Acta Botanica Brasilica - 34(4): 720-729. October-December 2020.
doi: 10.1590/0102-33062020abb0002

What factors guide healthcare strategies over time? A diachronic study focused on the role of biomedicine and the perception of diseases in the dynamics of a local medical system

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Received: February 1, 2020
Accepted: August 14, 2020

ABSTRACT

Among the recently discussed evolutionary issues on medical systems, one of the most controversial issues is the replacement of local medical systems with the biomedical system. Our study investigates the hybridization of two medical systems and the role that the perception of incidence and severity of diseases has in memorization and transmission of information about their treatments. We collected data from a rural population in Brazil during two different periods separated by eight years and compared the periods for changes according to the knowledge on treatments with drugs in the biomedical system and according to the incidence and severity of the diseases. We found 147 medicinal plants belonging to 58 botanical families. Our results show that biomedical and local systems complement each other and change over time for the cure of recurrent, instead of the most severe, events. We suggest that based on cultural biases, biomedical and local knowledge can coexist by complementing each other with regards to the range of resources used for healthcare, and that disease perception can guide the evolutionary path of medical systems. Our findings can help elucidate new biases that guide the evolution of medical systems and reinforce important issues in the healthcare literature.

Keywords: cultural evolution, cultural selection, evolutionary ethnobiology, intermedicality, local medical systems

Introduction

Human behavior changes and takes form in the search for solutions to collective and individual problems (Choi & Bowles 2007; Boyd & Richerson 2009), such as those related to healthcare. Several studies have revealed some patterns in medical systems (Vos 2010; Saslis-Lagoudakis *et al*. 2011; Medeiros *et al*. 2013; Díaz-Reviriego *et al*. 2016) that can serve as models for understanding important evolutionary processes of human culture. There are also some interesting reviews and field studies that show that a diachronic perspective can complement several theoretical findings and can reveal important contributions to cultural evolution theory about evolution of medical systems over time (Leonti 2011; Reyes-García *et al*. 2013; Dal Cero *et al*. 2014; Leonti *et al*. 2015; Nascimento *et al*. 2018). As mentioned by Mesoudi, “A complete understanding of cultural evolution requires observational field studies that track people’s real-life behavior overtime. Such studies can potentially address key questions about cultural microevolution.” (Mesoudi 2011).

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Medical systems are cultural systems that reveal what is considered health and disease by a certain group, as well as what are the chosen methods to treat such conditions (Dunn 1976; Kleinman 1978). Traditional (or folk) systems present in small local human groups that use medicinal plants and animals can be called local medical systems (Dunn 1976), and western medical system, whose main treatment strategy is the prescription of industrialized drugs that are sold on a wide scale, can be called biomedical or cosmopolitan system (Dunn 1976).

The increasing hegemony of western culture over other cultures has made some scholars wonder about a possible replacement of local medical systems by the biomedical one over time (Nolan & Robbins 1999; Vandebroek *et al*. 2004; Case *et al*. 2005; Saethre 2007; Ragupathy *et al*. 2008; Srithi *et al*. 2009; Vandebroek & Balick 2012). Although many other studies suggest a coexistence of both medical systems, which may be beneficial to local populations (Belliard & Ramírez-Johnson 2005; Giovannini & Heinrich 2009; Giovannini *et al*. 2011; Zank & Hanazaki 2017), this issue still lacks evidence. In addition to determining whether people consciously prefer to have diseases treated by resources and people of one medical system or another, it is important to observe how the dynamics of local medical knowledge behave over time. The study of the dynamics of the variation of medicinal plant knowledge can demonstrate whether there is a preference for sharing, enrich the strategies, or forgetting a particular treatment. If the decrease in plant knowledge is related to the current higher popularity of industrialized drugs, this may be indicative of the substitution of local medical knowledge by biomedical knowledge. If variation in the knowledge on medicinal plants used to treat a disease is unrelated to the popularity of drugs used to treat the same disease, it is unlikely that there will be a preference for biomedicine treatments over local treatments, promoting substitution over time.

Beyond the influence of industrialized drugs, changes in information about treatment may be guided by disease specificities, and its incidence and severity. Santoro *et al* (2015) and Nascimento *et al*. (2016) showed that local populations know more about medicinal plants that are used to treat diseases with high incidence compared to those that are used to treat rare diseases. It is adaptive to seek more information about incident diseases because of the need to have a greater medicinal pool for events more likely to happen. People could prioritize to experiment with new plants or search new resources (in magazines, markets, TV, or even in biomedicine) to treat the diseases that are most likely to occur according to them, thereby enriching the local medical system. However, based on the frequency of a disease, people would transmit more information about its treatment and the increase of transmission events could lead to an increase in transmission errors, generating cultural mutations that could be detrimental to health (maladaptive). This could be seen if there were more modifications over time in the composition of plants (not just the number) used to treat common diseases rather than rare diseases.

Santoro *et al*. (2015) and Nascimento *et al*. (2016) also showed that the local perception of disease severity was negatively related to the number of plants known for treatment. Among the hypotheses raised to explain this relationship were the possible transmission errors that would be less likely to remain in cases where there is greater danger to life. The low modification in the composition of plants used in the treatment of more serious diseases over time could also answer this question. However, it may also be that people seek to innovate less in the treatment for these diseases (because the risk of a new experiment could be fatal), which could be observed if, over time, there was a smaller increase in the number of medicinal plants used for the treatment of more serious illnesses rather than the other ones. In addition, severe diseases might also be rare or considered not important, which might happen if there is not enough information shared about them over time.

In order to verify the importance of biomedicine and of the inherent characteristics of a disease (severity and incidence) in the evolutionary path of a local medical system, we sought to answer the following questions:

1. Do people consciously prefer to seek medicinal information from people of one particular medical system over another? With this question we wanted to determine whether people consciously prefer to look for models from a particular medical system (doctors or local herbalists, for example) when they have to treat an unknown disease.

2. Is the variation over time in the number of medicinal plants used to treat a disease related to the popularity of industrialized drugs to treat the same disease? With this question, we sought to verify whether an increase or decrease in plant knowledge is influenced by the knowledge of industrialized drugs.

3. Is the variation over time in the number of medicinal plants used to treat a disease related to the perceived severity and /or incidence of the disease? With this question, we wanted to verify the importance of these factors in the selection of medicinal plants.

4. Is the variation over time in sharing of medicinal plants used to treat a disease related to the perceived severity and/or incidence of the disease? With this question, we wanted to verify the importance of these factors in the transmission of knowledge and forgetting of information.

5. Are changes in the composition of plants used to treat a disease related to the perceived severity and/or incidence of the disease? With this question, we aimed to verify whether the occurrence of cultural mutations is more common among more or less severe/incident diseases.

6. Does the number of industrialized drugs used to treat a disease vary according to the perceived severity and/or incidence of the disease? With this question, we wanted to determine whether the knowledge of industrialized

drugs is influenced by the same factors that influence the knowledge of medicinal plants.

Based on these questions and using a local medical system from the Brazilian semi-arid region as a model that was studied in two different periods 8 years apart, we have discussed microevolutionary processes that guide human behavior regarding healthcare strategies.

Materials and methods

Study population

The study was performed in a rural community of Carão, in the municipality of Altinho (geographic position at 8°29'32" S; 36°03'03" W), in the mesoregion of agreste de Pernambuco. The region is covered with arboreal hypoxerophytic vegetation including deciduous and semi-deciduous species, which qualifies it as a Caatinga ecosystem. The climate is semi-arid, according to Caruaru's weather station (60 km away from Altinho), and the level of rainfall is approximately 746 mm, with the rain season occurring between June and July.

Local population is small, with about 101 inhabitants, according to the information provided by the health center and confirmed by locals themselves. The main subsistence activity is cropping of corn, beans, and cassava (Alencar *et al*. 2014). The crops are consumed within the community and what is left is sold in Altinho's street market. Most of the adult population has no more than 5 years of formal education or is illiterate. However, there is an elementary school in Carão, while education for older children–and for teenagers–is offered in Altinho's downtown (Alencar *et al*. 2014).

Carão has a health center that gets weekly visits from a nurse and monthly visits from a doctor, and it provides some industrialized drugs. Besides, other drugs may be purchased in drugstores in Altinho's downtown. The community of Carão is 16 km away from Altinho's urban center, and it can be accessed through a one-way dirt road on a truck that belongs to a local family, who offers transportation daily at 7 h–from the community to Altinho's downtown–and at 12 h–from Altinho's downtown back to the community. For the correct interpretation of the data of the present study, it is important to emphasize that access to the urban center and pharmacies has stayed the same for over 15 years, including the entire period of this study. Additionally, the health center has been active since before the first period of analysis of this study.

The community of Carão has been at the center of many ethnobiological studies on aspects involving the knowledge and use of plants for wood harvesting, as food, and as medicine (Araújo *et al*. 2008; Ferreira Júnior *et al*. 2011; Melo *et al*. 2010; Alencar *et al*. 2010; Alencar *et al*. 2014).

Ethical and legal aspects and experimental design

In accord with the current legislation (Resolution no. 466 from December 12, 2012, by Conselho Nacional de Saúde–Brazil National Health Council), all people who accepted to take part in the research were asked to sign a Termo de Consentimento Livre e Esclarecido (TCLE),–Informed Consent Form–authorizing the collection, use, and publishing of the data obtained during this study. The research was also approved by the ethical committee of Universidade do Estado de Pernambuco (UPE)–Comitê de Ética em Pesquisa envolvendo Seres Humanos (Plataforma Brasil)–registered at no. CAAE: 64811715.3.0000.5207.

Data about the diseases recognized by locals and the medicinal plants used to treat them were collected from the community of Carão in two different periods. The first period was between January and June of 2007 (period one), and the second was from June 2015 to February 2016 (period two). Information about period one was obtained from the database of the Laboratório de Ecologia e Evolução de Sistemas Socioecológicos (LEA), which contains information about medicinal plants and diseases mentioned by all people older than 18 years who present in the community in period one, which amounted to 104 people (68 women and 36 men from 18 to 90 years old). These data were collected from free lists and individual semi-structured interviews (Bernard 2006).

The researchers who collected the data in period one were contacted before data collection from period two was initiated to ensure that the same methodological procedures would be adopted. The strong bond that the research group of LEA created with the community of Carão in 2007 cleared the way for our research group into the community in 2015, especially when some researchers from 2007 accompanied us during the first visits.

From 2015 to 2016, we carried out a population survey of all people older than 18 years in the community of Carão, including those who were not present in the studies from 2007. Two people declined participation in the study, so the sample from period two included 99 people (51 women and 48 men, from 19 to 88 years old), out of which 63 also participated in the studies in period one.

As in period one, in period two, the local knowledge of medicinal plants was achieved through individual semi-structured interviews, which began with the free list technique (Bernard 2006): informants were asked to list the medicinal plants they were familiar. The interviews in two periods posed the following questions: "What illnesses do these plants treat?" and "What is this illness called?" In period two, we also asked, "Is there any medicine from the drugstore that also treats this illness?" These questions were aimed at finding about the composition and the number of the medicinal plants, the diseases, and the knowledge of industrialized drugs (biomedical resource) for each target.

In order to verify whether people preferably seek help from actors (models) of the biomedical system (doctors and pharmacists) rather than from those belonging to the local system (healers and local specialists) when treating a disease, at the end of each interview, we asked them that from whom would they ask for help if they had to treat an unknown illness, that is, one against which they cannot self-medicate with plants nor industrialized drugs. In this question, we left room so that informants could respond if they prefer actors from one system or another, depending on the disease, or if they prefer actors from both systems equally.

In this study, we used the local classification of plants and diseases. Therefore, we took some time to standardize the local terminology of these variables. The descriptions of diseases that were given at the interviews helped us understand some synonyms mentioned during the two periods of research. For instance, when someone would say "comida que ofende" (food that makes you feel sick), the symptoms were the same of "barriga inchada" (swollen stomach). We repeated the interview with some informants in order to make sure that similar diseases with different names were, in fact, synonyms, and only when the person recognized two different names as having the same meaning did we standardize it with the most common name. With the mentioned plants, we sought help from three local specialists to ensure that some of the names were considered synonyms within the community, such as "imburana açu" and "imburana de cheiro" (both Commiphora leptophloeos). We collected some of the plants indicated in the interviews that were included in the collection of Professor Vasconcelos Herbarium, Universidade Federal Rural de Pernambuco (UFRPE), and duplicates were included in the collection of Professor Geraldo Mariz Herbarium, Universidade Federal de Pernambuco (UFPE) and Instituto Agronômico de Pernambuco (IPA). The plants were identified through comparisons with herbarium materials, expert advice, and a survey of the specialized literature.

Local perception of diseases incidence and severity

In order to gather information about the local perception of the disease incidence and severity, we conducted two participatory workshops (Sieber *et al*. 2014) in 2016 to which all members of the community were invited. In all, 35 people attended the workshop on incidence, and 24 attended the one on severity. Everyone who attended the latter was present at the former. For the execution of the participatory workshops, we prepared cards with names of diseases that were mentioned in the two research periods. During the workshops, we asked participants to rank the cards according to their incidence and severity in the last 10 years (in order to include the two periods of analysis), on a scale from 0 to 10, where 0 means no risk when asked about severity and no occurrence of disease when asked about incidence, and 10 means maximum severity and frequency. This methodology was applied in a previous study with the same goal (Santoro *et al*. 2015).

During the workshops, some synonyms of popular names of plants and diseases mentioned in the interviews of both study periods became clear, which allowed for a better standardization of the data. Some diseases could not be ranked due to a lack of consensus, which is a common bias in participative methods (Sieber *et al*. 2014). Therefore, 112 diseases were ranked according to their frequency, and 113 according to their severity (from a total of 203 diseases).

Data analysis

In this study, the units of analysis were the diseases that were known by the community, as well as the forms of treatment based on the use of medicinal plants and industrialized drugs. At first, we quantified the number of plants and diseases mentioned in the two periods of research, and the number of industrialized drugs mentioned in period two.

To determine whether people consciously prefer to seek medicinal information from people of one particular medical system over another, we determined to which medical system did the actors that were sought after for treating diseases belonged according to the interviews. Furthermore, we performed a χ^2 test to compare the number of people who claimed to look for doctors or pharmacists with the number of people who claimed to look for someone from the local community, such as healers or family relatives, whenever they would face a disease against which they did not know how to self-medicate.

To analyze whether the variation in the number of plants known is related to the current popularity of industrialized drug, we verified whether the decrease in the knowledge about plants throughout time is related to the number of people who know about industrialized medications used to treat the same disease. Even without data about industrial drugs in period one, we could estimate whether the popularity of those drugs threatened the knowledge of plants in case there was a decrease in the number of plants according to the popularity of industrialized drugs. For this analysis, the independent variable was the number of people who know about any industrialized drug to treat a disease and the dependent variable was the discrepancy over time in the number of plants used to treat the same disease (number of plants for each disease in period two subtracted from number of plants of the same disease in period one). This relation was verified in a Generalized Linear Model (GLM) using Poisson distribution and stepwise regression to obtain the best model based on the Akaike Information Criterion (AIC).

With a view to determine whether the disease incidence and severity shape the search for treatment, we linked the ranking of incidence and severity obtained from the workshops (from 0 to 10) to the following dependent variables:

(a) The increase and decrease in the number of plants over time (number of plants used for each disease in period two subtracted from number of plants used for the same diseases in period one);

(b) The increase and decrease in sharing information about the treatment of each disease over time (number of people who mentioned knowing how to treat each disease in period two subtracted from the number of people who mentioned the same in period one), as a way of determining possible transmission events and forgetfulness of people who already knew that information;

(c) The value of similarity of plants from period one to period two (we used Jaccard's similarity distance), that is, the variation in the composition (and not the number) of medicinal plants used for each disease over time, which shows possible cultural mutations;

(d) The number of industrialized drugs known to treat each disease, which shows whether these factors also influence the knowledge of industrialized drugs.

All the analyses of the relation between the variables were performed using a GLM, combining the same model analyses with the same dependent variables, which could be explained together (Tab. 1). The descriptive statistics of data used in GLM analysis is provided in supplementary Table S1 in supplementary material.

GLM analyses were performed based on Poisson distribution, except for analysis of (c) in which we used Gaussian distribution, as the independent variable was not continuous (Jaccard's dissimilarity distance value). After each GLM analysis, we used stepwise regression to obtain the best model based on the AIC. All analyses were conducted using software R version 3.2.3 (R Development Core Team 2010).

Results

The local medical system through time

People from the community of Carão recognized the existence of 151 diseases in period one, and recognized 96 of these 151 diseases in period two (see Tab. S2 in supplementary material). In period two, the total number of recognized diseases was 148, indicating that the knowledge of existence of 52 diseases was gained and that of 55 diseases was lost during the eight years that separates the two periods of the study. In period one, people mentioned 233 medicinal plants, and mentioned 162 of these 233 medicinal plants in period two (Tab. S3 in supplementary material). In total, 190 plants were recognized in period two, indicating that 28 plants mentioned in period two were not mentioned in period one. We identified 147 plants at the species level and 40 at the genus level, belonging to 58 botanical families. Many plants belonged to the same species were considered different plants by people (Tab. S3 in supplementary material). We did not have access to information on industrialized drugs in period one, but, in period two, 134 drugs from the biomedical system were acknowledged.

Table 1. Results of the analysis conducted using the Generalized Linear Model (GLM), organized by dependent and independent variables of each question in the present study.

Dependent variables	Independent variables	AIC	Explanatory Model		
		318	Estimate	z	p
Increase of number of plants	Popularity of industrialized drugs	316 [a]	0.049938	5.970	2.37e-09*
	Diseases incidence	316 [a]	0.195091	4.907	9.24e-07*
	Diseases severity		0.006778	0.226	0.821158
		458.31	Estimate	z	p
Decrease of number of plants	Popularity of industrialized medication	457.75 [a]	0.05433	-2.469	0.0135*
	Diseases incidence		-0.03753	-1.190	0.2342
	Diseases severity	457.75 [a]	0.02905	1.350	0.1771
		-24.857	Estimate	z	p
Discrepancy of plant composition (similarity)	Diseases incidence		0.001622	0.189	0.851
	Diseases severity		0.000292	0.042	0.966
		505.94	Estimate	z	p
Increase in sharing	Diseases incidence	504 [a]	0.214341	6.955	3.53e-12*
	Diseases severity		0.002786	0.113	0.9103
		606.67	Estimate	z	p
Decrease in sharing	Diseases incidence		0.036583	1.699	0.0894
	Diseases severity		0.009403	0.537	0.5913
		401.9	Estimate	z	p
Number of industrialized drugs	Diseases incidence	400.5 [a]	-0.01644	9.797	<2e-16*
	Diseases severity		0.25967	-0.785	0.4322

[a] AIC value of the variables that fit in the best model, according to Stepwise

* results considered significant, with $p < 0.05$.

Do people prefer biomedicine over local medical system?

People mostly sought help from actors who belong to the local medical system (n = 71), be they local specialists or family relatives, and not many people resorted to the biomedical system–doctors and pharmacists–(n = 12) (χ^2 = 41.94, p = 0.0001). A few people claimed that they do not trust anyone when looking for this kind of information (n = 9).

There was a positive relation between the increase in knowledge on plants over time and the current popularity of industrialized drugs, and a negative relation between the loss of knowledge on plants over time and the popularity of industrialized drugs (Tab. 1), i.e., for the same disease, there was greater or reduced accumulation of resources from both systems. Since we did not have access to information on knowledge of industrialized drugs over time, we could not determine whether the two types of knowledge grow and decrease together. However, our result indicates that the variation in knowledge about plants through time follows the popularity of industrial pharmaceuticals. If we assume that the popularity of medicines decreases or is maintained with the increase in knowledge of medicinal plants, then this would indicate that there is no competition favoring the biomedical system, but the local one. Only when we think of the alternative scenario, where the popularity of industrial drugs rises more significantly than that of medicinal plants, then it is possible that there will be a gradual replacement. Considering any of these hypothetical scenarios (since we do not have data on the industrial medicines in period one), our results show that the two systems move together in the same direction, as for the same disease, there is a greater and reduced accumulation of resources in both systems.

During the interviews, although it was not our focus, some people reported that doctors in the region also teach locals about plants, including plants used to treat diseases that can only be diagnosed in health centers–such as diabetes and high blood pressure. In addition, the nurses who work in Carão also encourage the use of medicinal plants. In Brazil, some government programs encourage the use of medicinal plants in the public health system, such as RENISUS and PPNPMF (Ministério da Saúde – Brasil 2008). Conversely, in period two, for some diseases, people knew about a relatively large number of drugs (134), which was not very different from the number of plants (190). In addition, some diseases can only be identified with the help of biomedicine, such as diabetes, high blood pressure, and cancer (see supplementary material), which may favor the understanding of some industrial remedies. These data show a dialog between the two medical systems.

Another important secondary data extracted via interviews was that some people stressed the importance of not mixing the two types of medicine, saying, "Both are effective, you can use drugstore medicine or plants, but never use them together," or, "you can use the plant by day and the drugstore medicine by night, but never at the same time." This type of discourse came voluntarily from five informants, used as secondary data, as they were not included in our interviews. Despite coming from a few informants, this information must be considered relevant, which shows that the two resources are perceived as belonging to different medical systems, even though both may be used.

What is the role of disease incidence and severity in the selection of medicinal resources?

Incidence is related with the increase in the number of medicinal plants and sharing of information over time. Incidence is also related with a higher number of industrialized drugs (Tab. 1). These results show that the frequency of a disease accounts for the quest for incrementing the set of knowledge regarding possible treatments, regardless of whether industrialized drugs or medicinal plants are used in the treatments. Even though incidence is an important factor in the emergence of new medicinal plants through time, it does not explain the decrease in the knowledge on medicinal plants (Tab. 1), indicating that people do not forget about the treatments of diseases that are rare. However, this also does not explain the variation in the composition of plants over time based on the similarity analysis between years (Tab. 1). Moreover, incidence has a positive effect on the variation of treatment possibilities (number), but not on the variation of composition (quality) of treatment, which could show substitutions following possible cultural mutations.

There was no relation between disease severity and the knowledge of industrialized drugs or the dynamics of the number and composition of plants through time. Severity was also not related to the dynamics of the sharing of information about each illness (Tab. 1).

Discussion

Do people prefer biomedicine over local medical system?

The diseases for which there was most increase in knowledge of plants over time were exactly those for which there was more popularity of industrialized drugs. The opposite also happened, with a greater reduction in the number of plants in those diseases for which little or no industrialized drug was known. We did not have information about the community's knowledge on the industrialized drugs in period one, which made it impossible for us to verify whether the knowledge increased or decreased throughout the years. However, we knew that access to these industrial remedies, as well as the presence of health centers, where these drugs were mostly prescribed, was the same in both periods of analysis. Indeed, our results revealed that the great popularity of biomedicine did not negatively influence the growth in the knowledge on medicinal plants, as expected in case of substitutions. It is even possible that the popularity of drugs has grown to a greater extent than plant knowledge, yet there was no clear forgetting of medicinal plants. On the contrary, the knowledge on plants used to treat diseases for which industrial pharmaceuticals were very popular had been enriched. Furthermore, people still claimed they would rather seek help from social actors who belong to the local system than from those pertaining to the biomedical system, such as doctors and pharmacists, when dealing with a new illness. These results support the idea that the medical systems complement each other.

According to some authors, the local and the biomedical systems are incompatible and impossible to link and that replacement of the local system with the biomedical system should be promoted (Nolan & Robbins 1999; Case *et al*. 2005; Saethre 2007; Ragupathy *et al*. 2008; Srithi *et al*. 2009). This seems plausible due to the common dominance of western culture over several other cultures (Starr 1982), which makes the models or the information from the biomedical system seem attractive for different human groups. However, as we see in our results, it is not a rule that the hegemony of the biomedical system leads to elimination of traditional medical practices, for they remain viable and may actually increase in popularity (Kaptchuk & Eisenberg 2001).

Indeed, it is known that there is a "competition" for memory space between the different cultural information that is vital for evolution (Cavalli-Sforza & Feldman 1981; Boyd & Richerson 1985), and we were able to see that some knowledge of the local medical system was eliminated with time, such as the diseases and plants that were not mentioned in period two. Nonetheless, apparently, this "competition" is due to other factors and is not related to the origin of the knowledge–that is, it does not matter if it came from the local or biomedical system, both sources of knowledge seem to contribute equally to the population's healthcare.

Giovannini *et al*. (2011) found results similar to ours in a synchronic analysis of the knowledge of lay people from a Mazatec community in Mexico. They found that the more a person knows about and uses medicinal plants, the more this person knows about industrialized drugs, showing that the two medical systems grow in the same direction, and do not replace each other. The same study suggested that the associations between knowledge of medicinal plants and industrialized drugs reflect the role of third variables, such as the frequency of self-medication. In our study, we can see that it seems that people prioritize transmitting and incrementing the treatment alternatives for a given group of diseases (namely the frequent ones, as we will discuss) using information from both sources.

The complementarity between two medical systems is known as medical pluralism (Singer & Baer 2012) or intermedicality (Greene 1998), which occurs when human populations mix different medical systems, and has been suggested by several studies on indigenous and rural populations (Cosminsky & Scrimshaw 1980; Belliard & Ramírez-Johnson 2005; Giovannini & Heinrich 2009; Zank & Hanazaki 2017). In some populations, those systems are clearly perceived as distinct, and are considered exclusive at times and complementary at other times (Calvet-Mir *et al*. 2008). This seems to be the case of the system studied here, in which strategies and models of both systems are seen as distinct, in which they can complement each other, but for some situations, only one of the systems is preferred (when seeking models for new medical information). In other populations, the intersection between them is so strong that the biomedical system enters the local one, promoting a syncretism, following which it is impossible to separate them, and biomedical system is then redefined to fit the local medical system (Cosminsky & Scrimshaw 1980).

The above phenomenon can be observed from the perspective of Rogers (1995), who described the adoption of innovations. The prerequisites to the adoption of innovations can be understood as a content bias, a bias that guides the cultural selection of new information (Boyd & Richerson 1985; Mesoudi 2011). Considering that the local medical system is older than biomedicine in our study population, we can see that local populations adopt new knowledge from the biomedical system because the information from this system is consistent with the previous information about medicine that they have. An evidence of this is the fact that biomedicine's references to them (doctors and nurses) also present knowledge of medicinal plants and encourage their use, as seen from the interviews. Although this bias allows the adoption of new knowledge, it does not lead to the replacement of the local system knowledge with the new information from the biomedical system.

According to Mesoudi (2011), beyond content bias, another class of cultural selection biases concerns the person from whom information is acquired. This person is considered a model, and his/her intrinsic characteristics (such as their prestige, sex, or age) can make people preferentially seek information from this model rather than other people. We do not have more in-depth results on possible model based biases (see Rendell *et al*. 2011 and Mesoudi 2011 for more information on cultural biases), but our results show that people prioritize local medical system models, such as local herbalists, rather than biomedical models, such as doctors.

Therefore, our findings support the idea that people can use resources from both medical systems, without losing knowledge of local system due to replacement. This shows that systems can coexist and complement each other, helping to maintain local health.

What is the role of disease incidence and severity in the cultural selection of medicinal resources?

Few studies have worked on the hypothesis that the severity and incidence of a disease may influence the choice of treatment, with analyses conducted in a single period. They have found that the higher the incidence of a disease, the higher the number of plants known to treat them; and the more severe a disease, the fewer the number of plants known to treat them (Santoro *et al*. 2015; Nascimento *et al*. 2016). Some explanations have been suggested for this pattern, and we will use them to discuss our results.

In a wide context, increase in the number of medicinal plants contributes to the medical system resilience, which makes it adaptable to eventual disorders (Albuquerque & Oliveira 2007; Nascimento *et al*. 2015). The frequency of an event may motivate people to broaden their treatment alternatives, which will enable them to ensure that they have an option for events that are most likely to occur, revealing an adaptive feature (Nascimento *et al*. 2015). Unlike previous studies, we not only saw a relationship between incidence and number of plants, we also found a significant increase in plant number over time. In addition, we have found a significant increase in the sharing of known plants for treatment of frequent diseases, which is a great indicative of the priority of transmission of this knowledge. The changes in number and sharing occurred in a short period of eight years, which reveals that the local medical system responds quickly and is able to adapt to conditions that are perceived as frequent.

In fact, the greater occurrence of an event would allow circulation of more information about this event in the population, thus increasing its share over time. This may result in an increase in the number of plants used to treat these diseases, as shown in our results. This may be because there is a greater likelihood of transmission of errors in a larger transmission chain, leading to random aggregation of new information–as happens in Chinese whispers in which a greater number of people increases the occurrence of errors in the transmission of the original message (Mesoudi 2011). Therefore, the increase in the number of plants used to treat incident diseases could be a result of cultural mutations (changes in original information that occurs accidentally, due to transmission errors–see Mesoudi 2011 and Kempe *et al*. 2012) that occur because of the frequency of disease related information transfer events. In this case, the higher number of plants used to treat incident diseases would be the reflex of a maladaptation process due to the persistence of errors.

However, if the increase in the number of plants were a consequence of errors in transmission, we would expect to find more discrepancy in the composition of plants used to treat diseases that are more common between the two periods. Our findings, however, do not indicate a greater variation in plant composition used for incident compared to those used for less frequent diseases. Indeed, there is no relation between variation in composition and incidence. Thus, we can sustain that the increase in the number of treatments for frequent diseases is due to the voluntary increment in the knowledge of medicinal plants (obtained by the search for plants in markets or new knowledge learned from TV and magazines), and not due to cultural mutations.

Based on this perspective, we can say that the incidence of a disease encourages people to prioritize information about its treatment in memory and transmission, and in search of new treatments. According to Mesoudi (2011), any condition where some information is more likely to be acquired and transmitted than other information is called "cultural selection." Cultural selection can lead to changes in the proportion of information that is shared in a population over time, as we have seen. Therefore, we propose here that the incidence of an event may act as a cultural selection bias.

Conversely, the severity of a disease seems to have no influence on the dynamics of medicinal knowledge according to our results. We expected that the degree of danger of an event may encourage people to give more importance to that event, thereby leading to an increase in sharing of information on how to deal with the event. According to previous studies, we also expected a negative relationship between severity and the number of known medicinal resources (Santoro *et al*. 2015; Nascimento *et al*. 2016). According to those studies, people are more likely to try new strategies of treatment in less severe events than in serious ones if serious events carry grave threats to one's health, which would result in fewer known resources for more serious diseases. This reasoning makes sense, and it is based on a strong theoretical line that says that in dangerous situations it is not advantageous to produce new knowledge (Laland 2004).

However, we think that experimentation is always dangerous in the setting of healthcare attention, not only for the most severe diseases. We agree with Soldati *et al*. (2015) that experimentation with new plants is unlikely to happen in the context of a medical system, which is not valid in other areas of ecological knowledge, such as the use of plants as food or for wood harvesting. Therefore, the increase or decrease in the number of plants would not be affected by the danger in conducting new experiments with plants. Furthermore, it is important to understand that the studies that found that plant number is negatively related with severity also found that severity and frequency are interconnected (Santoro *et al*. 2015; Nascimento *et al*. 2016), which was not observed in our study. Therefore, the effect of severity could be masked by the effect of incidence in those studies.

Combining our findings on the dynamics of knowledge of medicinal plants, which revealed the significant relationship between knowledge of industrialized drugs at a given time and the incidence of diseases, we can suggest that the frequency of a disease encourages people to search for and share the information about that disease.

Limitations of the study

We assume that a study done at two different times with two different teams has limitations. In spite of our best efforts to minimize possible research biases by following the same procedures used by the researchers of period one, we know that using interviews conducted by different people may lead to loss of data. Nevertheless, as we analyzed the collected data, we observed that the mentions of plants and diseases followed the same patterns, and, in general, there was not a significant loss of information through time.

During the workshops on perception of diseases, we asked people to rank the frequency and severity of the illnesses according to what they had observed in the last 10 years, but we are aware that people may not always recall such information accurately. In some cases, when a great discrepancy was observed in the frequency of a disease in the past years, informants pointed out that the frequency of the disease was only in the last year, so we took them out of the analyses that considered the two periods.

We only had data on industrialized drugs only from period two. We know that the lack of data from period one limits our results, and we tried to make it clear in our discussion. Besides, in period two, we collected information about the industrial drugs that people knew; however, we did not have data on the actual use of the drugs (although, based on secondary data and observation in the field, people were found to use resources from both medical systems). We hope to repeat this study in the future with a larger dataset.

Conclusions

Our study sheds light on some questions about what motivates people to search for healthcare resources. With regard to the so-called replacement of local medical systems with the biomedical system, we bring more evidence that both systems can complement each other. At least consciously, people still prefer copying new information from models of the local medical system, but they adopt a lot of knowledge of biomedical resources without losing previous knowledge on medicinal plants. Indeed, people seek knowledge of the two systems to treat especially the most incident diseases.

Therefore, incidence was shown to be an important characteristic of a disease that guides knowledge transmission and search for treatment. People would rather transmit, and search information related to those events that are the most frequent, seeking for information from different sources in order to deal with the most common health problems. In addition, it should be noted that the disease severity might also be a key factor in the development of local medical systems and it may be responsible for the act of resorting to the biomedical system, although this can be only true when the disease lasts for longer periods of time, which we were not able to cover in our study. Thus, our results allow us to state that the frequency of an event may act as a cultural selection bias, making information more attractive than other factors. It should also be noted that local health systems are complex, influenced by different components and processes, and the aspects addressed in this study are influenced by other broader aspects that interrelate, such as cognitive, social, and political aspects. Finally, even if our results reflect only one specific community, many other medical systems are undergoing the processes similar to those seen in our study and our findings can broaden our view of the processes behind healthcare decision-making.

Acknowledgements

To the community of Carão for their support. This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES), Finance Code 001, with contributions from the INCT Etnobiologia, Bioprospecção e Conservação da Natureza certified by CNPq, and financial support from FACEPE (Fundação de Suporte a Ciência e Tecnologia do Estado de Pernambuco - Grant number: APQ-0562-2.01/17). We also would like to thank the CNPq for the productivity grant awarded to UPA.

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