between agents than generosity does. Error bars = 95% CI.

Figure 4. Effect of the asymmetry in domain specificity on the evolution of the prioritization of generosity, split by cognition type and expected number of interactions. On the left of each graph, generosity is more domain specific than productivity; on the right of each graph, productivity is more domain specific than generosity. Error bars = 95% CI.

Plots of how the prioritization of generosity evolved over 3000 generations at each of the parameter setting are presented in online SI. These graphs support the conclusions drawn above:

The prioritization of generosity is promoted by increasing individual differences in generosity and domain specificity of productivity, and by decreasing individual differences in productivity and domain specificity of generosity; the effect of variance in domain specificity is null when relationships are single-shot, but increases as the number of expected interactions increases; and

variance in individual differences has an effect when agents must choose whether to learn their partners' generosity or productivity (leaving the other trait unknown), but has no effect when agents have complete information on their potential partners.

5. Discussion

The results of the agent-based models supported our predictions, thereby demonstrating the plausibility of our hypothesized selection pressures. As expected, the prioritization of generosity was selected for when generosity was more variable in the population than productivity, and when productivity was more domain specific than generosity. These are likely features of the social and cooperative ecologies in which humans evolved (see Introduction), suggesting that they may be the ultimate explanation for the oft-observed prioritization of generosity/warmth/morality/communion over productivity/competence/agency. The key insight underlying these models is that, in a cooperative ecology like the one in which humans evolved, both abilities and dispositions can have profound effects for the self and for others. These models therefore connect the warmth and competence literature to the growing literature suggesting that the need to choose cooperative partners in fitness-enhancing ways was a powerful selection pressure in human evolution (e.g. Barclay, 2016; Cosmides et al., 2010; Cottrell et al., 2007; Delton & Robertson, 2012; Eisenbruch, Grillot, Maestripieri, & Roney, 2016; Eisenbruch, Grillot, & Roney, under review; Eisenbruch & Roney, under review; Hall, 2011; Lewis et al., 2011; Lukaszewski, Simmons, Anderson, & Roney, 2016; Smith & Apicella, 2019; Vigil, 2007).

The model results further suggest that it was truly the asymmetries in how productivity and generosity were distributed between and within potential partnerships that created these

selection pressures, rather than any intrinsic features of productivity and generosity themselves. Note that productivity and generosity remained equally valued when they were equally variable between and within agents, and that the selection pressures reversed, favoring the prioritization of productivity, when productivity was more variable in the population and less domain specific than generosity. Also, as expected, domain specificity had no effect when agents interacted only once, and the population variance of traits had no effect when agents had complete information on their potential partners (i.e. in the information weighting condition). These results suggest that the prioritization of generosity evolved not because generosity is intrinsically more “other-profitable” or important in a cooperative partner than productivity, but because specific features of the ecology – the existence of long term relationships, the need to make decisions under uncertainty, the population variance of these traits, and the domain specificity of these traits – interacted to favor the evolution of this preference.

We suspect that ancestral humans experienced a shifting amalgam of the conditions that we modeled: they likely experienced different degrees of uncertainty in different situations, calling for different degrees of information choice and weighting; relationships likely had different lengths (though one-shot relationships would have been rare; Krasnow, Delton, Tooby, & Cosmides, 2013); and the between- and within-relationship variance in productivity and generosity may have shifted across times, places, and relationship types. Therefore, we interpret these models as demonstrating a range of plausible conditions under which the prioritization of generosity is likely to evolve, and we think it is likely that the relevant features of the ecology in which humans evolved fell within this range (see Introduction).

This approach may help explain sex differences in the degree to which generosity is prioritized. It has been widely observed that men do not prioritize warmth over competence in

social cognition to the same extent that women do (see Introduction), that men are more willing to tolerate defections in their relationships than women are (e.g. Benenson et al., 2014, 2009), and that men are relatively more sensitive to productivity information than women are when dividing resources and choosing social partners (e.g. Eisenbruch et al., 2016; Eisenbruch, Grillot, & Roney, under review; Eisenbruch & Roney, under review, 2017; Hall, 2011). We suggest that this may be because ancestral men and women chose partners for cooperation in different domains in which the distributions of productivity and generosity differed. Specifically, large game hunting and coalitional violence were activities more often pursued by ancestral males, and these domains may have been especially high in interindividual variance, particularly variance in outcome due to differences in productivity (see Introduction). Therefore, ancestral men may have found themselves in ecologies in which the individual differences in generosity exceeded those in productivity to a lesser degree than women did (i.e. to the right in Figure 1), thereby exposing men to weaker selection for the prioritization of generosity. This argument is not mutually exclusive with an explanation of sex differences based on contemporary social roles (e.g. Eagly & Wood, 2016), so an important area of future research will be testing the degree to which observed sex differences in social cognition appear calibrated by ancestral ecologies versus current socialization.

Our cooperative partner choice-based approach also accommodates the finding that the priority of warmth over competence in social cognition reverses when people think about themselves or others very close to them (see Introduction). We can think of decreasing social distance as decreasing the variance in generosity that one might receive from a partner. To compare extremes: a stranger may or may not be considerate of an observer's interests, but a person is (nearly) always considerate of their own interests. Effectively, a person can reliably

expect a high WTR from a close friend, so the variance in possible generosity is very low. As the present models show, decreasing inter-individual variance in generosity while holding variance in productivity constant (i.e. moving to the right in Figure 1) causes generosity to be prioritized less in partner choice. This approach may therefore help clarify and demonstrate why warmth-related traits can become more or less salient depending on the target of evaluation.

We are careful not to conclude from these models more than they can tell us. First, these models were designed to test the evolution of the prioritization of generosity over productivity in partner choice, not the evolution of either of those traits themselves or other features of partner choice. Therefore, we deliberately did not allow productivity or generosity levels to evolve, nor did we model mutual partner choice and/or assortment by trait levels. There are existing models addressing these topics (e.g. Aktipis, 2004, 2011; Barclay, 2011; Debove, André, & Baumard, 2015; Debove, Baumard, & André, 2015; Debove, Baumard, & Andre, 2017). Second, the success of these models in demonstrating the evolution of the prioritization of generosity does not exclude the possibility of other potential explanations for this phenomenon. Other selection pressures, as well as cultural processes and individual learning, for example, may also contribute to the prioritization of generosity. Finally, these models are simulations using simplified cognitive processes and ecological features. They suggest a plausible evolutionary path from the distributions of generosity and productivity in the environment of our ancestors to the prioritization of generosity observed in contemporary humans, but the plausibility of this evolutionary process does not prove that this is what actually occurred during human evolution.

One specific limitation of the models is that it was not possible for agents to inflict harm on each other. In the real world, people sometimes take resources or otherwise hurt each other, and the importance of harm avoidance may motivate the prioritization of warmth. Note that this

is not an alternative explanation to our own, but a quantitative extension of our model. By limiting generosity in our model to be strictly positive, we likely underestimated the effect of generosity variance on the evolution of the prioritization of generosity. Allowing negative generosity (i.e. taking resources or inflicting harm) while maintaining the range of productivity values would result in the population variance of generosity exceeding that of productivity to an even greater degree (i.e. extending Figure 1 to the left), likely leading to even stronger prioritization of generosity. The argument that warmth information is prioritized because of the possibility of harm is thus consistent with our model, merely redescribing the premise that WTR values can range negative by design, unlike productivity.

Thinking of social preferences as heuristics for making decisions under uncertainty, and of variance in traits as sources of uncertainty, may yield interesting predictions for social cognition. The relative preferences for warmth and competence may vary between places and time periods depending on how much each parameter varies both within and between relationship partners, similarly to how cognitive and social styles vary with local modes of production (e.g. Talhelm et al., 2014) and relational mobility (e.g. Schug, Yuki, & Maddux, 2010). This calibration could take place over evolutionary time, as demonstrated here, or perhaps via individual learning or cultural change. One fruitful area of future research could be testing the calibration of the prioritization of generosity to local conditions, and discerning the mechanism(s) of this calibration. Other types of preferences – e.g. mate preferences, food preferences, friend preferences – could be subjected to similar analyses as well. One interesting area of future research could be testing the functional fit between preferences in different domains and the fitness-relevant variance in the trait to which the preference applies. This

approach could unify the study of preferences across different domains, and shed new light on why preferences exist and how they operate.

6. Conclusion

In the present paper, we have presented a new explanation for the phenomenon – widely observed across multiple domains – that people care more about another person’s warmth-related traits (generosity, morality, intentions) than about their competence-related traits (agency, productivity). In contrast to existing explanations, we do not assume that generosity is intrinsically more consequential for an observer. Our argument is that asymmetries in the distributions of these traits in the social ecologies of ancestral humans, such that generosity varied more than productivity between relationship partners but productivity varied more than generosity within relationships, created selection pressures promoting the prioritization of generosity in social perception. The anthropological literature suggests that these distributions were likely characteristic of human ancestral ecologies, and agent-based models demonstrate that these ecological features are likely to lead to the evolution of the prioritization of generosity. We hope that this approach will foster new research advances, and further ground social psychology in evolutionary thinking.

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Supplementary Information

Figure S1. The prioritization of generosity across 3000 generations, at different parameterizations of generosity individual differences and productivity individual differences. Values are means of the likelihood of choosing to learn the potential partners' generosity levels (versus productivity levels), averaged across all model runs at the specified parameterization. The cognition type is information choice, and the number of expected interactions between partners (w) is 1.

Figure S2. The prioritization of generosity across 3000 generations, at different parameterizations of generosity individual differences and productivity individual differences. Values are means of the likelihood of choosing to learn the potential partners' generosity levels (versus productivity levels), averaged across all model runs at the specified parameterization. The cognition type is information choice, and the number of expected interactions between partners (w) is 10.

Figure S3. The prioritization of generosity across 3000 generations, at different parameterizations of generosity individual differences and productivity individual differences. Values are means of the likelihood of choosing to learn the potential partners' generosity levels (versus productivity levels), averaged across all model runs at the specified parameterization. The cognition type is information choice, and the number of expected interactions between partners (w) is 50.

Figure S4. The prioritization of generosity across 3000 generations, at different parameterizations of generosity individual differences and productivity individual differences. Values are means of the weight given to the potential partner's generosity levels (versus productivity levels), averaged across all model runs at the specified parameterization. The cognition type is information weighting, and the number of expected interactions between partners (w) is 1.

Figure S5. The prioritization of generosity across 3000 generations, at different parameterizations of generosity individual differences and productivity individual differences. Values are means of the weight given to the potential partner's generosity levels (versus productivity levels), averaged across all model runs at the specified parameterization. The cognition type is information weighting, and the number of expected interactions between partners (w) is 10.

Figure S6. The prioritization of generosity across 3000 generations, at different parameterizations of generosity individual differences and productivity individual differences. Values are means of the weight given to the potential partner's generosity levels (versus productivity levels), averaged across all model runs at the specified parameterization. The cognition type is information weighting, and the number of expected interactions between partners (w) is 50.

Figure S7. The prioritization of generosity across 3000 generations, at different parameterizations of generosity domain specificity and productivity domain specificity. Values are means of the likelihood of choosing to learn the potential partners' generosity levels (versus productivity levels), averaged across all model runs at the specified parameterization. The cognition type is information choice, and the number of expected interactions between partners (w) is 1.

Figure S8. The prioritization of generosity across 3000 generations, at different parameterizations of generosity domain specificity and productivity domain specificity. Values are means of the likelihood of choosing to learn the potential partners' generosity levels (versus productivity levels), averaged across all model runs at the specified parameterization. The cognition type is information choice, and the number of expected interactions between partners (w) is 10.

Figure S9. The prioritization of generosity across 3000 generations, at different parameterizations of generosity domain specificity and productivity domain specificity. Values are means of the likelihood of choosing to learn the potential partners' generosity levels (versus productivity levels), averaged across all model runs at the specified parameterization. The cognition type is information choice, and the number of expected interactions between partners (w) is 50.

Figure S10. The prioritization of generosity across 3000 generations, at different parameterizations of generosity domain specificity and productivity domain specificity. Values are means of the weight given to the potential partner's generosity levels (versus productivity levels), averaged across all model runs at the specified parameterization. The cognition type is information weighting, and the number of expected interactions between partners (w) is 1.

Figure S11. The prioritization of generosity across 3000 generations, at different parameterizations of generosity domain specificity and productivity domain specificity. Values are means of the weight given to the potential partner's generosity levels (versus productivity levels), averaged across all model runs at the specified parameterization. The cognition type is information weighting, and the number of expected interactions between partners (w) is 10.

Figure S12. The prioritization of generosity across 3000 generations, at different parameterizations of generosity domain specificity and productivity domain specificity. Values are means of the weight given to the potential partner's generosity levels (versus productivity levels), averaged across all model runs at the specified parameterization. The cognition type is information weighting, and the number of expected interactions between partners (w) is 50.