HHS Public Access
Author manuscript
Evol Hum Behav. Author manuscript; available in PMC 2024 February 11.

Published in final edited form as:
Evol Hum Behav. 2018 May ; 39(3): 355–363. doi:10.1016/j.evolhumbehav.2018.03.003.

Evidence from hunter-gatherer and subsistence agricultural populations for the universality of contagion sensitivity

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Abstract

The phenomenon of *magical contagion* – the unobserved passage of properties between entities that come into physical contact – was described by anthropologists over a century ago, yet questions remain about its origin, function, and universality. Contagion sensitivity, along with the emotion of disgust, has been proposed to be part of a biologically-evolved system designed to reduce exposure to pathogens by increasing the avoidance of "contaminated" objects. Yet this phenomenon has not been studied using systematic psychological comparison outside of industrialized populations. Here we document contagion sensitivity in two culturally, geographically, and economically distinct populations with little exposure to Western biomedicine and formal education: the Hadza hunter-gatherers of Tanzania and Tannese subsistence-agriculturalists of Vanuatu. In both populations, a majority of individuals rejected familiar and palatable foods when contaminating items touched the food but were subsequently removed. The Tannese children in our study showed a similar response, consistent with previous research with Western children. Our data support the proposal that contagion sensitivity is universal in human populations.

Keywords

Biological reasoning; Contagion; Contamination; Disgust; Folkbiology; Pathogen avoidance; Small-scale societies

1. Introduction

The belief that physical contact between two entities often entails the passage of properties between them, even after contact has been severed, was labeled as the *law of contact or magical contagion* by anthropologists >100 years ago (Frazer, 1922/1890; Freeland, 1980; Mauss, 1972/1902; Tyler, 1974/1871). Magical contagion was thought to be a

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Contributions
CA, CL, and PR designed the study. JB, RW, CA and CL collected and analyzed data. CA, CL and PR wrote the manuscript. All authors provided extensive feedback on each draft.

Appendix A. Supplementary data
Supplementary data to this article can be found online at https://doi.org/10.1016/j.evolhumbehav.2018.03.003.

ubiquitous and fundamental feature of magical practices and rituals in traditional societies and folklore.[1] A common instantiation of this principle relates to food and disgust: a favored or acceptable food is often rejected after it has, even briefly, contacted a certain class of offensive objects. A widely held view is that both the contamination sensitivity surrounding offensive items and its associated disgust response are part of a biologically-evolved system designed to reduce the transmission of pathogens and disease (e.g., Oaten, Stevenson, & Case, 2009; Curtis, Aunger, & Rabie, 2004; Curtis & Biran, 2001; Tybur, Lieberman, Kurzban, & DeScioli, 2013). Indeed, contagion is regularly associated with the emotion of disgust and a defining feature of disgust-eliciting objects is their contaminating properties (Rozin & Fallon, 1987). Though systematic cross-cultural data are lacking, studies with U.S. adults in the late 1980's suggest that contagion is widespread in Western, educated adults (Rozin, Millman, & Nemeroff, 1986; Rozin, Nemeroff, Wane, & Sherrod, 1989). Here we examine the presence of contagion beliefs in two culturally, geographically and economically diverse and remote populations with relatively little experience with Western biomedicine and formal education: the Hadza hunter-gatherers of Tanzania and the Tannese subsistence agriculturalists of Vanuatu.

In the current study, we examined contagion in the domain of pathogen avoidance (e.g., rotten or contaminated food and bodily fluids) and poison avoidance (e.g., toxic plants and inedible objects). The properties of contagion are consistent with cues that correlated with pathogen presence in ancestral environments (Tybur et al., 2013). Disgust may have evolved to regulate the avoidance of substances harboring pathogens (Rozin, Haidt, & McCauley, 2008; Tybur, Lieberman, & Griskevicius, 2009) and may have been co-opted to regulate behavior in other domains related to reproduction and social transgressions (Rozin, Haidt, & McCauley, 1993; Schaich Borg, Lieberman, & Kiehl, 2008; Tybur et al., 2009).

According to Rozin and Nemeroff (1990), the properties of contagion are as follows: First, the contaminant must physically contact the target entity. Second, contagion is dose insensitive; even brief contact with the contaminated object is sufficient to produce a strong negative response and this does not increase much with higher doses. Third, rejection of the contacted target is permanent so long as the person in question remembers the past contact - thus the description of contagion as "once in contact, always in contact" (Mauss, 1972/1902). Fourth, contagion is manifested much more generally, and in higher magnitude, if the source entity is hazardous, hence the frequent use of the word contamination to describe contagion. Fifth, contagion beliefs can account for both the transmission of specific attributes from the source to the target (e.g., "you are what you eat", Nemeroff & Rozin, 1989), but also a general negative valence. Finally, the contagion process may best be described as a transfer of some kind of essence from the source to the target (Raman & Gelman, 2004).

[1]Tyler, Frazer and Mauss provide treatises on the mental foundations of religion, mythical thought and magic. The laws of magic, including the law of contact, were formed by Tyler and later developed by Frazer and Mauss. All provide the example of magical punishment, whereby a person can be acted upon by others through the use of an object in which she had once been in contact, including their clothing hair and nails. Frazer further described examples of magical contact that can occur between friends and other relations, such that the behavior of one affects the behavior of another. Likewise, he documents examples of sympathetic eating such that an individual is said to acquire the traits of the animal or person she consumes. None of the authors systematically cataloged examples of magical contagion. Nevertheless, we provide a summary of their examples, but note that most examples are of backward contagion which does not fit the pathogen model (Table S1).

Because viruses and bacteria tend to be invisible, cognitive (contagion sensitivity) and affective (disgust) processes may have evolved to prevent individuals from making contact with hazardous items (Tybur et al., 2013). Specifically, contagion beliefs may be shaped by a specialized learning mechanism designed to modify the disgust response adaptively depending on local environment and culture (Curtis, de Barra, & Aunger, 2011). That is, the disgust system is specially designed to interact with local conditions such that the items that induce disgust and contaminate will vary between groups in ways that are beneficial for preventing the spread of disease within those groups. That said, some disgust cues (e.g. bodily fluids, rotten foods, toxic plants) are expected to be culturally invariant because of their adverse effects in *all* environments. The emotion of disgust, with its distinctive facial expression (Brown, 1991; Ekman & Friesen, 1971) and characteristic feelings of revulsion (Angyal, 1941; Rozin & Fallon, 1987), is likely universal (e.g. Curtis & Biran, 2001), however, it is currently unknown whether contagion beliefs involving disgust-eliciting items are also universal.

A number of observations support the hypothesis that the original function of disgust and contagion was pathogen avoidance (Curtis, 2013; Rozin et al., 1993; Rozin, Haidt, & McCauley, 2016; Tybur et al., 2013). First, the transmission of infectious disease is a ubiquitous problem and natural selection has produced an array of taxa with various pathogen-avoidance mechanisms. For instance, mangabey (*Cerocebus albigena*) movement patterns respond, in part, to the risk of parasitic infection from contaminating fecal matter of conspecifics (Freeland, 1980). Second, physical contact with an infected entity can, and often does, transmit pathogens from the source to the target (Rozin et al., 1986; Rozin & Fallon, 1987). Third, a wide range of data supports the link between the emotion of disgust and items that spread disease (Oaten et al., 2009).

Contagion beliefs exhibit design features indicative of adaptations including reliability, precision, efficiency, complexity, and logic (see Williams, 1966). Disgust-eliciting items reliably contaminate items once physical contact is made, regardless of the item it is contaminating, and does so, with precision. A pen and a spoon would both become contaminated after making contact with fecal matter, but these effects would not generalize to other uncontacted spoons and pens. Contagion beliefs also efficiently solve the problem of pathogen exposure since contagion leads to revulsion and rejection of potentially hazardous, pathogen-laden items. The fact that exposure to contaminants are largely dose-insensitive, such that brief contact will have contaminating effects, suggests that the system is well-calibrated for avoiding harmful micro or ultra-microscopic bacteria and viruses. Finally, this constellation of features displays a degree of complexity that makes arguments that it arose by chance unlikely. It is hard to imagine another specific and recurring problem that contagion beliefs so fittingly solve.

The strong inference that a feature of human behavior is evolved, in the absence of an historical record, also depends on assembling a range of convergent evidence. The most persuasive evidence is presence in other primates and/or presence at birth. That said, adaptations do not need to be present at birth, rather, they need to develop reliably and at a time during development when the trait would be needed (Cosmides & Tooby, 1997). Pathogen and poison contagion awareness develops robustly in early and middle childhood in Western industrialized populations (Legare, Wellman, & Gelman, 2009). And while there are clear developmental trends toward greater awareness and understanding with age (Au & Romo, 1999; Au, Sidle, & Rollins, 1993; Fallon, Rozin, & Pliner, 1984; Hejmadi, Rozin, & Siegal, 2004; Rozin, Fallon, & Augustoni-Ziskind, 1985), 3- and 4-year-olds have shown initial contamination understanding in a few studies (Kalish, 1996, 1999; Siegal & Share, 1990). Other research suggests that a rudimentary awareness of plant toxicity may be present in infancy (Wertz & Wynn, 2014a, 2014b).

Other questions about the adaptationist account of pathogen and poison contagion remain unresolved. Many elicitors of disgust are not actually harmful or contagious. A notable example is moral disgust.[2] Again, explanations for other forms of disgust do not preclude pathogen-avoidance accounts. In fact, it has been argued that disgust in these other domains was co-opted from its original purpose (pathogen-avoidance) to serve different functions (i.e. Rozin et al., 1993, 2008; Tybur et al., 2013). One even wonders whether magical practices relying on contagion/contact, were also co-opted from this original purpose?[3] Another problem is that many contagion responses are resistant to acts like sterilization which eliminate the contagion (Nemeroff & Rozin, 1994; Rozin et al., 1986). Since many of the safety practices that are used to destroy, remove, or deactivate pathogens (e.g. pressure, chemicals, radiation) are recent technological inventions in human history, this is not a serious problem for the evolutionary account. Genetic evolution is a slow process and adaptive lag is anticipated given the speed at which technology has changed the environment in which humans operate.

Contagion beliefs about pathogens and poison are shaped by cultural input and experience (Curtis, Danquah, & Aunger, 2009). Global public health research has demonstrated that extensive education is often required to increase compliance with sanitary behavior (Biran et al., 2014; Freeman et al., 2014). Contagion beliefs are heavily influenced by learning about the presence of pathogens and toxins and how they are transmitted. The germ theory of disease rose to attention in late 19th century France and is now globally accepted, with numerous public-health interventions and awareness campaigns happening worldwide (Biran et al., 2014; Freeman et al., 2014).

Strong evidence to support the idea that pathogen and poison contagion beliefs are part of an evolved species-typical architecture would be to demonstrate its universality. Testing evolutionary hypotheses that predict universality is best accomplished by sampling diverse populations isolated from the influence of Western biomedicine and formal education (Apicella & Barrett, 2016). Whereas there is some evidence for the presence of a disgust face in slash and burn farmers (i.e., the Fore of New Guinea) (Ekman, 1992), contagion beliefs about pathogens have primarily been studied in industrialized populations (e.g., Hejmadi et al., 2004; Rozin et al., 1986).

The objective of the current studies was to test for pathogen and poison contagion sensitivity in two small-scale societies that differ markedly from both each other and Western

[2]To the extent that behaviors spread through social networks (i.e., Centola, 2010; Christakis & Fowler, 2013) immoral behavior may, in fact, be "contagious".
[3]Note that some examples of magical contagion are of backward contagion, which does not correspond well to the pathogen model.

populations. We predicted that across populations, adults would demonstrate reluctance to consume edible and desirous substances upon contact with disgust-eliciting, pathogenic, and poisonous objects. We also examined whether contagion beliefs were sensitive to contact with items posing a greater risk of harm by testing contaminant versus control items. We predicted that participants would be less likely to consume an edible substance after contact with a contaminant (e.g. feces) than a control item (e.g. a decorative bead). Third, we examined how contamination beliefs change over development in the Tannese. We predicted that children (6–11-year-olds) would be more rejecting than older children or adults of all items that make contact, whether or not a potential pathogen might be involved. We also predicted that with age, maturation, experience, and socialization, rejection would focus more on contacts with entities that would potentially be contaminants. Reference to germs would suggest some cultural contamination, given the late arrival of germ theory in Western cultures.

The tests employed involved multiple suspected disgust-eliciting or harmful entities, which briefly contacted (fell into but removed) a target, a familiar and liked food modified to be appropriate to the cultural context. For the Hadza, the target foods were honey and boiled broth and for participants in Tanna, cooking yams. Images of the physical “pots” containing the target foods were identical across cultures. Controls are contact of the same liked food(s) with non-disgust-eliciting or harmless entities that are common in each population. The scenarios were coordinated so that the situations were as parallel as possible, based on the knowledge of the relevant author of the paper with one or the other culture, and with the tasks as similar as possible to standard contagion tasks used with American participants.

2. Study 1: contagion among the Hadza

The Hadza are one of a few remaining hunter-gatherer populations left in the world and provide one of the best models available for how our hunter-gatherer ancestors lived, especially for behaviors related to diet and food practices (for discussion see Apicella & Crittenden, 2016). They reside in Northern Tanzania in the Great Rift Valley close to a shallow and seasonal lake (i.e. Eyasi) in mobile camps that number about 30 individuals. Major foods in the Hadza diet include: meat, honey, baobab fruit, berries and tubers. Men hunt animals with bow and arrow, collect honey, and engage in some foraging activities. Women, on the other hand, exclusively forage, collect water, and firewood. Foraged items include nuts, fruits, and tubers. It is estimated that fewer than 400 Hadza still practice a hunter-gatherer lifestyle though about 1000 individuals claim Hadza identity (Marlowe, 2010). The current research focuses on a subset of Hadza on the Eastern side of Lake Eyasi, whose subsistence still primarily relies on hunting and gathering.

While some sex differences in food preferences exist (e.g. men rank meat higher than berries and for women the ranking is reversed) (Berbesque & Marlowe, 2009) nearly all Hadza list honey as a favorite food (Marlowe et al., 2014). Few foods exist that the Hadza actively avoid (e.g., hyena and snakes). It is perhaps fear that leads them to avoid snakes since they are considered dangerous (Marlowe, 2010). It is unknown why the Hadza do not eat hyena. Some maintain that in the past they would leave dead bodies for hyenas to eat, so it might be that carrion eating is a basis for rejection hyena meat. The Hadza also do not eat termites even though they are plentiful and when asked why, some claim it is because they bite (Marlowe, 2010). Few foods are considered taboo. “Epeme” meat, which includes meat that derives from organs including the kidneys, lungs, and heart of an animal, is forbidden to be consumed by females, boys, and “non-epeme” men. Offenders are thought to be in danger of sickness or death. To become an “epeme man”, one either has to reach full adulthood or kill a large animal. The Hadza occasionally attribute negative outcomes (e.g. teeth falling out) to epeme meat violations (Marlowe, 2010). Adult men do not eat tortoises claiming that it will render the poison on their arrows (panjube) ineffective (Marlowe, 2010). We know of no other food taboos. Generally, the Hadza have few supernatural beliefs (Apicella, 2017) so these beliefs concerning food are particularly striking.

2.1. Method

2.1.1. Participants—Data collection took place over two consecutive years (2013, 2014) by a Tanzanian research assistant. In 2013, data collection was directly supervised by one of the authors (C.L.A.) and in 2014, it was supervised by a PhD student at the University of Cambridge. In 2013, 51 Hadza participants, ages 20 to 71 (M = 40.06, SD = 12.05) from 7 different camps around the Eastern side of Lake Eyasi were recruited to participate. Fifty-seven percent (N = 29) of the participants were men. During the summer of 2014, 66 individuals from 4 different Hadza camps were visited and all adults in each camp were recruited to participate. Adults ranged from 18 to 75 years old ($M = 39.52$, $SD = 14.66$). Thirty-two (48.5%) of the participants were men. All interviews took place in private and were conducted in Swahili. While Hadzane is the native language spoken by the Hadza, all participants understood basic Swahili and storyboards were used to facilitate comprehension.

2.1.2. Procedures—In 2013, participants were first asked to name a food that they find disgusting and will not eat: “Tafadhali taja chakula (vyakula) ambacho (ambavyo) kinakuletea (vinakuletea) kinyaa na huwezi kuvila”. Please note that “kinyaa” is a good cognate for disgust and refers not only to something that is disgusting/repugnant, but can also be used to refer to filth and excrement. Participants were also explicitly asked whether they like to eat hyena meat and to provide a reason for their response. Following questioning, participants were shown six different storyboards/scenarios where three different items (i.e. a piece of hyena, a man coughing and poison[4]) made contact with either 1) a pot of honey or 2) a pot of boiling meat broth (see Supplementary materials for storyboards) but were subsequently removed. Both honey and broth are staples of the Hadza diet in both children and adults. In fact, both are commonly used to wean children off breast milk. The storyboards contained simple illustrations, accompanied by brief and plausible scenarios of how the contaminant got into the pot. Participants were asked whether they would eat the honey (or broth) and to provide a justification for their answer.

In 2014, two storyboards were shown to the Hadza where a bead from a woman’s headband – a typical decorative band worn around the forehead – fell into 1) a pot of honey or 2) a pot

[4]Panjube is a poison that Hadza manufacture by pounding the branches and seeds of certain plants (e.g., *Adenium obesum*) to use on the tips of their arrows. It is stored as a dried up ball of dough covered in ash, until applied to arrowheads. It causes cardiac arrest in animals when it enters their bloodstream (Bartram, 1997).

of boiling broth. The wording was paralleled the initial study in 2013 (see Supplementary materials).

Fourteen of the participants who were questioned in 2014 also participated in 2013. The overlapping participants' ages range from 28 to 63 years ($M = 40.36$, $SD = 10.7$) and six (42.9%) are men. While the bead data were collected in a separate year, we still compare rates of endorsement of eating the contaminated food (i.e. honey and broth) by contaminant type (i.e. hyena, cough, poison, and bead). We also do this separately for our Hadza informants who participated both years.

2.1.3. Coding—Local research assistants translated participants' responses from Swahili to English. Research assistants in the U.S. coded participants' responses into nine categories using these translations. The *sickness/disease* code was used for any response that indicated that consuming the target would result in illness. The *germs* code was used for any response that indicated that the foreign object would introduce germs into the target items. The *presence* of item code was used anytime a participant simply stated that the presence of the foreign object was the reason for eating or not eating the target items. The *dirty* code was used if a participant stated that the foreign object made the target unclean or dirty. The *poison* code was used if a participant said the foreign object would make the target poisonous to eat. The *choke* code was used if the participant stated that you could choke on the foreign object. The *change in smell/taste* code was used anytime a participant said that the addition of the foreign object would alter the targets' flavor or smell. If a participant stated that it was fine to eat the target the ok to eat code was used. Finally, if a participant said they were unsure if they would eat the target or did not know, the *unsure* code was used.

2.2. Hadza results

When asked to name a disgusting food that they will not eat, snake and hyena were the most commonly reported items, named by 37% and 57% of participants, respectively. Baboon and honey badger were each named by one respondent. One respondent reported that there were no foods that they found disgusting. When explicitly asked if they like to eat Hyena, all but two of the 51 respondents said no. The two most common reasons provided for not eating hyena were 1) that it is not meat (25%) and 2) hyenas eat humans (29%).

Table 1 reports the proportion of Hadza participants that endorsed being okay with eating the honey and broth by item type (i.e. hyena, cough, poison and bead). Rejection rates were high. Since, presumably all subjects would eat the uncontaminated broth or honey, even just a few rejections would be notable. For the three contaminants; the percent of Hadza who endorsed being okay with eating the food varied between 4 and 10% for honey and 6 and 12% for broth. These are all massively below the expected rate of 100% for uncontaminated food. In fact, binomial proportions tests reveal that individuals endorsed eating both honey and broth after contaminated with hyena, a cough and poison significantly <0.50 (all $p < 0.000$) suggesting that the Hadza were not just randomly answering the question. Moreover, we can say with 95% certainty that no >16% of the Hadza would eat the food items contaminated with hyena, no >24% would eat the foods contaminated by a cough and no >13% of Hadza would eat the foods contaminated with poison. Acceptance rates for the honey and broth after making contact with a bead are also far below 100%, but much higher than for the three contaminants. For both our overlapping and non-overlapping participants, the point estimates for the percentage of participants who would accept the food items, range between 36 and 44%. Table 1 reports the data separately for the subjects who did and did not also participate in 2013. That said, chi-square proportion tests of the number of participants who would eat the honey ($\chi^2(1) = 0.005$, $p = 0.95$) and broth ($\chi^2(1) = 0.07$, $p = 0.78$) after a bead fell into it, do not differ between the two groups.

To test whether there is a contamination response for hyena, cough, and poison versus the bead, we run six separate Fisher's Exact tests excluding those subjects in the control group who also participated in the study in 2013, so that there is independence between the groups. Note that the Fisher Exact test is similar to Pearson's Chi-Square but preferred when cell values are small and/or zero, as is the case here. All six tests showed an association between item type and response such that each of the contaminants (i.e. hyena, cough and poison) elicited greater rates of rejection of the broth and honey compared to the bead (all $p <$ 0.001).

Whereas the Hadza were much more likely to endorse eating foods after contamination with the bead than after contamination with hyena, coughing or poison, the differences could theoretically be due to differences in the participants sampled during the two years rather than differences in the item types. That said, we think this implausible for three reasons. First, Hadza in 2013 and 2014 were collected from the same geographic region of Hadzaland and no differences in age ($t = -0.30$ (87), $p = 0.771$) or frequency of gender (χ^2 (1, N = 89) = 1.292 $p = 0.256$) between the two samples was found after excluding participants for whom we have data from both years. Second, when examining the point estimates for our small sample of overlapping participants from both years ($n = 14$), the proportion of participants endorsing eating foods after being contaminated by hyena (honey = 7%, broth = 7%), a cough (honey = 0%, broth = 29%) and poison (honey = 7%, broth = 0%) was much smaller than when the bead was the contaminant (honey = 43%, broth = 36%). Finally, even despite our very small sample of overlapping participants from both years ($n = 14$), we were still able to detect differences in choices among these subjects using McNemar's related samples tests in the cough vs. bead for honey condition ($p = 0.031$). We also reach significance at the 10% level for poison vs. bead for honey ($p = 0.062$) and broth ($p = 0.062$).

We also use Cochran's Q test for related samples to compare whether the distribution of responses differs between hyena, cough and poison in both the honey and broth condition. The distributions of responses did not vary when the contaminant was hyena, cough, or poison ($p = 0.417$) in the honey. However, the distribution of yes/no responses varied between the three contaminates in the broth condition ($p = 0.034$). Multiple pairwise comparisons using McNemar's test suggest that individuals were more likely to endorse eating the broth after being her contaminated by a cough than by poison ($p = 0.031$). No differences were found between hyena and poison ($p = 0.250$) and hyena and cough ($p =$ 0.453).

Participants provided a number of reasons for not eating the honey and broth after being contaminated by the different items (see Table 2).

Restatements about the presence of the item were common responses. In fact, restatements were most common when hyena contaminated the honey (75%) and broth (75%). The lethal qualities of poison and pathogen transmission of the cough lead to health risks so it is possible that other explanations come more readily. When a person coughed over the honey, the most common reason reported for not eating the honey was fear of getting sick (94%). Some participants even mentioned the possibility of contracting tuberculosis. For the broth condition, sickness was also the most common reason cited for not eating the broth after a cough (63%) though the number of participants citing this as a concern decreased and the number of participants who restated the presence of someone coughing in the broth increased (29%). Interestingly, four of the individuals who said that they would eat the broth after a sick Hadza coughed over it claimed that boiling action would kill the germs/disease. When the contaminant was poison, the vast majority of participants claimed that they would not eat the honey (94%) or broth (98%) because it was poisonous. Finally, the most common reason for not eating the honey after being contaminated with a bead was dirtiness (41%), but the most common response was that it was okay to eat the honey after contacting the bead (42%). For the bead contacting the broth, most participants stated they would not consume it by restating the presence of the bead in the broth (52%) while many also stated that it was okay to eat the broth (39%). Thus the reason pattern was different for each contaminant, with poison dominating for poison, sickness for cough, restatement for hyena, and dirtiness or restatement for bead.

3. Study 2: contagion among the Tannese of Vanuatu

Vanuatu is a Melanesian island nation in the South Pacific and one of the most remote, culturally and linguistically diverse countries in the world (Norton, 1993). Our participants are from the island of Tanna – one of the larger islands located in the Tafea province of Vanuatu, with approximately 30,000 inhabitants – and predominately speak Bislama and English (as well as a large number of indigenous languages). Tanna provides a uniquely informative context for studying contagion because it is a population that has relatively recently begun to attend formal schools and still relies on the natural world for survival through subsistence agriculture, foraging, and fishing (Peck & Gregory, 2005; Watson-Jones, Busch, & Legare, 2015).

Despite the influence of Presbyterianism on the island (see Supplementary materials), many villages have maintained *kastom* (custom), or “ancestrally enjoined rules for life” (Keesing, 1982, p. 360). In a recent survey of national identity in Vanuatu, maintaining kastom, as well as being Christian were considered two of the most important aspects of what it means to be from Vanuatu (Clarke, Leach, & Scambary, 2013). Formal education is also a relatively recent institution on Tanna. Missionaries set up rudimentary schools in the early 1900s (Gregory & Gregory, 2002). There was, however, no standard curriculum until the last three decades when British and French run schools began providing primary and secondary education (Peck & Gregory, 2005). Additionally, parents in Tanna often have to pay to send their children to school, and children from kastom villages have only recently begun to attend. Most children spend time in similar-aged peer groups or helping their parents with the family gardens and/or tending domesticated animals. On Tanna, people live primarily from subsistence agriculture (Cox et al., 2007), consume domesticated animals (e.g., pigs and chickens) and some hunting of bats and fishing. Thus, children in Tanna live "close" to nature (Unsworth et al., 2012; Watson-Jones, Busch, Harris, & Legare, 2017). For example, they are likely to be observers of, or participants in, subsistence agriculture, coastal fishing practices, pig and chicken husbandry, and the hunting of flying foxes (Busch, Watson-Jones, & Legare, 2018).

3.1. Method

3.1.1. Participants—Data was collected with $n = 20$ children (6–11-year-olds), $n = 21$ adolescents (13–17-year-olds), $n = 22$ adults. All participants were recruited and participated in the study in and around the village of Lenakel on the island of Tanna, Vanuatu.

3.1.2. Procedure—After providing informed consent, participants were presented with eight storyboards describing scenarios where a foreign object comes into contact with a pot of cooking yams. The study procedure was conducted in the national language, Bislama, and all participants completed the study individually. Half of the scenarios described control items contacting the yams, and half described contaminant items contacting the yams. For all eight scenarios the researcher read a short description to the participant: "Imagine there is a pot of yams for you to eat. Now imagine [a contaminant/control item is introduced] to the pot of yams. [The contaminant/control item is removed] from the pot of yams and the food continues to cook." In addition to hearing this scenario, the researcher presented participants with a picture board, which depicted simple illustrations of the foreign object entering the yams (see Supplementary material for full stimuli and slight variations). Participants were asked two follow up questions for each of the eight scenarios, 1) "would you still eat the yams, yes or no?" and 2) "why or why not." The four true contaminants included blood, cough, chicken feces, and a fly. The four control items included ocean water, a stone, a bead, and a leaf.

3.1.3. Coding—Local research assistants translated participants' responses from Bislama to English. Research assistants in the U.S. coded participants' responses into nine categories using these translations. The nine coding categories were the same as those used on the Hadza data.

3.2. Vanuatu results—First, we present data on participants' binary yes/no responses to whether the yams could still be consumed after the removal of the contaminant. Then we present data on participants' responses to the openended follow-up question about why the yams could or could not be consumed.

Rejection of a potentially contaminated food was scored as 1, while acceptance was scored as 0. The data show there was no difference in endorsement of eating/not eating the yams after any of the contaminate items (feces, blood, fly, or cough) had fallen into the food ($p = 0.166$, related-samples Cochran's q test). There was also no difference in endorsement of eating/not eating the yams after any of the control items (leaf, stone, bead, ocean water) had fallen into the food ($p = 0.130$, related-samples Cochran's q test, see Table 3 for means and standard deviations for each of the items). Therefore, summary scores were created for the contaminated items (0–4) and the control items (0–4). A repeated–measures ANOVA with age group (6–12-year-olds; 13–17-year-olds; adults) as the between-subjects factor and responses to the items that fell into the food (contaminated, control) as the within-subjects factor revealed no significant effect of age, $F(2, 60) = 2.40$, $p = 0.099$, $n^2_p = 0.074$. There was a main effect of item type (contaminated or control), $F(1, 63) = 36.11$, $p < 0.0001$, $n^2_p = 0.367$. Participants were much less likely to endorse eating the contaminated items (M = 0.16, SD = 0.45) than the control items (M = 0.98, SD = 1.24).

Participants' responses to the open-ended, "why," questions were coded into the same nine categories as were used with the Hadza (see Supplementary material). Both explanations for the endorsement of eating and the endorsement of not eating the yams following the items falling in the pot were used in the following analyses. The most common responses across both item types (contaminates and controls) were responses indicating a reluctance to eat the yams due to the presence of the item in the yams (81% of participants provided this type of response at least once). Next, most common were responses appealing to sickness and disease (75% of participants), followed by responses indicating that the item would change the smell or taste of the of (68%), followed by responses that the item would make the food dirty (65%), followed by responses indicating that it is okay to eat the item (49%), and lastly followed by responses referring to germs (46%), see Table 4 for means and standard deviations for each type of response by age group and item type.

We examined whether there was any difference in the frequency of explanation types by item type (contaminant vs. control) and age group (child, adolescent, adult). Summary scores of participants' responses indicating they would not eat the yams were created for the contaminate items (0–4) and the control items (0–4). Then a repeated measures ANOVA was conducted with age group (6–12-year-olds, 13–17-year-olds, adults) as the between-subjects factor and item type (contaminants, controls) as the within-subjects factor. Since these studies examine contamination beliefs, we only analyzed responses relevant to contamination (i.e., disease, germs, dirty, and okay to eat).

For responses appealing to sickness and disease as the reason for not eating the yams, a repeated measures ANOVA with age group (6–12-year-olds, 13–17-year-olds, adults) as the between-subjects factor and item type (contaminate, control) as the within-subjects factor revealed a main effect of item type, $F(1, 60) = 72.94$, $p = 0.0001$, $n^2_p = 0.549$. Participants referenced sickness and disease in their explanations more for the contaminated items (M = 1.30, SD = 1.24) than for the control items (M = 0.16, SD = 0.41). There was also a main effect of age group, $F(2, 60) = 8.78$, $p = 0.0001$, $n^2_p = 0.226$. Bonferroni corrected post hoc tests revealed that adolescents (M = 2.33, SD = 1.56) provided more explanations appealing to sickness and disease than did younger children (M = 0.65, SD = 0.75), p = 0.0001, and marginally more than adults, (M = 1.36, SD = 1.40), $p = 0.051$. The analysis also revealed an interaction between item type and age group, $F(2, 60) = 6.82$, $p = 0.002$, $n^2_p = 0.185$. Bonferroni corrected pairwise comparisons revealed that, for the contaminated items, adolescents (M = 2.05, SD = 1.36) provided more explanations appealing to sickness and disease than did younger children (M = 0.60, SD = 0.75), $p = 0.0001$, and marginally more than adults (*M* = 1.23, *SD* = 1.11), $p = 0.055$. For the control items, there was no difference between the three age groups in providing a response referencing sickness and disease.

Statements appealing to germs as the reason for not eating the yams following an item falling into it were summed to create scores for the contaminate items (0–4) and the control items (0–4). A repeated measures ANOVA with age group (6–12-year-olds, 13–17-year-olds, adults) as the between-subjects factor and item type (contaminate, control) as the within-subjects factor revealed a main effect of item type, $F(1, 60) = 48.34$, $p < 0.0001$, $n^2_p = 0.446$. Participants referenced germs as the reason for not eating the yams for the contaminated items (*M* = 0.49, *SD* = 0.59) more than for the control items (*M* = 0.02, *SD* = 0.13). There was no main effect of age group, $F(2, 60) = 2.36$, $p = 0.103$, $n^2_p = 0.073$.

Responses indicating that the item would make the yams dirty were summed to create a score for the contaminate items (0–4) and the control items (0–4). A repeated measures ANOVA with age group (6–12-year-olds, 13–17-year-olds, adults) as the between-subjects factor and item type (contaminate, control) as the within-subjects factor revealed no main effect of item type, $F(1, 60) = 2.47$, $p = 0.121$, $n^2_p = 0.040$ or of age group, $F(2, 60) = 2.74$, $p = 0.072$, $n^2_p = 0.084$.

Participants reports of the yams being okay to eat if the item was taken out were summed to create a score for the contaminate items (0–4) and the control items (0–4). A repeated measures ANOVA with age group (6–12-year-olds, 13–17-year-olds, adults) as the between-subjects factor and item type (contaminate, control) as the within-subjects factor revealed a main effect of item type, $F(1, 60) = 28.82$, $p = 0.0001$, $n^2_p = 0.324$. Participants provided more “okay to eat if the item is taken out” responses for the control items (*M* = 0.76, *SD* = 1.01) than for the contaminate items (*M* = 0.14, *SD* = 0.40). There was no effect of age group, $F(2, 60) = 2.29$, $p = 0.110$, $n^2_p = 0.071$.

4. Discussion

The present study provides new insight into our understanding of the origins of contagion sensitivity by testing for its presence in two populations with markedly divergent social, cultural, and economic ways of life from each other and from Western societies. We find evidence that contagion sensitivity is present in both Hadza hunter-gatherers and Tannese subsistence-agriculturalists. These findings, coupled with other work showing that the emotion of disgust is widespread and probably universal, are consistent with the hypothesis that disgust and contagion are part of a evolved system designed to prevent exposure to pathogens and disease. While our participants had little to no formal Western education and remain relatively isolated from Western influences, we nevertheless cannot rule out that contagion sensitivity is learned. Likewise, we also stress that our results do not imply that cultural differences – especially regarding the items deemed disgusting – do not exist. Instead, our data support the proposal that evolution has shaped contagion sensitivity to be flexible, allowing it to interact with local ecological and cultural contexts. Such a system allows for individuals to learn through direct experience and from each other about which items should be avoided.

We see large differences in both populations in rates of rejection between contaminants and control items. For the Hadza, the mean rejection rate was 94% for the three contaminants in both honey and boiling broth, compared to the control item (a bead), where rejections averaged 68%. Because we used both honey and broth, we can rule out the possibility that food type is driving the results. The results from the Tannese correspond well to those from the Hadza; there was a mean rejection rate of 94% across the four contaminants, compared to 66.5% for the four controls.

Notably, there were high rejection rates for the control items in both populations. For the Hadza, a single plastic bead, used in decorative headwear, led to food rejections more than half the time. Because the bead was in contact with the body of a person before making contact with the food, it may have become viewed as a potentially harmful contaminant. Indeed, the most common response for not eating the honey after a bead fell into it, was for sanitary reasons (e.g. dirty). Among the Tannese, the bead also shows a higher rejection rate than the other three control entities further suggesting that it may have been viewed as harmful to participants in both societies. It is also possible that a bead in any of the foods (honey, broth, yams) could be considered “matter out of place” (Douglas, 1966) or a choking hazard, and hence produced a rejection. In prior work on contamination, a modest percentage of Western adult respondents show rejection of favored beverages after brief contact with harmless, control, entities, such as birthday cake candles (Rozin et al., 1986; see also Rozin, Grant, Weinberg, & Parker, 2007). More directly related to the present work, 32% of both Indian and American 8-yearolds rejected a favored juice that was briefly contacted by a piece of spinach (Hejmadi et al., 2004).

All four of the Vanuatu contaminants are potentially infectious, so we cannot make the infectious versus non-infectious “bad” entity distinction that was possible with the Hadza. For the case of the Hadza, only one of the three contaminants (i.e., cough) was actually contagious, although there is a possible infectious component to hyena meat. Low levels of the arrow poison may be harmful if ingested. The poison is a on the Hadza arrows is made from a flowering plant in the genus *Adenium*, which contains a cardiotoxic glycoside. While ingestion of plants containing these poisons can cause gastrointestinal upset and vomiting, for death to occur upon ingestion, very large amounts would need to be consumed. The plant is also extremely bitter and the Hadza avoid eating meat around the opening where arrows have pierced the animal, possibly because of the taste. Indeed, some Hadza cited the poison’s bitter taste when asked why they would not eat the honey or broth. Contagion sensitivity to the arrow poison cannot be justified in terms of the multiplication of very small doses of microorganisms in the body. However, Westerners often treat toxins as if they are micro-organisms.

Hyena meat effectively transmitted its disgust-eliciting properties to the foods: rejection rates were over 90%. When asked why, the most common response was a restatement of the situation, indicating possible dumbfounding. Here we use dumbfounding to mean the inability of participants to provide articulable reasons for rejecting the food items so that they instead rely on restatements. Similar responses were also observed in Westerners with cockroach contamination (Haidt, Bjorklund, & Murphy, 2000; Rozin et al., 1986, 1989). Rejection of the hyena could be due to mistaken beliefs about microbial contamination, but in prior work (Rozin et al., 1986), sterilization of an animal carcass (i.e. roach) has only a very modest effect on rejection. It may be that the disgust responses entail activation of contamination responses, even in cases where there is not (as for the case of many disgust-eliciting entities) an actual microbial threat. Why do the Hadza consider eating hyena disgusting – an aversion shared with San hunter-gatherers living thousands of miles away (Tanaka, 1996)? It is possible that hyena is, itself, tainted by the laws of contagion due to its contact with rotting human and animal corpses. Thus rejection of the honey and broth is merely a second order effect: rotting carcasses contaminate hyenas, which in turn, contaminate other items.

It is striking that the "cough" rejection level is not higher than the virtually harmless hyena meat. It is also notable that rejection only slightly decreased when the cough went into boiling broth (which would kill micro-organisms), as opposed to the honey. These findings, coupled with very low levels of formal schooling in the Hadza, as well as high rejection levels of the bead, argue against the idea that contagion sensitivity arises from learning about germ theory. However, it is important to note that a few Hadza explicitly mentioned germs and indeed, they are not completely isolated and some do attend school. Future work is needed to explicitly test knowledge of germ theory in the Hadza and Tannese.

For the Tannese, all the contaminants have clear contagious potential (fly, feces, cough from sick person, and blood), but in all cases the contaminant is added to cooking yams, which continue to cook and should thereby be sterilized by heat. Based on the Tannese responses to the open-ended follow-up questions, it is clear they believe these contaminants may cause disease. It is unknown, however, whether they understand the process of sterilization by heat. Germs are infrequently mentioned as a cause of rejection, and the most common reason was the "presence of the contaminant" in the cooking yams. As with the Hadza, mere presence (essentially a description of the situation) is the most common reason for rejection of contaminants, again indicating a sort of dumbfounded response, as observed with Westerners (Rozin et al., 1986, 1989). It is also possible that contagion sensitivity evolved to cause rejection of potentially contaminating entities, without any knowledge or influence of the role of heat sterilization, a rare event in nature. Contagion responses are surprisingly resistant to explicit heat sterilization manipulations in Americans (Nemeroff & Rozin, 1994; Rozin et al., 1986).

There is clear evidence for a contamination response in 6–12 year olds from Tanna, as there is in Western and Hindu-Indian children (Hejmadi et al., 2004). The data from Tanna also suggest that children may be more likely to reject food contaminated by the non-contagious control items than adults though this result did not reach significance. This raises the possibility of the role of cultural pedagogy in the development of children's disgust response (Liberman, Woodward, Sullivan, & Kinzler, 2016). Children may initially develop a broad and inexact conception of contagion due to an error-management strategy (avoid all foods that have any contaminant in case that contaminant is physically harmful or contagious (see error management theory, Haselton & Buss, 2000). This inexact conception of contagion might then be refined over ontogeny, through cultural input, to specific, truly contagious entities. There is some evidence that the avoidance of contaminants as a method to avoid disease and sickness becomes more potent with age in Tanna, although the adolescents show the strongest motivations to avoid contagious contaminants for this reason. This may result from the fact that the adolescents are much more likely to have received formal schooling than the adults, and have learned about disease transmission and this information would be particularly salient if learned recently. As far as we know, there is no comparable evidence comparing adolescents with adults for any other population, but in most cultures, the adults have also received some formal schooling.

The current study has some potential limitations. First, we use hypothetical questions which could lead to demand characteristics. However, we limited this possibility by 1) keeping our research assistants blind to the hypotheses, 2) using scripted questions and 3) utilizing storyboards which drew visual attention away from the research assistant. Because the participants offered explanations for refusing the items that were not part of the questioning, we do not think demand characteristics to be a major problem here. A second concern is that in the Hadza, our control item elicited a contagion response though rates of rejection were much lower than the three contaminants. Nonetheless, we think the finding demonstrates the strength of contagion sensitivity. It would have been useful to have control conditions where contaminants are proximally close, but not touching, the foods. Contact is critical in most studies of contagion from developed cultures, but there may be a residual effect from proximity.

Overall, the results are strikingly similar to the results from the U.S. and India (Hejmadi et al., 2004; Rozin et al., 1986, 1989). Individuals in both societies show a strong rejection response to desirable food entities that have contacted any inappropriate entity. Consistent with the developmental data from India and the U.S. (Hejmadi et al., 2004; Legare et al., 2009), the basic contagion response is present by age six (or younger). These results provide some of the strongest support for the position that contagion sensitivity is a universal feature of human cognition. The results also provide evidence that, together with the emotion of disgust, contagion is part of a system that evolved to prevent exposure to dangerous and pathogenic items. An important design feature of this system is that it allows for environmental and social input such that individuals can learn from their own direct experience, and from others, about items that they should and should not eat. This type of system would allow humans to effectively deal with novelty and develop preferences and aversions to those items they are likely to encounter in their environment, as opposed to evolving countless aversions to the many harmful items found in the world. Thus, we argue that contagion sensitivity and the emotion of disgust are panhuman but that experience and culture will influence which items are favored and which are rejected.

The nature and origin of disgust and contagion continue to be issues of concern in psychology. The evidence presented in this paper suggests that contagion sensitivity is likely universal, appearing in childhood, which is consistent with a biological evolutionary account. Nevertheless, questions remain. One is whether the contagious (presumably pathogen linked) beliefs extend to the spread of immorality, as for the case of moral disgust in other societies. Another has to do with how and when non-contagious entities come to be treated as contagious – a question that has not been addressed in the general contagion literature. A third has to do with understanding of the fundamental difference between contagious and non-contagious illnesses. As globalization proceeds, it is becoming increasingly difficult to obtain data from the few remaining populations that have not been heavily exposed to formal education. We urge further exploration of contagion-sensitivity and disgust in small-scale populations.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements

CA would like to thank Duncan Stibbard Hawkes, Deus Haraja, Ibrahim Mabulla and Charles Endeku for their research assistance in the field and Audax Mabulla for his continued support. CL would like to thank the Tafea Cultural Center in Tanna, Chief Peter Marshall, Chief Kaimua, Chief Yappa, George, Jimmy Takaronga, Teana Tufunga, Jean-Pascal, Janet, Anna, Bev, and Aurora Brinkman. CA also thanks Daudi Peterson and Stephanie Schnorr for helpful advice. CA was supported by funds from the University of Pennsylvania. CL, JB, and RW were supported by funds from the John Templeton Foundation [grant number 40102] and an ESRC (Economic and Social Research Council) Large Grant [REF RES-060–25-0085].

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Table 1

Proportion of Hadza participants that endorsed being okay with eating the honey and broth by contaminate type (i.e. hyena, cough, and poison) and control (i.e. bead). Upper and lower exact 95% binomial confidence bounds are reported. For the bead condition our values are disaggregated by whether or not they also participated in 2013.

	Percentage	Lower confidence bound	Upper confidence bound
Honey			
Hyena (2013)	0.10	0.03	0.21
Cough (2013)	0.05	0.01	0.16
Poison (2013)	0.04	0	0.13
Bead non-overlapping participants (2014)	0.44	0.30	0.58
Bead overlapping participants (2014)	0.43	0.18	0.71
Broth			
Hyena (2013)	0.06	0.01	0.16
Cough (2013)	0.11	0.04	0.24
Poison (2013)	0.00	0	0.06
Bead non-overlapping participants (2014)	0.40	0.27	0.55
Bead overlapping participants (2014)	0.35	0.13	0.65

Note: For the three contaminants (N = 51); for bead non-overlapping participants (N = 52); for bead overlapping participants (N = 14).

Table 2

Proportion of participants providing each response type to open-ended questions about decision to eat or not eat the honey or broth by contaminate.

	Honey				**Broth**			
	Hyena (*n* = 51)	**Cough (*n* = 51)**	**Poison (*n* = 51)**	**Bead (*n* = 66)**	**Hyena (*n* = 51)**	**Cough (*n* = 51)**	**Poison (*n* = 51)**	**Bead (*n* = 66)**
Sickness/disease	0.08	0.94	0	0.03	0.02	0.63	0	0
Germs	0	0	0.02	0.02	0	0	0	0
Presence of item	0.75	0	0	0.02	0.75	0.29	0	0.52
Dirty	0	0	0	0.41	0	0	0	0.09
Poison	0	0	0.94	0	0.04	0	0.98	0
Choke	0	0	0	0	0	0	0	0
Change in smell/taste	0.16	0	0.14	0	0.12	0.02	0.10	0
Ok to eat	0.04	0	0.02	0.42	0	0	0	0.39
Unsure	0	0	0	0	0	0	0	0

Table 3

Proportion of participants that endorsed eating the yams by age group and item.

	Age groups			
	6–12-year-olds	**13–17-year-olds**	**Adults**	**Collapsed**
Contaminates				
Cough	0.05 (0.22)	0.05 (0.22)	0.09 (0.30)	0.06 (0.24)
Feces	0	0	0	0
Fly	0	0.05 (0.22)	0.05 (0.21)	0.03 (0.17)
Blood	0.05 (0.22)	0.05 (0.22)	0.09 (0.30)	0.06 (0.24)
Controls				
Leaf	0.10 (0.31)	0.33 (0.48)	0.36 (0.49)	0.28 (0.45)
Bead	0.15 (0.37)	0.24 (0.44)	0.23 (0.43)	0.20 (0.40)
Ocean	0.10 (0.31)	0.38 (0.50)	0.45 (0.51)	0.31 (0.47)
Stone	0.15 (0.37)	0.10 (0.30)	0.32 (0.48)	0.18 (0.39)

Note. N = 63 (20 6–11-year-olds, 21 13–18-year-olds, and 22 adults). (Standard deviation.)

Table 4

Mean number of response types to open-ended questions about decision to eat or not.

	AGE GROUPS			
	6–12-year-olds	**13–17-year-olds**	**Adults**	**Collapsed**
Contaminates				
Sickness/disease	0.60 (0.75)	2.05 (1.36)	1.23 (1.11)	1.30 (1.24)
Germs	0.65 (0.49)	0.57 (0.68)	0.27 (0.55)	0.49 (0.59)
Presence of item	2.4 (1.05)	0.52 (0.68)	2.05 (1.24)	1.62 (1.30)
Dirty	0.40 (0.82)	0.81 (0.98)	0.41 (0.59)	0.54 (0.82)
Poison	0.05 (0.22)	0	0	0.02 (0.13)
Choke	0	0	0	0
Change in smell/taste	0.05 (0.22)	0	0.09 (0.29)	0.05 (0.21)
Ok to eat	0.10 (0.45)	0.14 (0.36)	0.18 (0.39)	0.14 (0.40)
Unsure	0.10 (0.31)	0.05 (0.22)	0.09 (0.29)	0.08 (0.27)
Controls				
Sickness/disease	0.05 (0.22)	0.29 (0.46)	0.14 (0.47)	0.16 (0.41)
Germs	0	0.05 (0.22)	0	0.02 (0.13)
Presence of item	2.1 (1.3)	0.38 (0.97)	1.04 (1.36)	1.16 (1.39)
Dirty	0.40 (0.82)	0.95 (0.86)	0.91 (0.97)	0.76 (0.91)
Poison	0.10 (0.31)	0.52 (0.60)	0.36 (0.58)	0.33 (0.54)
Choke	0.15 (0.37)	0.19 (0.40)	0.23 (0.43)	0.19 (0.40)
Change in smell/taste	0.65 (0.49)	0.76 (0.44)	0.64 (0.49)	0.68 (0.47)
Ok to eat	0.35 (0.67)	0.86 (0.96)	1.05 (1.21)	0.76 (1.01)
Unsure	0.20 (0.41)	0.48 (0.75)	0.18 (0.66)	0.29 (0.63)

Note. N = 63 (20 6–12-year-olds, 21 13–17-year-olds, and 22 adults). (Standard deviations.)