An Agent-based Model for the Humanities

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Abstract

The Humanities now confront a new era in cultural representations — the digital age. As a consequence, our approach to culture may be modified because technology allows us to now visualize our thoughts and theories using digital and computing techniques. This research focuses on merging humanities research with computational sciences to explore the processes involved in culture dynamics. We present an interdisciplinary approach that combines literary studies, economics, and agent-based modeling (ABM) and give details of how literature maybe used as a data set that can be translated into a dynamic Java-based simulation of human interactions constructed around Game Theory. Our model of Cross-Cultural Cooperation is designed to study culture at various levels of granularity simultaneously in order to show how micro-behaviors might lead to macro outcomes such as cultural group formation. We present one experiment based on the literature of discovery and conquest in the U.S. Southwest translated into the language of ABM. Additionally, we explore the role of space, time, and population-size in this process and offer a discussion of possible future directions for this type of research. The creation of our simulator of cultural exchange between individuals of differing cultures allows researchers to experiment with ideas about first and ongoing contact and speculate with "What if?" scenarios.

Introduction

The humanities now confront a new era in cultural representations — the digital age. As a consequence, our approach to culture may be modified because technology allows us to now visualize our thoughts and theories using digital and computing techniques [Berry 2011, 1]. For this, we need an analytical framework that integrates various disciplines synergistically. In this research, we offer the possibility of complexity science and computer simulation as a means of accomplishing this goal in the humanities.

[1]

This work focuses on merging humanities research with computational sciences to explore the processes involved in culture dynamics. We present an interdisciplinary approach that combines literary studies and agent-based modeling (ABM). The article divides into five sections. In the first, we describe our approach to culture. Next, we explain our "computational turn" by presenting the idea of agent-based modeling in the humanities. In section three, we give details of how literature may be used as a data set. We present our model and the results from one experiment using our own ABM simulation in section four. And finally, we conclude with a discussion and possible future directions for this type of research.

[2]

Hispanic Culture in ABM Perspective

The intent of our work is to better understand what behaviors give rise to diversity within a cultural group, specifically the Hispanic culture as our area of research interest. Dawkins (1978, 1999), Cavalli-Sforza and Feldman (1981), Cavalli-Sforza (2000), and Sperber (2006, 2007) and others hold that that culture[1] is a second process marching in step with biological evolution. The evidence of this process might be viewed from a materialistic position (Gabora 2007) such that, artifacts in the form of tools are taken to indicate the existence of a "culture." Consequently, if we follow the evolution of "tools" in terms of their nature, number, and complexity, we have a materialistic approach to culture and its development

[3]

over time. Alternatively, we might focus on the intangible aspects of culture such as the abstract systems of language and behaviors (institutions) that transmit information between individuals and groups of individuals, leading to learning over generations (Cavalli-Sforza and Feldman 1981). These abstractions depend on mind processes such as awareness, perception, judgment, and problem-solving [Wilson and Keil 2001]. In this view, "Culture is the mental equipment that society members use in orientating, transacting, discussing, defining, categorizing, and interpreting actual social behavior in their society" [Wilson and Keil 2001].[2]

When we add "Hispanic" to culture, we are limiting the view of culture to some extent; however, there are diverse views on what Hispanic culture means. For some, the Southwestern United States Borderlands embody the Hispanic, but why? Is it as simple as the presence of the Spanish at some point? This simplification obscures the fact that more complex processes have taken place over time between numerous individuals and groups including but not limited to Anglo, Hispanic and Native American. The complexity of the process is manifest in the definitions for the term "Hispanic." For example, the Real Academia Española notes that it often refers to the populations of Hispania, the Roman name for the Iberian peninsula, although the dictionary also notes that the term applies to the countries of *hispanoamérica* and more specifically to individuals in the United States whose origin is hispanoamérica [Real Academia Española 2001]. Across the Atlantic, in the late nineteenth century the term "hispanic" referred to the Spanish-speaking New World [Harper 2010–2012]. More recently, Hispanic is the term used by U.S. government for census purposes to identify members of certain groups (Cuban, Mexican, Puerto Rican, Central and South American [US Bureau of the Census 1970]). The tag arises from a process of "self-identification" based on a set of prompts such as "Mexican, Puerto Rican, Cuban, Central or South American, or some other Hispanic origin" (U.S. Bureau of the Census 1993). However, this Hispanic label concerns various groups who feel that it does not adequately reflect the totality of their experiences. Hence, we now see Latinos, Chicanos, Hispanos and other identities. This diversity of self-identification and its expression as a group-level phenomenon known as "culture" is at the very heart of our research.

The "Computational Turn"

Complexity or complex systems analysis is concerned with how the "simple" organizes to become the complex. For example, how does a single cell become a brain? How is it that a number of individuals acting in an individual way give rise to larger social structures such as cultural groups, economies, financial or political systems that span the globe? These systems seem to act in ways that are difficult to perceive at certain levels of disaggregation (granularity). Additionally, their emergence over time is equally difficult to predict, although from the perspective of complexity science we can understand the possible systemic outcomes if we can understand the nature of individual interactions within a certain context.

The starting point for this research is based on complexity; that is, to identify the overarching system and then to further disaggregate this entity into its individual parts such that we understand the correlation in the behaviors of individuals that lead to a higher-order system. Individuals and their behaviors are the focus rather than simply the individual as a unit in a linear system that adds two and two to result in four. The rules of behavior between individuals are about the transmission of information and are in fact very simple and limited. However, the emergent system, as the interplay of individual behaviors is called, is believed to differ from the sum of its parts, and the system itself changes over time. Mitchell offers as examples of these types of systems a solar system, the brain, a stock market, and global climate change [Mitchell 2009, 16]. These are extremely complex systems but when disaggregated into their parts planets, cells, individual equity traders, and simple molecules are interacting with each other in a way not clear to us if we take a systemic view. This is where complexity science differs from traditional reductionist scientific analysis in its methodology and view. That is to say, complexity science acknowledges there is no clear way to reduce a complex whole into the sum of its parts because other forces must be at play between the parts. However, we can take a small segment of this complexity and break it down into its parts and rules that govern the behavior of these parts in order to better understand how a dynamic system emerges with sometimes difficult to predict outcomes.

For our research, we consider "culture" a macro-level phenomenon that may be visualized as a dynamic process using ideas from complexity in combination with new computational technology. In order to arrive at this end, we combine "data" from a set of cultural artifacts — written artifacts to be precise; (2) the concepts of evolution and emergence from

complexity; (3) a behavioral mechanism consistent with culture but translatable to computer code — Game Theory; and (4) a method of encoding and visualizing these ideas. In our case, the process of self-identification by individuals is recast in terms of game theory in order to better understand how individual choice leads to group-level diversity. This, we believe, means that a group as it is broadly interpreted contains individuals that share a common process of self-identification; however, when the level of granularity for self-identification changes, suddenly not everyone in the group fits into the previously clear-cut category as was once thought. This we believe approximates emergence because it is an inevitable consequence of the expansion of simple rules governing individual self-identification. By studying these ideas using complexity, we hope to better understand how cultures emerge or evolve, rather than simply accept their existence.[3]

Literature as Data

Literary objects such as written texts are cultural objects that represent cultural information. In this respect they might be viewed as material evidence of a culture's existence. In other words, they may be considered as either data points or sets relating to a culture. For example, one could count the number of books (data points) produced in a given space of time and assign a meaning to the output such that it becomes a measure of cultural development expressed through book production. In fact, the United Nations Education, Scientific and Cultural Organization (UNESCO) has taken on the task of measuring culture through data such as book publications on a yearly basis as one means of measuring the standard of living in a country [United Nations].

Another view of texts might be that the books themselves contain information about the relationships and interactions between individuals within a culture or multiple cultures at the time the work was produced. On one level, they represent information that may be fact or fiction. On another they contain information that has meaning in a cultural context and "reproduce" in the histories of cultural systems. In this respect, Dawkins' concept of cultural *memes* as a counterpart to genes in evolutionary biology might be used to suggest that a book possesses a meme or its content a number of memes that are somehow translated to whomever interacts with the book. However, unlike genes, memes undergo continuous mutations [Dawkins 1978, 208–209] because each individual experience differs, making the fidelity of a given meme ambiguous in terms of the process of culture. In other words, the interpretation of the information in the book constantly changes through individual experience. Notwithstanding, this Darwinian analogy of cultural evolution has found favor with some researchers because it structures the idea of culture as an evolutionary process such that new techniques might be used to explore the process[4]. However, as researchers at the London School of Economics point out, memes have no constant physical representation making them *per se* difficult to substantiate and study [Howlett 2011].

Fortunately or not, when studying culture, we are left with cultural products such as books and their ambiguous content as sources of information on the past, making research difficult. For our study, we suggest that the ambiguity of interpretations arising out of historical texts should not eliminate them as a viable source for historical research into culture. In fact, we take the view that individuals interact with each other through a process of encounter and self-identification, and that through a number of different processes, these encounters impact on individuals leading to a group-level dynamic [Sperber 2007]. The key point is that we are not seeking to identify a specific idea or meme and follow its evolution over time. Rather we focus on individual behaviors based on what we believe to be an original point of understanding based on a text. From here, our interest is, as Daniel Sperber writes, how "Cultural information spreads across members of a population through their interactions, that is, through their producing, in their common environment, events and objects that carry information that others can pick up" [Sperber 2007].[5] The cultural information we are interested in relates to self-identification.

As noted above, our research interest is the Hispanic, more specifically the Southwestern U.S. and, to some extent, Northern Mexico. These are modern-labels placed on a landscape previously unencumbered by political divisions such as an international border between Mexico and the United States, and subdivisions such as California, Arizona, New Mexico and Texas, or Baja California, Sonora, Chihuahua, Coahuila Nuevo Leon, Tamaulipas. In fact, as Arias and Meléndez note, this mapping of the region begins with the exploration and conquest of these lands by numerous

Europeans and their attempt to contextualize their own experiences [Arias and Meléndez 2002]. This being the case we return to first contact between Europeans and the pre-existing indigenous groups in a specific area of the Mexico-U.S. Borderlands around present-day Santa Fe, New Mexico, because this area represents a region known to have been inhabited by Pueblo Indians prior to first contact and subsequently inhabited by the Spanish and later Hispanics. It is an area of continuous settlement that serves as a starting place for our research on the emergence of the Hispanic. We will use modern-day labels for consistency.

Four Spanish Borderlands texts, or *crónicas*, were studied for their clues as to the possible decisions that Spaniards employed when encountering the Pueblo Indians of New Mexico. It is important to note that the Spanish writings were produced under very strict regulations governing these official reports to the Spanish monarchs from the New World. In fact, Valcárcel (2010) and Mignolo (1999, 1995) maintain the *relación* (account), typical of writings between 1505 and 1573,[6] operated under two sets of rules, the ones handed down by the Crown on the requirements for these reports and those issued by the local governors.[7] Since Native groups were an integral part of the process of first contact, where possible we attempted to find the Native American voice in these stories. In the Pueblo case, the vast majority of the written record stems from research and interests external to their world; that is, by non-Pueblo authors such as the early chroniclers working under strict guidelines. This presented a significant challenge to any attempt to evaluate the Native experience of first contact, given that so much has been written and documented by "outsiders." Notwithstanding, one means of gauging the Pueblo view of their history was through their testimonies as contained in the *crónicas*. The Spanish colonial records submitted by secular and religious groups recorded Native American belief systems, customs, social organization and economic activities but to find these same materials written by Native Americans themselves is another matter. Nevertheless, embedded within the *crónicas* are fleeting glimpses of these groups. Any early Native view contained in the crónicas was mediated through the Spanish writer. We have also consulted a second source: works by modern-day members of the Pueblo, some of whom have endeavored to record and preserve their histories in writing.

Two chronicles consulted deal with Francisco de Coronado's (1540) expedition to modern day New Mexico and Kansas in search of Cíbolo and Quiviria. Captain Juan Jaramillo's chronicle was written some 20 years after the expedition returned from its travels and is considered by historians as a useful primary source on the geography of the region [Jaramillo 2004].[8] Jaramillo's text makes references to encounters with indigenous groups in terms of marching past "*rancherias*" or staying near "indiezuelos" and "ranchos," where Indians cultivated beans, maize, and squash ("Fue ansí, y todo lo que por allí vimos, fue unos indiezuelos en algunos valles poblados, como en ranchería, tierra estéril…") [Jaramillo 2004]. Although fleeting in their representations, these references portray contact with indigenous groups that transpired without incident ("...llegamos a otro arroyo a donde estaban unos indios poblados que tenían ranchos de paja y sementeras de maíz y frisoles y calabazas…"). Jaramillo's account also includes descriptions of tense even hostile encounters between the explorers and tribes in what is now the Great Plains of the U.S. ("Aquí donde hallamos los indios y nos vieron, se comenzaron de alborotar con voces y muestras de huir, y aun tenían allí algunos sus mujeres consigo, …"). There is evidence of cooperation as we noted the importance of translators or collaborators with the Spanish ("comenzoles a llamar el indio Isopete en su lengua,…"). In fact, Adolphus Bandelier emphasized that the interpreters who travelled with the Spanish explorers were almost certainly from different indigenous groups, such as the Mexica or Tlaxcanas of Central Mexico — two of the many groups that accompanied the Spanish — were not always at hand when encounters occurred, and when they were, there was a question of competency as well as fidelity in the work of translation. Between Coronado's *entrada* and the *reconquest*, modern surveys of the area suggest that very little Spanish entered into the native languages. That is, the Pueblo retained linguistic purity [Bandelier 1910, 3].

The second chronicle is Pedro de Castañeda's narrative of the same Coronado expedition [Winship 2009]. Just as Jaramillo wrote some 20 years after the fact, Castañeda also recalls events two decades later, but his motivation for writing the chronicle is to correct the misleading accounts of the mythical land of Cíbolo. He wrote that the furthest reaches of the New Spain did not hold great wealth and populations like those in Mexico or Peru. His report tells us that in some instances the expedition encountered depopulated areas or relatively small settlements ranging from several hundred to perhaps one thousand inhabitants. This is significant because modern scholarship suggests that the population of the region was on the order of 50,000–60,000 at the time of first contact with the Spanish [Flint and Flint

2012]. There is some continuity between Castañeda and Jaramillo, as both write that native populations are seen to live in *rancherias* and sustain themselves from hunting and other activities. Castañeda's narrative contains more detail on the landscape and distance between the indigenous communities and larger topographical features. As he explains, Cíbola was not unpopulated; indigenous populations lived in communities separated by several *leguas* but in the eyes of Spanish conquistadores were considered a single agglomeration of population. Modern-day researchers find the Castañeda account particularly important in terms human geography.

The third Spanish chronicle is by Gaspar Castaño de Sosa,[9] *alcalde mayor* of modern-day Monterrey, Nuevo León (Villa de San Luís), during the late sixteenth century. When the original governor of the region, Luis de Carvajal, was denounced as a crypto-Jew, Castaño de Sosa was elevated to *teniente de gobernador* of Almadén (present day Monclova, Nuevo León).[10] In 1590 Castaño de Sosa was forced to leave Almadén having been himself denounced before the Real Audencía by Juan Morlete as a slave trader and possible crypto-Jew. His flight from Monterrey to Santa Fe was published in 1592, and again in a collection of writings from the Archivo de Indias in 1871. Gaspar Castaño de Sosa's *Memoria* is an interesting document to the extent that it details the exploits and encounters of this unauthorized expedition to New Mexico some eight years ahead of Juan de Oñate, whose conquest would lead to a more permanent settlement of New Mexico [Castaño de Sosa 2004]. The work itself has received relatively little critical attention when compared to the more known exploits such as those of Coronado or Juan de Oñate.[11] While the historical significance of this chronicle is not the focus of this research *per se*, it is interesting that Castaño de Sosa names and takes possession of lands as he makes his way to Santa Fe, following the norms established by the Spanish Crown. We read in his narrative that the first encounter with the indigenous populations, described as *gente de paz* (literally "peaceful people"), is facilitated by a native identified as Miguel, who is familiar with Spanish, having served with an unidentified group of soldiers from whom he learned the language. He is welcomed into the Castaño de Sosa retinue as a translator [Castaño de Sosa 2004]. Another interesting aspect of Castaño de Sosa's *Memoria* is that encounters with Native Americans are almost a daily occurrence and seemingly friendly by all accounts [Castaño de Sosa 2004]. However, it is curious that in this time period, we find Indians who have already acquiesced to the will of the Spanish Monarchy and the Catholic Church. In the first one hundred years after Cortés, the north-western frontier was, according to Castañeda, at Culiacán in Sinaloa [Winship 2009]. The northern frontier according to Matson and Schroeder was at the San Gregorio River in southern Chihuahua in 1581, although slave raids had reached beyond [Schroeder and Matson 1965, 6]. In fact, Capitan Lope de Aritit had reached the Concho River in search of slaves. Captain Mateo Gonzales had taken slaves from the junction of the Rio Grande and Rio Conchos, and Gaspar de Luxan also entered the region in 1581. The north-eastern frontier during this period would have been at Monterrey (present-day Mexico) at best. The fact that slaving raids were taking place indicates that this region was beyond Spanish control, which means it remained virtually impossible that as Castaño de Sosa moved across this region, he truly found native groups who had submitted to Spanish authority. Notwithstanding, the Castaño de Sosa report contains many references to encounters with indigenous groups that were mostly friendly but turned hostile once he reached modern-day Santa Fe [Castaño de Sosa 2004].

The last Spanish chronicle consulted discusses the travels of two Franciscan friars, Francisco Domínguez and Silvestre Vélez de Escalante, who set out from Santa Fe, New Mexico in 1776 to open a route to Monterey, California. Thanks to Father Escalante's chronicling of the expedition, their attempt to link New Mexico with the Pacific coast could be considered a final point in the cycle of Spanish conquest and exploration of North America. Many U.S.-Mexico Borderlands scholars view the content of this record as an important contribution to knowledge on the Pueblo Indians and Hispanic life in the present-day U.S. Southwest. The Domínguez-Escalante *Derrotero* y *diario* (route and diary) consists of documents not the least important of which is Father Escalante's report (Vélez de Escalante and Domínguez 1777).[12] Among the supporting documents in the archive is a 16-page analysis by Juan Augustín Morfí of the contents of the *Derrotero y diario* and its general relevance to the entire Spanish enterprise of conquest and discovery. Because Morfí's analysis represents a consolidation of views held by authorities and scholars of the late-eighteenth century, it is revealing in terms of Spanish perceptions of European-Native encounters and views of a continuously ambiguous frontier region. Morfí is also known in the Borderlands for his work on the history of Texas, completed as part of the Teodore de Croix inspection (1777).[13] The contents of Morfí's comments are significant because they reveal a number

of considerations. Firstly, as late as the end of the eighteenth century, communication between New Mexico and "old" Mexico was limited meaning the colonial seat at Santa Fe functioned in relative isolation. Morfi also writes that of all the indigenous groups in America (North, Central and South), the only ones to have actually declared "war" with the Spanish are the Apaches and Comanches in the north. This is significant because, if true, the fact highlights a great difference between the northern and other frontier-regions in Spanish America. Finally, his writings highlight that Native Americans were far from monolithic and their inter-relationships were as much a balancing act between themselves and their distinct cultures as their experiences with the Spanish. Morfi's work also gives us a more concrete view of how the Spanish crown thought to delimit its boundaries, following geographic landmarks such as the Colorado River and the Red River. The urgency to label, define and delimit was sparked by French incursions in Texas and Louisiana, and Russian and British explorers in the Upper Pacific Northwest. Father Morfí's analysis of the Domínguez-Escalante diaries serves as an excellent bookend to the reading of these chronicles because it truly represents an end to the cycles of conquest and discovery. Subsequent writers would increasingly address military and political considerations rather than the raw nature of the region, taking for granted that Spain had imprinted itself on the land and its people.

In terms of what might have been said or written from the perspective of Native America during this early period, precious little survives. One source may be found in the documents of the Juan de Oñate expedition which ended with a pogrom against the Ácoma Pueblo in 1599. The details of this event have been well researched, most notably by historians such Marc Simmons (1993) as well as H.H. Bancroft (1889), G. Hammond and A. Rey (1953). An official enquiry into the reports of atrocities committed during the pogrom reached Mexico and Spain, leading to the trials, subsequent conviction, and banishment of Oñate from New Mexico. These records include statements from numerous eyewitnesses including natives of central Mexico who traveled with Oñate and a number of Ácoma.[14] For example, a native from Tlatenango in the present-day state of Puebla is reported to have companied Oñate to New Mexcio.

In the wake of the Pueblo Revolt, the Spanish, along with 317 Tiwas, retreated to Paso del Norte, leading to the establishment of Nuestra Señora de Corpus Christie mission and the first significant populating of present day C. Juárez, Chihuahua — El Paso, Texas.[15] John Kessell (1989) writes that the news of the Pueblo success against the Spanish encouraged other groups to test their possibilities. Although never brought to fruition, the rumblings of a revolt at Paso del Norte precipitated an enquiry into the plotting of a rebellion, which is another source of the Native voice.[16] The significance of this enquiry is the fact that whilst the Northern Pueblo were enjoying a long decade of cultural renaissance, the Southern Pueblo remained under Spanish control, albeit by choice given that they retreated with them to Paso del Norte. Still, this fact did not constitute a complete acquiesce to Spanish rule. In segments of testimony from the trails we read that the governor of the Tigua and his lieutenant, as well as representatives from the Piros, were called before a tribunal presided over by Domingo Jirona de Cruzate, governor and captain general of the Spanish at Yselta. The testimony begins by stating that the governor of the Tigua, his lieutenant, and two Piro Indians were brought before the tribunal to give testimony. We also learn that Manos Indians, already Christianized, are also in the area and friendly with the two other groups. One of the Piros, Ventura, understands the Manso language, thereby allowing the Piros and Tiguas to communicate about a potential uprising. In another interesting and very relevant segment in the testimony, we read of the inter-marriages. The point here, without reading too much into the primary texts, is that at every moment some form of individual cultural contact was taking place, whether this occurred intra- or extra-tribally, is to some extent unimportant. However, we can see that Pueblo, Piro, Manso, Apache, and others interacted with each other as well as with the Spanish.

The work of Joe Sando,[17] a native of the present-day Jemez Pueblo,[18] explains that considerable differences existed between and within native groups. He maintains that the Pueblo underwent fewer fundamental changes than other tribes who were subjected to forced relocation and even complete destruction. This perseverance is attributed by Sando to an attitude of "accommodation" toward European cultures. Of course, this notion of "accommodation" is of great interest to this research because it suggests that beyond individual encounters or interactions, a broader strategy existed within the Pueblo that permitted the emergence of a cultural cohesiveness.[19] Another highly regarded Pueblo scholar, Alfonso Alex Ortiz, a member of the modern-day San Juan Pueblo, writing in 1994, frames the question of Pueblo culture in a more fundamental way: He asks if it makes sense to lump the Pueblos together in one group [Ortiz

1994, 296].[20] "Does the term Pueblo, or Indian for that matter, truly represent the relative or is it an artificial construct developed by the Spaniards and perpetuated by later historians, anthropologists and the like?" This, Ortiz maintains, is the fundamental question at the heart of whether or not a "Pueblo" culture survives. That is, do the "Pueblo" themselves know if they are different from other groups they know or have known? Ortiz writes that he believes it can be demonstrated that the Pueblo people have believed themselves to share a common culture despite linguistic differences. In other words, their cultural cohesiveness is not based on language as is often considered key to this notion. Ortiz offers that there is no single institution that unifies the groups over the past 2,000 years [Ortiz 1994, 297]. However, a non-social structural and non-cultural factor is shared by all surviving Pueblos, and as Sando also noted, the Pueblo have never been displaced from their homeland. It is the sense of place that predominates and unifies the Pueblos [Ortiz 1994, 297]. He writes that the Pueblo had a long history of contact well before the arrival of the Spanish, much of which is only subject to conjecture in modern day research [Ortiz 1994, 298]. There is a broad history of cross-cultural contact between the groups that encompasses material trade in food, wares, and clothing, religious contact, and repeated contact such that the Pueblo tribes have, "touched each other's lives in the most fundamental of ways" [Ortiz 1994, 299]. Furthermore, the network of contacts extended into Meso-America. The experience with Coronado later served as a learning tool for future generations of Pueblos. Specifically, Ortiz writes that taking refuge in the ancestral mountains was known to happen on many occasions during the Spanish period and helped the groups survive [Ortiz 1994, 300]. He offers as examples the fact that the Tewa fled to the Hopi and the Jemez to the Navajo.

With the writings of Alfonso Ortiz and Joe Sando, this research can formulate a more general picture of the Pueblo view of first encounters and ongoing contacts. Clearly, there were misunderstandings in terms of signals and their meanings despite the best effort of the Spanish to use non-Pueblo translators to infer and imply significance. It is clear that the pattern of individual and group contact resulted in exchanges that in turn resulted in cultural modifications, the extent of which is contentious at best. Nevertheless, we see that there is an element of ambivalence in the Pueblo view of their contact with the Spanish. For example, Ortiz in particular expresses animosity toward the European intrusion and its consequences for Pueblo life; however, he also notes that accommodation was instrumental to their resilience. Sando appears less reticent in his observations on the Spanish impact on natives, in general. Both agree that Native groups interacted with each other on a number of levels and that the Spanish and other European groups were not the only cultural factors influencing their way of life. It is interesting to note that neither author underscores the presence of Tlacaltecans, México, nor other groups from the south as particularly influential; rather they are clear that regional contacts with each other and tribes from the Great Plains were more significant. 20

We believe we have gleaned data from these texts on individual choices about self-identification as well as cultural group formation. We take the view that the literary record contains information about individual decision-making and that aggregations of these decisions are an appropriate analogy for cultural beginnings, transformations, and advancements that can be used to explore how behaviors lead to more complex systems such as culture. In this regard, our reading of the text has given us an idea of the individuals who participated in the cultural system, and the types of rules that governed their behaviors. 21

Agent-Based Modeling for the Humanities

The process of self-identification contained in the chronicles is based on rules governing individual action within a context and includes a number of aspects, among them decision-making. We focus our efforts on decision-making because it is particularly well-suited to computer coding easily translatable to mathematics. Table 1 presents examples of text-based references identified as behaviors manifested by Spanish and Pueblo individuals upon contact. These references were translated into a format more appropriate for game theory (GT), which is nothing more than a mathematical expression of different people interacting with each other, sometimes cooperatively, and other times in competition with each other, but certainly expressing both potential behaviors to varying degrees. John Holland notes, games, strategies, payoffs and other scientific metaphors are characterized by rules that are more readily converted to "mathematical" analysis [Holland 1998]. He also stresses that this process is not absolute, in and of itself; however, the decisions of the two individuals is important within the context of other simultaneous decision-makers such that a blending of players' mutual and conflicting interests makes the combination of multi-agent simulation and GT interesting 22

for this research. While this world of games and their mathematical expression exhibits some explanatory powers, the important point is that a wide variety of outcomes may be considered. Furthermore, the human behaviors modeled take place outside a market construct: In other words, rather than using a market, pricing model, and utility theory, game theory centers on strategies and choices.

Source	Interpretation	Choice/Strategy
Juan Jaramillo's Relación		
" *..un camino todo poblado y en paz…* "	Already intermixing	Cooperate always
Pedro de Castañeda		
" *…diciendo que un hombre le había forzado a su mujer…* "	Violent encounter	Defect
Gaspar Castaño de Sosa		
" *…y dos días antes, vino a la dicha villa, un indio, llamado Miguel…* "	Friendly encounter	Cooperate
Analysis of Juan Morfí		
" *Los Tarahumaras y algunos otros cuando quieren reducir el de la obediencia hallan la misma protección en los Navajos y Lipánes.* "	Inter-tribal cooperation	Cooperate
Ácoma trials		
Al ser preguntado por qué este confesante y los demás indios de su pueblo mataron al dicho [maestro] de campo y a otros diez españoles y a dos [chicos], dijo que los dichos españoles hirieron a un indio del pueblo y que por esto se enojaron y los mataron.	Violent encounter	Defect
Joe Sando		
"…an attitude of 'accommodation' toward European cultures…"		Cooperate
Alfonso Ortiz		
"…the Pueblo tribes have, 'touched each other's lives in the most fundamental of ways.' "	Tolerance for ideas	Cooperate
Ysleta del Sur		
" *…pues los dichos Pedro y Ventura eran de nación Piros y los indios todos eran uno, y eran sus amigos los Tiguas del pueblo de la Isleta, les fueron a hablar y a convocarlos para que todos juntos ejecutasen…* "	Inter-tribal competition	Cooperate

Table 1. Table 1 - Select Text Analysis, Encounter, and Choice/Strategy

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Instead of counting the number of passages in which an encounter between Spanish and Native American was mentioned, we translated passages into game theory and computer code for multi-agent simulation. Table 1 also presents a short list of interpretations and translations of behaviors for encoding. The artificial world of ABMs allows us to imagine a virtual space in which individuals have a limited number of choices, fulfilling one of the fundamental criteria of complexity — that a limited set of simple rules govern individual behavior [Aschenwald 2002].
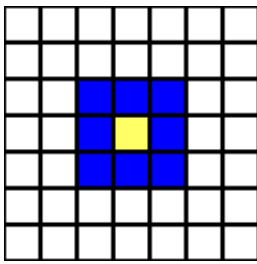
Figure 1. Panel A: Typical cellular automata grid and visualization after computational instructions. This first image is a typical grid with one yellow cell encircled by eight blue neighboring cells. Source: *Introduction to the Theory of Cellular Automata and One-Dimensional Traffic Simulation* [Cochinos 2000].
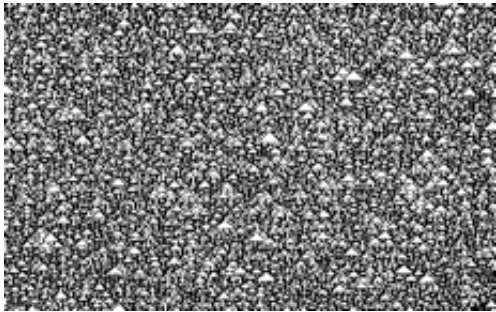

Figure 2. Panel B: Typical cellular automata grid and visualization after computational instructions. This second image represents a transformation of cells based on a set of instructions by Richard Cochinos. Source: *Introduction to the Theory of Cellular Automata and One-Dimensional Traffic Simulation* [Cochinos 2000].

The cellular automata model is a common ABM because it incorporates numerous individuals.[22] Each cell represents an individual — referred to as agents — that resides on a grid in a certain state, chosen from a small number of clearly defined possible states, such as "on"/"off" or "alive"/"dead." The visualization (see Figures 1 and 2) is similar to a sheet of graph paper of arbitrary size, dimension, and geometry with a certain (randomized) initial setting. In a dynamic model, the future state of each agent is determined by its current state as well as the current states of its neighbors. This is important in complexity because the context of each individual influences his or her state. In Figure 1 we see one yellow cell surrounded by eight blue cells. This is understood as an individual surrounded by eight other individuals. In the simulations, the yellow cell selects one of its eight neighbors and communicates information based on a set of rules that are uniform for all cells [Cochinos 2000, 41].[23] The outcome of the information exchange is conditioned on the status of one or more of its neighbors.[24] In this way, the model is set such that the rules governing an individual's behavior may be simple, but the outcomes of each encounter by pairs of individuals when aggregated may become very complex, as shown in Figure 2.

Game theory figures into the simulations when individual actions are expressed in terms of choices based on a decision strategy. A number of researchers ([Page and Bednar 2007], [Boyd and Richerson 2005], [Axelrod and Hammond 2006]) have sought to understand phenomena such as culture through the lens of complexity . In these and other works some form of game theory and complexity have been combined. We are following their research models by opting to use decision-making strategies as proxies for cultural attitude, as these lend themselves to encoding. This means individuals of a particular culture possess a common attitude toward members of their own as well as toward other cultures. The result of each encounter between individuals can subsequently be expressed as a payout (cost or benefit). For example, two individuals — **A**1 and **A** — encounter each other. As they are pre-programmed with a behavior because of their culture, they identify the other based on a notion of self and make a decision to interact or not, as the case may be. This interaction is termed cooperate (C) or not cooperate (D). In code, this cooperate situation would be expressed as CC if both individuals cooperate. When one of the two differs, CD and DC are the possible combinations. In the case of both refusing to cooperate with each other, this produces DD. Table 2 lists the possible behaviors of each individual, and Table 3 translates these into coded outcomes.

Table 2	Types of Behaviors Possible
Always Cooperate	Individual always cooperates
Alternate	Individual alternates behavior no matter what experience
Tit-for-tat	Individual alternates depending on previous experience
Grudger	Individual begins with cooperate and defects
Always Defect	Defect agent always changes strategy

Table 2.

Table 3	Coded Outcomes
CC	Both Cooperate A1 and A2
CD	Agent A1 cooperates, Agent A2 does not
DC	Agent A2 cooperates, Agent A1 does not
DD	Agents never cooperate

Table 3.

What does each individual gain from each encounter? In our view, interactions between individuals do not simply end with a code. We have taken the position that individuals are impacted by contact since it involves an exchange of information. This requires additional thought on possible outcomes. As noted above, other researchers have used biological notions such as reproductive capabilities or life spans as features of social systems. This, we thought, would help incorporate a dynamic population that might approximate the Borderlands. Consequently, when the encounters resulted in an outcome of C, the ability to reproduce of an individual improves. On the other hand when the encounter generates a D, the individual and consequently the population experiences a decline in reproductive opportunities; stated another way: the possibility of death increases for any individual in the entire population.

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More importantly, as we are interested in showing that encounters between individuals of different cultures can impact on individual perceptions of self, we translated this into "tolerance," here defined based on how each individual views his or her neighbor in terms of self. The idea is that a member of a cultural group has a predefined notion of self, but this may change as members of other cultures are encountered or even as members of own-culture who have experienced outsiders are encountered. In this way, we have attempted to incorporate the notion of self as one of perception and the question of cultural group membership as a question of scale or granularity from the perspective of the observer. This means that on one level there are the inter- and intra-cultural interactions, represented by individual agents and their interactions with each other. On another level, there is the cultural whole operating within a larger system of multiple cultures. The vision from above is one in which large cultural complexes can be seen as different, but from below, there is individual as well as subgroup-level diversity. As a general rule, we have taken the position that an individual's tolerance for difference improves with positive encounters (C) with members of a different culture group. Conversely, an in encounter that produces a negative experience (D), the individual with D becomes more intolerant. The degree to which these changes take place are predetermined by the researcher. Referring back to Figure 1, we see that each individual cell has eight neighbors, and each of the other neighbors has eight neighbors. In other words, each pair of individuals is part of a larger system of pairs of individuals who are simultaneously making decisions based on their culture. However, because the process of decision-making is iterative and takes place simultaneously over multitudes of pairs of individuals, notions of self can change, and when they do, the summation of these individual interactions generates a group-level dynamic from which additional cultural groups emerge.

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We tested our ideas on group-level diversity using an ABM titled Borderlands5 in which the landscape is represented as a two-dimensional finite grid with each cell "alive" (color) or "dead" (black).[25] Individuals may be alone or belong to groups (differentiated by color) meant to simulate the sharing of common characteristics. An important feature of our model is the fact that individuals are immobile, that is they do not move from the cell to which they have been assigned, but they will interact with one of the individuals occupying a neighboring cell (out of eight possible) giving the illusion of movement. Each original individual is born into the landscape with a culture that is represented by one color (vector). Each color corresponds to a decision-making strategy to be used when encountering an individual or culture. All

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individuals of the world work simultaneously over time, measured in terms of ticks of the ABM clock. Additionally, all individuals follow the rules of the world in a synchronous manner and modify their individual parameters accordingly. The process is as follows:

1. At any given step in time (or tick of the clock), a cell will randomly select one of its neighbors, forming a pair.
2. The two individuals decide to cooperate or not based on a pre-determined approach (culture group membership).
3. Depending on the outcome of the decision because another individual is involved, a number of additional variables adjust in order to capture a population-wide impact or outcome.

Our actual focus is self-identification, consequently the agent does not move rather she perceives what is happening around her. In our experiment, self-identification is not static rather it is subject to change based on a change in "tolerance." In Borderlands5 this factor is designed to approximate the process of self-identification based on cultural similarity. Tolerance is expressed as a value between zero (0) and (1) and is set by the researcher such that it may be very strictly defined or very flexible. In the best-case scenario, if both sides cooperate, both sides become more tolerant. In the worst-case scenario, neither is tolerant, and no one cooperates. In the two intermediate positions (A1 cooperates but A2 does not, *vice versa*) either Individual A1 or A2 will receive a positive benefit from cooperative behavior despite the fact that the other is uncooperative. At the beginning of the simulation, all individuals have a tolerance level of zero (0), although this changes as the model progresses. Zero tolerance means that there is no opportunity for cooperation based on similarity — agents must be exactly alike. When the tolerance level is increased (tolerance > 0.0) cooperative behavior extends beyond those agents who are exactly alike to everyone who is the same. If the tolerance level is pushed to the other extreme (0), everyone is intolerant of all other agents and chaos ensues; each individual sees herself as unique. As long as individuals A1 and A2 determine that the color of the other is less than the pre-set tolerance factor, each individual recognizes the other as from the "same" culture and implements a strategy that corresponds to interactions with somebody of the "same" culture. On the other hand, if the distance is greater than stipulated by the system, an alternative strategy will be played. It is important to note that if one of the individuals is more tolerant than the other, it can transpire that one individual "interprets" that both are of the same culture, while the other "interprets" that the cultures are different. This is ambiguous yes, but it is this unexplained phenomenon that permits individuals to possess a more fluid self-identity within limits. By setting up the model as described, we are conforming to the guidelines of complexity, that a limited number of rules govern individual action and impact on a small number of parameters. And yet, there is a broader context that is capture by population-wide factors.
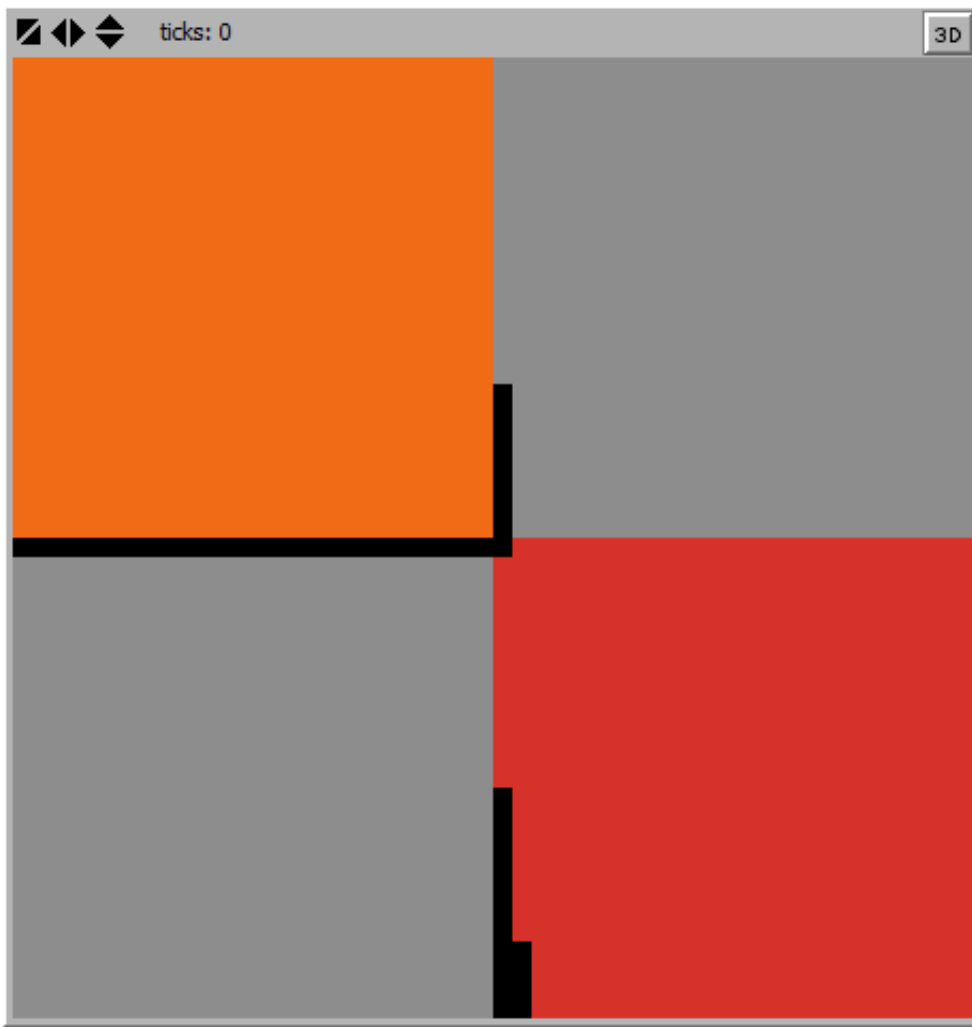
Figure 3. Borderlands5 — Panel A: This panel shows the three cultures with clearly demarcated boundaries.

Figure 4. Panel B: This panel shows the same population covering only 50 percent of the available space.

In Borderlands5 we created a world with three cultures each occupying a different location in the space; however, the total population does not exceed 50 percent of available cells. We have deliberately created several "borders" between groups (see Figures 3 and 4). These are meant to simulate distinct separations between groups such as physical barriers — rivers or mountains. What does this all mean? In our abstraction, we are visualizing three cultural groups one of whom is Spanish and the other two distinct Native American groups — one larger than the other. These cultures possess cultural attributes expressed as strategies. The largest of the Native American groups will always alternate strategies as they encounter members of the two smaller groups. One of the smaller groups will always operate with the largest group (say a Spanish behavior), and the other will only use an alternating strategy with the smaller group (say Native-Spanish ambivalence). Each member of a cultural group always cooperates with those identified as from the same culture. This is one of our interpretations of how first and ongoing contact might have taken place between the Spanish and Native Americans.
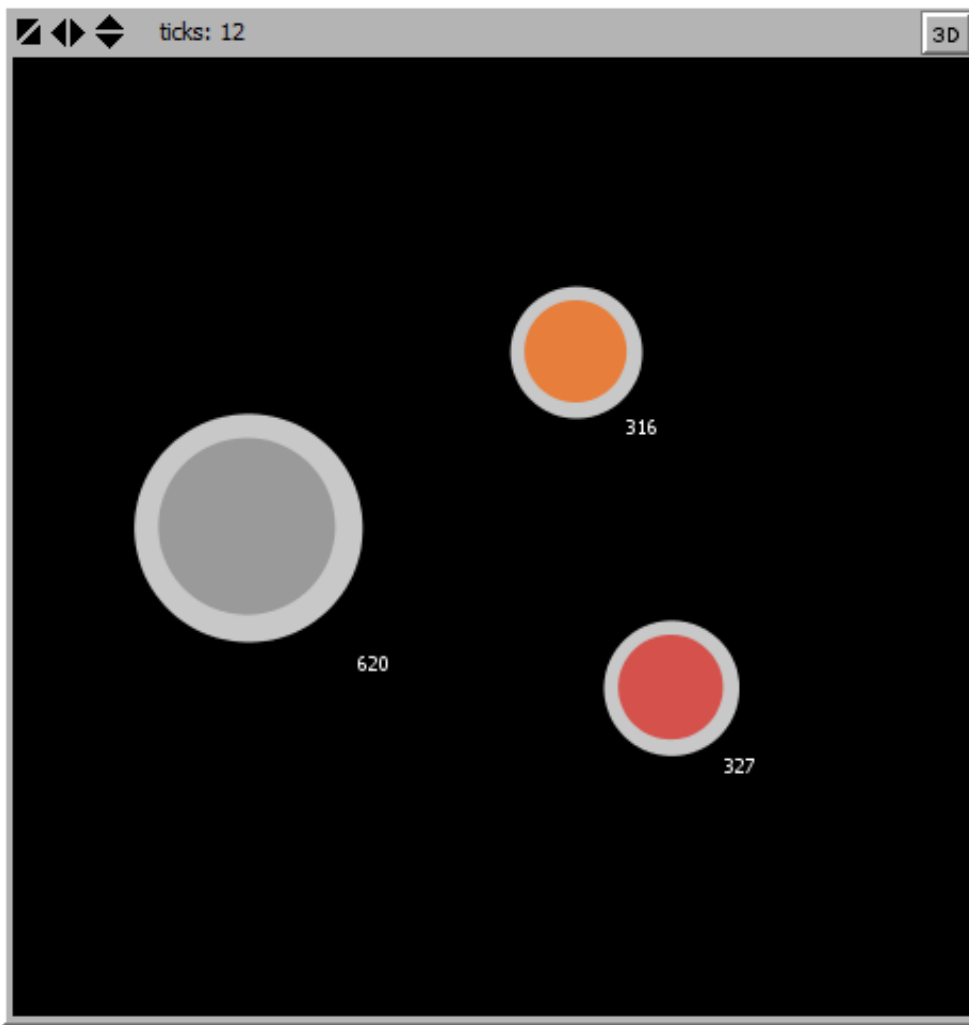
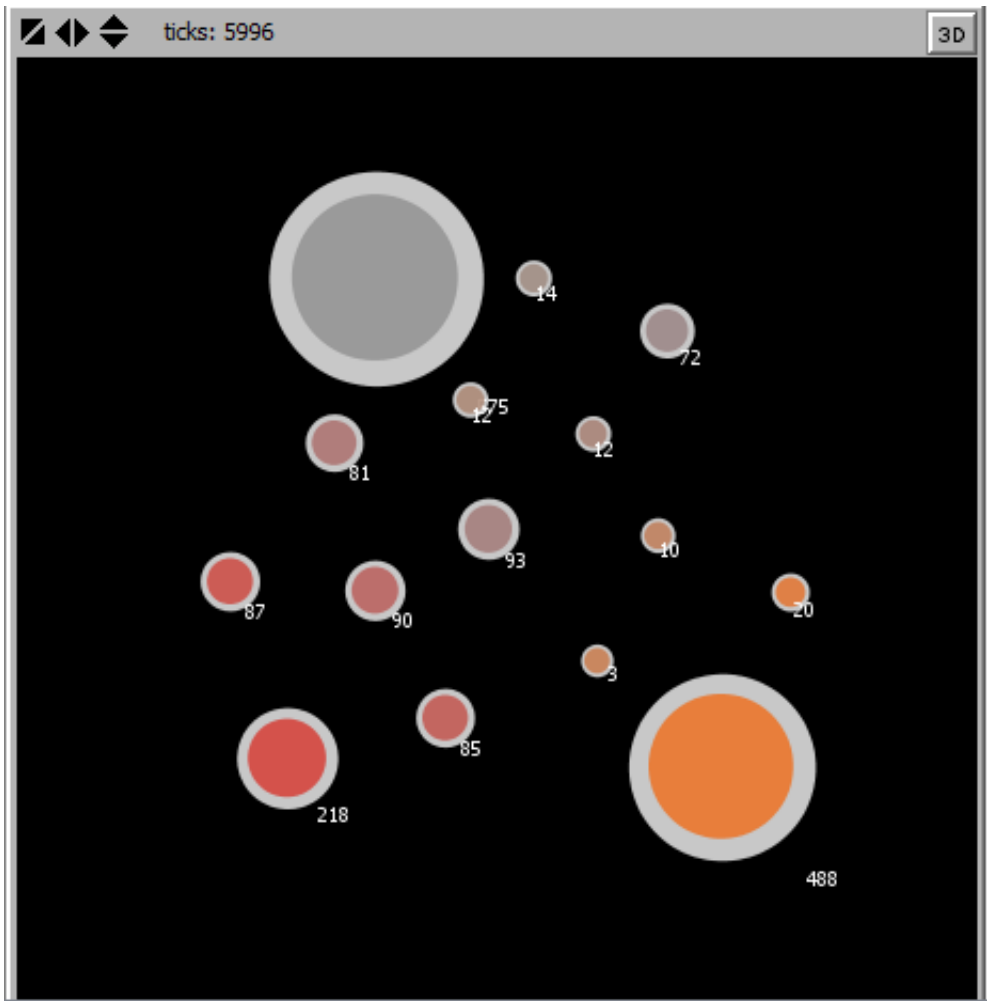**Figure 5.** Panel A - Initial Groups for Borderlands5
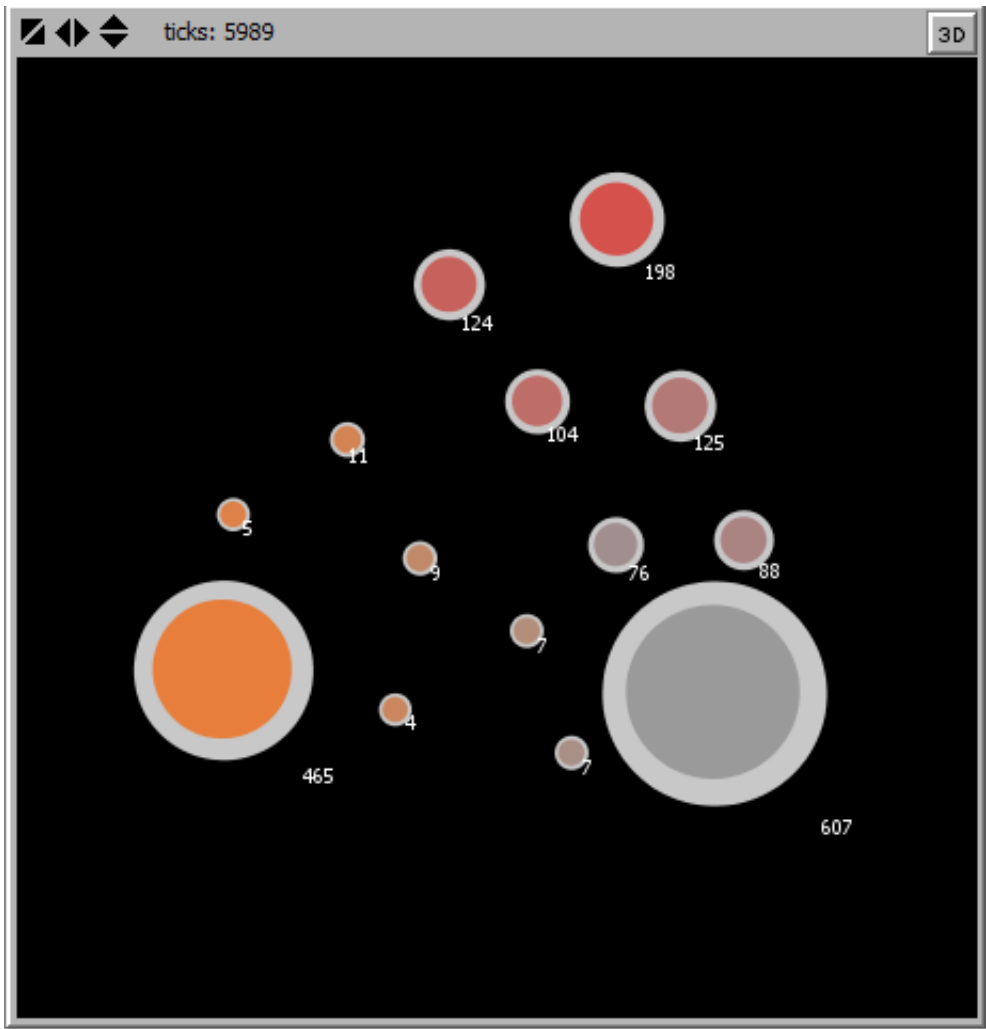
Figure 6. Panel B - 50% Population Density
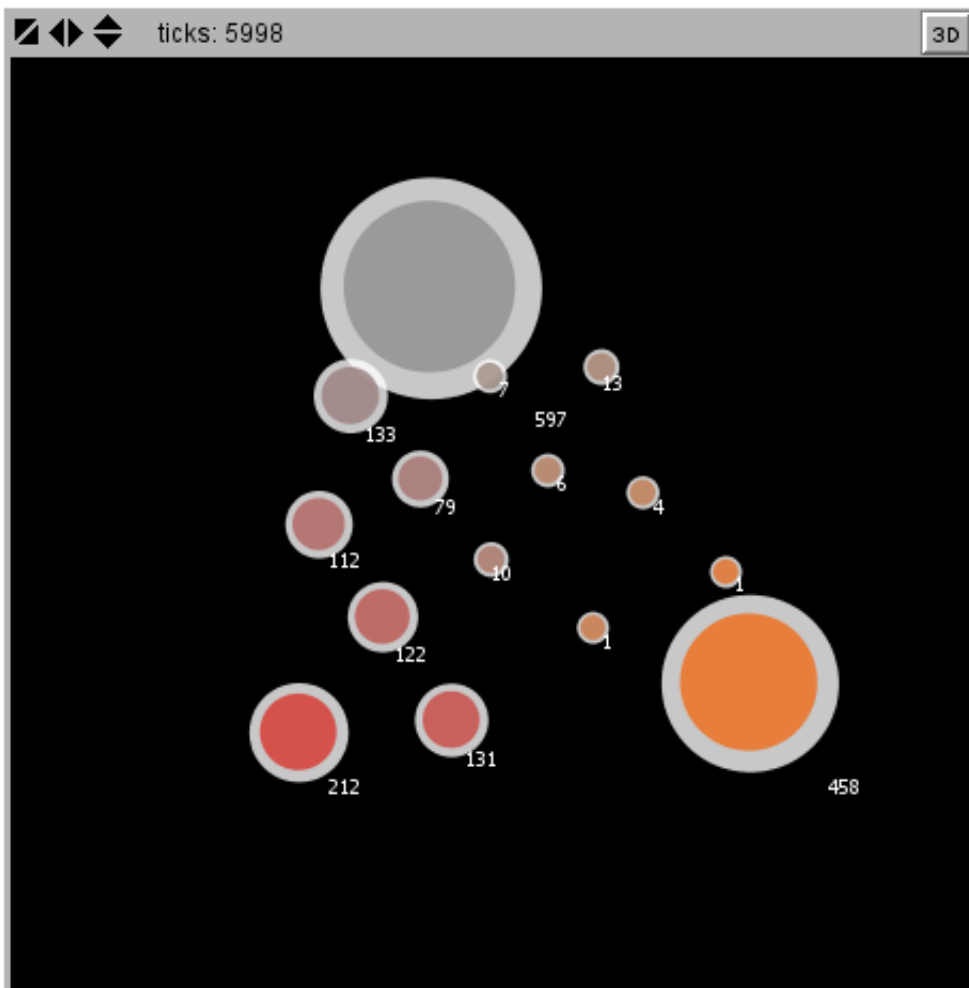
Figure 7. Panel C - 25% Population Density

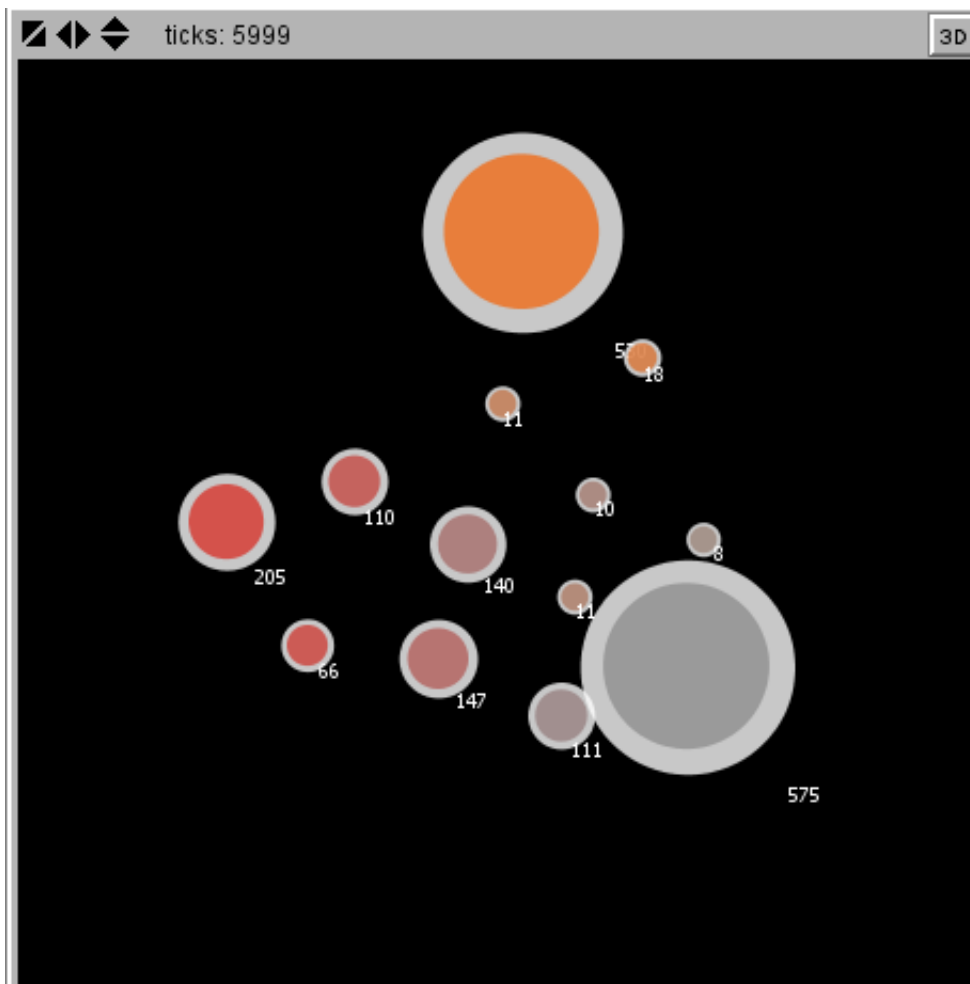**Figure 8.** Panel D - 75% Population Density

Figure 9. Panel E - 100% Population Density

Since our interest is the group-level experience, we grouped the individual cells in Figure 4 along color lines. Our baseline was the initial setting as seen in Figure 5. The images that follow (Figures 7 through 9) show how the original three groups have evolved over time, giving rise to additional groups — that a far more complex system of identities. The passage of time was simulated by allowing our model to run for a period of 6,000 ticks of the ABM clock (in our imagination something akin to 500 years). The initial settings were not altered except in one specific way — density of population. This means that in a series of experiments, we altered the number of active cells along the following lines 25%, 50%, 75%, and 100%. Our intent was to explore in greater detail the role of population density in group formation. These variations were run 20 times in each case and results were essentially the same: an average of 10–11 new groups emerged from the initial settings governing individual actions. This is interesting to the extent that it suggests that population density may not be a determining factor in cultural group formation, rather the key component may be individual cooperative or uncooperative behavior. Whether or not this outcome reflects reality requires additional testing by us as well as researchers who might be interested in this methodology and process. Notwithstanding, the fact that our model does not actually incorporate geography possible thorough the use of digitized topography maps, does not invalidate our findings. Rather, we would like to suggest that self-identification contributes to group formation not only on land but may also be the case in cyberspace. In which case, our research only leads to more questions and applications.

Conclusions

We have used literary studies as a broad guideline for translating historical texts into an agent-based modeling experiment on a small aspect of culture — how it might evolve over time into a diverse and complex system. The individual actors we have read about in the accounts of Spanish conquistadors and Native Americans have been

transformed into computer-based agents operating in a virtual world. Their individual attributes have become colors, and each interacts using a game in which their decisions center on cooperation; that is, the choices are presented as a form of game theory in which any one individual may defect or cooperate with the outcome impacting on the tolerance of other cultures as well as their ability to reproduce. In other words, we have created an interdisciplinary view of culture: one that involves humanities, complexity and computational technology.

We have used a great deal of imagination and creativity in our research — virtual studies require this of the researcher. And although there are limitations, we can see that culture may be visualized and studied in this new environment. That is to say, a humanistic background does not preclude researchers from attempting to use the latest technology to explore ideas common to the humanities. However, it does require that we consider how our ideas translate into methods outside our disciplinary boundaries. In this case we have used complexity science in conjunction with text analysis as methodological approach for studying the intricacies of human interactions. This is a bottom-up approach that focuses on the interactions of individuals and their role in generating larger and more complex structures that cannot be predicted in a linear fashion from the characteristics of the individual actors. Furthermore, we have shown how a small set of simple ideas can lead to a broader outcome. This is at the very heart of complexity and agent-based modeling. Our research suggests that this methodology introduces some interesting benefits for the study of culture and its emergence and transformation over time; however, much of this exploration is taking place outside the humanities.

Appendix 1

Source	Interpretation	Choice/Strategy
Juan Jaramillo's Relación		
" *..un camino todo poblado y en paz…* "	Already intermixing	Cooperate always
" *… aquí vimos un indio y dos que parecieron ser después de la primera población…* "	Sighting	
" *... todos estos indios….nos recibieron bien* "	Already intermixing	Cooperate always
Pedro de Castañeda		
..parecía en otro tiempo haber sido casa fuerte en tiempo que fue poblada y bien se conocía ser hecha por gentes extranjeras políticas y guerreras venidas de lejos …	Inter-tribal warfare/politics	Grudger
" *…en lugar de poblados, hallar grandes despoblados, y en lugar de ciudades populosas, hallar pueblos de doscientos vecinos y el mayor de ochocientos o mil;* "	groupings of natives	group vector
" *…diciendo que un hombre le había forzado a su mujer…* "	Violent encounter	Grudger
" *…hubo lugar que las lenguas hablasen con ellos y se les hiciese requerimientos por ser gente bien entendida…* "	Linguistic contact - interpreter	Cooperative
" *…otro día fue Don Garcia López de Cárdenas a ver los pueblos y tomar de ellos lengua* "	Linguistic contact - interpreter	Cooperative
Gaspar Castaño de Sosa		
" *…y dos días antes, vino a la dicha villa, un indio, llamado Miguel…* "	Friendly encounter	Cooperate
" *… y que dio, acabo de tres días, con muy gran cantidad de gente de nación despeguen, el cual fue de ellos muy bien recibido…* "	Grouping of natives, friendly	Cooperate
" *…no dio lengua ninguna, de muchas que llevaba, que le entendiesen persona…* "	Linguistic contact - Interpreter	Cooperate
" *…quedó el dicho Joan de Vega, indio; y visto que quedaba solo, asieron del algunos indios, y lo echaron en el río y le quitaron unas amarras, y le dieron tres flechazos…* "	Violent encounter - Natives	Defect
Analysis of Juan Morfí		

" *Los Tarahumaras y algunos otros cuando quieren reducir el de la obediencia hallan la misma protección en los Navajos y Lipánes.* "	Inter-tribal cooperation	Cooperate
" *Y no es increíble que algunos Comanches, de los que se califica más fieles, se empeñasen, por algún premio, en acompañar a la expedición, en calidad de guías, mientras sus Parientes se ocupan en la guerra.* "	Tribe joins Spanish	Defect
Ácoma trials		
" *En este dicho día luego incontinente el dicho señor gobernador hizo [presentarse] ante si a un indio que mediante el dicho intérprete dijo llamarse Caucachi.* "	Linguistic contact - interpreter	Cooperate
Al ser preguntado por qué este confesante y los demás indios de su pueblo mataron al dicho [maestro] de campo y a otros diez españoles y a dos [chicos], dijo que los dichos españoles hirieron a un indio del pueblo y que por esto se enojaron y los mataron.	Violent encounter	Defect
Joe Sando		
"Thus, the Pueblos have common elements, but are distinctive entities in their own right"	Cultural Unity/Differentiation	Tit-for-tat
"…an attitude of 'accommodation' toward European cultures…"		Cooperate
"…the writings of Bartolomé de las Casas and Francisco de Vitoria, were responsible for a change in Spanish attitudes after the re-conquest of New Mexico in the 1690s. He suggests that their writings lead to a policy of mutual accommodation…"	Tolerance or accomodation	Cooperate
Alfonso Ortiz		
"Ortiz writes that he believes it can be demonstrated that the Pueblo people have believed themselves to share a common culture despite linguistic differences."	Cultural Unity/Differentiation	Tit-for-tat
"…the Pueblo tribes have, 'touched each other's lives in the most fundamental of ways.' "	Tolerance for ideas	Cooperate
"…the Pueblo tribes have, 'touched each other's lives in the most fundamental of ways.' "	Tolerance for ideas	Cooperate
Ysleta del Sur		
" *…pues los dichos Pedro y Ventura eran de nación Piros y los indios todos eran uno, y eran sus amigos los Tiguas del pueblo de la Isleta, les fueron a hablar y a convocarlos para que todos juntos ejecutasen…* "	Inter-tribal competition	Cooperate

Table 4. Table 1 - Extended Text Analysis, Encounter, and Choice/Strategy

Notes

[1] E. Slingerland suggests the humanities have much to offer natural sciences as discoveries possess new challenges to our understanding of us, each other, and life [Slingerland 2008]. He also writes that the humanities can benefit from science such that the two may be integrated. Human experiences are part of human existence and must be studied as an integrated whole. Consequently, bringing the two branches of knowledge together is a goal of this interdisciplinary work.

[2] Taken from *MIT Encyclopedia of Cognitive Sciences*, ed. Robert A. Wilson and Frank Keil. Boston, MA, MIT Press, 2001, p. 120. This definition is attributed to the goals of cognitive anthropology.

[3] Determining how an individual came to recognize the need or the ability to dominate the external world is not the purpose of this work *per se*. However, the idea that a group-level behavior such as "culture" emerged from individual decisions, is the foundation. In order to pursue this line of investigation, an interdisciplinary approach is needed. Therefore, extensive use is made of concepts normally found in the natural, social, and computational sciences, in order to study the emergence of a specific culture — in this case a cultural system labeled Hispanic.

[4] Whilst for Dan Sperber and Nicolas Claidière, culture spreads like an addiction through individuals, but the transmission mechanism of

cultural information is more akin to that of epidemiology (virus) instead of natural selection [Sperber and Claidière 2006].

[5] He also notes that, "The state of a culture at a given moment corresponds to the distribution of variants resulting from these micro-events, and the evolution of culture is that of this distribution" [Sperber 2007].

[6] See [Insula 1999]. The entire volume contains analyses and commentaries on the crónicas, relaciones ,and other early colonial writings.

[7] In fact, in several secondary works the compendium of documents and detailed analysis may be found in [Vázquez Coronado 2004].

[8] Scant information is available on Juan Jaramillo, but [Flint and Flint 2012] offer similar observations to those found in [Thrapp 1991]=, as well as other works such as [Winship 2009], Herbert Eugene Bolton, George P. Hammond and Agapito Rey, as well as a relatively new entry in the *Cervantes Virtual Portal de la Cultural Chicana*.

[9] See Schroeder and Matson 1965. Schroeder and Matson include a complete English translation of the Alonso de Leon chapter on Castaño de Soso. According to this version Castaño de Sosa's "talents" were greatly esteemed by Governor Gomez Perez de las Marinas on the entrada to the Islanda of Moluccas [Schroeder and Matson 1965 , 9]. They write that Andres Perez de Verlanga's first hand account is the only known account of the expedition ([Alessio Robles 1978], [Chipman 1992], [Weddle 1985]). Luis Carvajal was considered one of the first to enter Texas from Mexico. He was also born in Portugal. He and his wife Guiomar de Ribera were Jews converted to Christianity. His wife was the daughter of a royal slave factor and originally from Lisbon. Archivo General de Indias, *Archivo General de Indias de Sevilla* (Madrid, 1958) (Duaine 1971, Toro 1944, Weddle and1985).

[10] See [Schroeder and Matson 1965]. See also [Obregón 1928].

[11] See [Bancroft 1889] and Dorothy Hulls' summary. Matson and Schroeder suggest that the journalist may have been Andres Perez, although they are not certain [Schroeder and Matson 1965 , 17]. Interestingly, they note that two Indians who remained with the Pueblo after Castaño de Sosa's case was remanded into the custody of Spain's representatives in 1593 also appear in the record regarding Juan de Oñate's activities in the region [Schroeder and Matson 1965 , 16].

[12] The copy utilized for this research was found at the Newberry Library in Chicago, Illinois.

[13] Among the publications that deal with this tour include *Diario y derrotero, 1777-1781, Compendio del diario del viaje a las Provincias Internas [de fray Juan Agustín Morfi]: Chihuahua, 26 abril 1778,* and *History of Texas, 1673-1779* [Morfí 1967]. For his diary and travel routes in digital format, see [Morfí 1967].

[14] Many thanks to the Research Center for Romance Studies, International and Area Studies, University of California, Berkeley; specifically, the generous help of Jerry R. Craddock, Director, who kindly offered electronic copies of the center's translation work which form part of the Cíbola Project. Quotes for this section were taken with permission from Jerry R. Craddock and John H. R. Polt (2008), specifically, as noted in the document, the paleographic transcription of the primary text, collation with the second text, and translation into English. This work is based on Archivo General de Indias, Patronato, legajo, 22, ramo 13, ff. 1036r-1085r (94r-143r); ff. 1086r-1131v.

[15] Tiwa is part of the Tanoan-Kiowa language grouping. The members of this tribe that retreated with the Spanish adopted Ysleta as part of their name rather than Isleta, which was the name of their original settlement near modern-day Albuquerque, New Mexico. Their modern name is Tigua.

[16] The documents associated with this case are entitled *Año de 1685 Numero 4 Autos sobre los socorros que pide [e]lgouernador de la Nueva Mexico y otras noticias tocant[es] a la subleuazion de los yndios bar[ba]-ros de aquella prouinzia y la mudanza del Puesto del Pa[so] [d]el Rio del Norte al de la Ysleta a ynstanzias y pedimentos de los vezinos y Padre Procurador Fray Nicolas Lopez, y la gente y demas socorros que pide para este efecto Testimonio sacado a la letra de los autos criminales que se fulminaron contra los mansos apostatas y sus aliados. Contiene quinze foxas escritas y una blanca. Año de 1684 años*.

[17] Joe S. Sando was born into the Sun Clan at Jemez Pueblo, New Mexico. He received his education at Eastern New Mexico University and Vanderbilt University. His career includes teaching Pueblo history at the University of New Mexico and ethnohistory at the Institute of American Indian Arts in Sante Fe. Currently, Sando is Director of Archives, Pueblo Indian Study and Research Center, at the Pueblo Cultural Center in Albuquerque, New Mexico. He also serves as consultant to the National Museum of Indian History in Washington, D.C.

[18] This pueblo was one of the largest at the time of first contact with the Coronado Expedition in 1541. The records of the Antonio de Espejo Expedition indicate that the populations might have been as much as 30,000 in 1583.

[19] He has published several volumes on the Pueblo including most recently, *Pueblo Nations: Eight Centuries of Pueblo Indian History* [Sando 1992], *Nee Hemish, A History of the Jemez Pueblo* [Sando 1982] and *The Pueblo Indians* [Sando 1976].

[20] Alfonso Alex Ortiz was born in San Juan Pueblo, New Mexico. He received his B.A. from the University of New Mexico in 1961 and his M.A. and Ph.D. from the University of Chicago in 1963 and 1967, respectively. Ortiz's career included assistant professor at Pitzer College, Claremont, California; professor, Princeton University, and professor of anthropology at the University of New Mexico. Ortiz's interests included contemporary Indian affairs, religion and society, and oral tradition. He also edited Native American writings. He was a Guggenheim Fellow, 1975–76; MacArthur Fellow, 1982–87; and awarded the Indian Achievement Award, 1982. His books include: *American Indian Myths and Legends* [Ortiz 1984], *New Perspectives on the Pueblos* [Ortiz 1972], *North American Indian Anthropology: essays on society and culture* [Ortiz 1994], and *The Tewa World: Space, Time, Being and Becoming in a Pueblo Society* (Ortiz 1969).

[21] An extended version of this table may be found in Appendix 1.

[22] Not included in this work are network-based models in which the relationship between entities is key. This method of complex system analysis identifies nodes and linkages between the nodes. The goal is to understand the interconnectedness of the nodes. Mitchell offers an excellent review of this process in Chapter 15 of her book. She cites the hyperlinks between web pages, a neural system, and social relationships as examples [Mitchell 2009, 234].

[23] John Conway's Game of Life is the most famous of simulations in this class. See [Cederman 2005].

[24] John von Neumann and Stanislaw Ulam (1940s) offered a model of life and self-reproduction.

[25] This modeling simulation was encoded with the close collaboration of Fernando Sancho Caparrini, University of Sevilla, Department of Computer Science and Artificial Intelligence. His work on this modeling project and others is part of a larger research project funded by the Canadian government to investigate the impact of the Hispanic Baroque as a cultural system, under the direction of Juan Luis Suárez, Professor of Spanish, Department of Modern Languages at the University of Western Ontario.

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