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Original Article

Quantifying cultural macro-evolution: a case study of the hinoeuma fertility drop

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ABSTRACT

Understanding patterns and underlying processes of human cultural diversity has been a major challenge in evolutionary anthropology. Recent developments in the study of cultural macro-evolution have illuminated various novel aspects of cultural phenomena at the population level. However, limitations in data availability have constrained previous analyses to use simplest models ignoring factors that potentially affect cultural evolutionary dynamics. Here, we focus on two such factors: accumulated effects of cultural transmission between populations over time and variation in social influence among populations. As a test case, we analyze data on the hinoeuma fertility drop, the Japanese nation-wide drastic decline in the number of births caused by a culturally-transmitted superstition recurring every sixty years, to show that these factors do play significant roles. Specifically, our results suggest that transmission of the superstition in a short timescale has tended to occur among neighboring populations, while transmission in a long timescale is likely to have occurred between populations culturally close to each other, with the cultural closeness being measured by similarity in dialects. The results also indicate a special role played by a population occupying a center in a language–distance network (the cultural center) in the spread of the superstition.

1. Introduction

The study of cultural evolution is an application of methods and concepts in evolutionary biology to cultural phenomena (Boyd & Richerson, 1985; Cavalli-Sforza & Feldman, 1981). Cultural evolution can be roughly divided into two related processes, cultural micro-evolution within a population and macro-evolution among populations, as a cultural analogue of genetic micro- and macro-evolution. Studies on cultural micro-evolution have revealed how various factors, including learning bias (Boyd & Richerson, 1985), pathways of cultural transmission (vertical, horizontal, and oblique transmission) (Cavalli-Sforza & Feldman, 1981; Ihara & Feldman, 2004; Tamura & Ihara, 2012), spatial/social structure (Kobayashi & Wakano, 2012; Rendell, Fogarty, & Laland, 2010; Tamura, Kobayashi, & Ihara, 2015), and variation in social influence (Cavalli-Sforza, Feldman, Chen, & Dornbusch, 1982; Ihara, 2008; Yeaman, Schick, & Lehmann, 2011), can affect temporal changes in the frequencies of cultural variants in a population. Since a population of individuals is often characterized or even defined by a set of cultural traits shared within them, there is also a growing body of literature on cultural macro-evolution investigating the documented cultural diversity at the population level (Brown et al., 2014; Guglielmino, Viganotti, Hewlett, & Cavalli-Sforza, 1995; Hewlett, DeSilvestri, & Guglielmino, 2002; Ross, Greenhill, & Atkinson, 2013; Savage, Brown, Sakai, & Currie, 2015). These latter studies have attempted to identify the population structure in the cultural diversity (Brown et al., 2014; Ross et al., 2013; Rzeszutek, Savage, & Brown, 2012) and obtain inferences about processes shaping patterns in the diversity (Towner, Grote, Venti, & Borgerhoff Mulder, 2012).

Cultural macro-evolution can be affected considerably by transmission of traits between populations. Previous studies have evaluated the extent of transmission between populations by using geographic or linguistic autocorrelations in cross-sectional data as a signature of the influence that neighboring populations (in the geographic or linguistic space) give on each other (e.g., Towner et al., 2012). We argue, however, that this approach may be potentially misleading for two reasons. First, the extent of transmission between populations depends not only on the geographic/linguistic distance, but also variation in the strength of social influence among the populations. For example, there may be a highly prestigious population whose cultural traits are more readily transmitted to other less prestigious populations than vice versa. Although the existence of such a "cultural center" seems plausible, previous studies have failed to consider it. Second, transmission between populations usually refers to an accumulated effect of multiple events of transmission that take place during a certain period of time. Thus, transmission between populations may occur concurrently with micro-evolution within populations. For the sake of illustration, consider three populations, A, B, and C, and a cultural trait that is present only

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in population A. Suppose that somewhere between two time points ($t = 0$ and $t = 1$) the cultural trait is transmitted from population A to populations B and C and then population A loses the trait through micro-evolution. In this case, we cannot infer the transmission from population A to populations B and C by the use of cross-sectional data at $t = 1$. Only with appropriate longitudinal data can we obtain inferences about the true history, which may be captured under the term "long-term cultural interaction" between populations, or the effect of transmission from population A at $t = 0$ to populations B and C at $t = 1$. These two factors (i.e., variation in social influence and accumulated effects of transmission over time) seem to be particularly important in some specific cases. For instance, to explain a "concentric distribution" of dialects, Yanagida (1927) proposed a process of cultural transmission, in which a word newly invented at a cultural center diffuses into surrounding populations and further outward, while at the center the new word is replaced by another invention and the same process is repeated.

In the present study, we first propose a theoretical framework to study cultural transmission between populations which explicitly includes the above-mentioned factors. Within this framework, we then investigate a documented case of cultural transmission of a superstition in Japan, which has caused geographically large-scale declines of fertility, known as the hinoeuma fertility drops. Japan has experienced nation-wide marked fertility drops in the hinoeuma years, which come every sixty years. People deliberately refrain from having a baby in these years as clearly shown in the available formal demographic record: births dropped by 25% in 1966, the most recent hinoeuma year, and rose by 42% in 1967, dropped by 7% in 1906 and rose by 16% in 1907 (Statistics and Information Department, Minister's Secretariat, Ministry of Health, Labour and Welfare, 2005). It has been considered that the unprecedented extent of fertility decline in 1966 was due to the prevalence of contraception methods and information transmission by the mass media (Aoki & Tomizawa, 1968; Inoshita, Minami, & Sano, 1977; Kurosu, 1992; Usui, Katabami, & Kaneko, 1976; Yamagami, 1967).

People's choice not to have a baby in a hinoeuma year is motivated by the hinoeuma superstition, which states that a woman born in a hinoeuma year will not be a good wife being unable to control her temper (Konno, 1965). The hinoeuma superstition, originally from the Chinese horoscope, became the present form probably after the story of Yaoya Oshichi, a girl who lived in Edo (present-day Tokyo), was popularized by authors such as Saikaku Ihara in the 17th century. Reportedly, Yaoya Oshichi was burnt at the stake for attempted arson that she committed for the sake of romance and her birth year was a hinoeuma year. In addition to the recorded fertility drops, there are anecdotal reports suggesting substantial influence of the superstition on the people's behavior, such as circulation of poems (senryu) ridiculing hinoeuma-born women, deaths of pregnant women from use of abortifacients, and even suicides of hinoeuma-born women (Konno, 1965). Hinoeuma fertility drops provide a rare opportunity to demonstrate how human behavior can be affected by a culturally-transmitted belief.

Within Japan, there are regional differences in the extent of the hinoeuma fertility drops. This difference can be, at least in part, accounted for by cultural transmission of the hinoeuma superstition or of attitudes toward the superstition. Specifically, if regions geographically or culturally close to each other tend to exhibit similar extent of fertility drop, that may be indicative of the influence of cultural transmission. Although some previous studies have suggested that cultural transmission may have contributed to the variation in the extent of fertility decline, the effects of cultural factors have not been quantitatively investigated so far (Kurosu, 1992; Usui et al., 1976).

The hinoeuma fertility drop has some advantages as a test case for the study of cultural transmission between populations. First, since large census data are available in and around hinoeuma years, we can obtain exceptionally reliable and objective measures of changes in people's behavior in response to a culturally-transmitted belief. Second, because of the quantitative nature of the census data, we can estimate the prevalence, rather than just the presence or absence, of a superstition in each population. Third, the census data are available for each of Japanese prefectures, which have been used as the units of analysis in a previous study on dialect diversity in Japan (Lee & Hasegawa, 2011). This enables a direct comparison of the similarity in dialects between a pair of prefectures with the similarity in the prevalence of the hinoeuma superstition between the same pair of prefectures. We can also identify a putative cultural center among all prefectures using the linguistic data. Fourth, since the hinoeuma fertility drop is a periodic phenomenon, we can compare the most recent hinoeuma year with the preceding one. The last point is particularly important because it means that we can analyze longitudinal data to evaluate the relative importance of the short- and long-term cultural interaction at the population level.

Investigations on the hinoeuma fertility drop can provide further implications. A drastic and persistent decline of fertility has been documented repeatedly in the demographic transitions. During the process, the bulk of individuals in a society voluntarily choose a behavior that seemingly reduces their fitness. This is puzzling from the evolutionary perspective because both natural selection, which acts on fitness differences among individuals, and rational choice, which itself relies on evolved psychological mechanisms, seem to disfavor these behaviors (Borgerhoff Mulder, 1998). A key issue is to examine to what extent human behavior is affected by social learning, or more specifically, whether a culturally-transmitted belief can alter human decision-making related to reproduction (Borgerhoff Mulder, 1998; Boyd & Richerson, 1985; Cavalli-Sforza & Feldman, 1981; Mace, 2014; Richerson & Boyd, 2005). There is some evidence indicating that cultural transmission plays a role in the demographic transition (Bongaarts & Watkins, 1996; Coale & Watkins, 1986; Ihara & Feldman, 2004; Kendal, Ihara, & Feldman, 2005). Coale and Watkins (1986) showed that in the European demographic transition, the onset of fertility decline in a region of a country was often followed after a short delay by neighboring regions with the same language or cultural background, even when the latter was socioeconomically less developed. Ihara and Feldman (2004) also argued, based on their mathematical analysis, that the level of education in a society can play a role as a cultural background affecting the mode of cultural transmission (i.e., vertical versus oblique transmission), and as a result, facilitate the spread of a preference for small family size, which may in part explain a radical fertility decline as documented in the demographic transitions.

In addition, variation in social influence may contribute to the spread of a maladaptive belief. Studies using mathematical models have suggested that structure of cultural transmission can alter the dynamics of cultural evolution (Kobayashi & Wakano, 2012; Rendell et al., 2010; Tamura & Ihara, 2012; Tamura et al., 2015), with particular emphasis on the roles of heterogeneity of social influence among individuals (Yeaman et al., 2011). Yeaman et al., (2011) compared various network structures in terms of "cultural load," which is an analogue of the genetic load in population genetics and represents the effect of a given deleterious cultural trait on the mean fitness of a population. They also showed that a heterogeneous network can promote the spread of deleterious cultural traits. In a heterogeneous network, there are hub individuals, who are connected to more individuals than others are and thus can be considered as of high social influence. This variation in social influence among individuals seems to be the basis of maladaptive cultural evolution in a heterogeneous network. The result of this study can be applicable not only to cultural micro-evolution but also to macro-evolution: the existence of a population, group, or region of high social influence, from which cultural traits are transmitted outward to other less influential regions, can promote the spread of maladaptive cultural traits among populations.

In the following analysis, we examine, by use of a mathematical model, whether cultural transmission of the hinoeuma superstition has occurred between prefectures that are geographically and/or linguistically close to each other. In doing so, we evaluate the relative importance of the short- and long-term cultural interaction at the