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Historical change, cultural learning, and cognitive representation in Zinacantec Maya children

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Abstract

Against the background of an unchanging sequence of representational development, we demonstrate that implicit processes of learning and cognition can change from one historical period to another. One generation of Zinacantec Maya children was studied in 1969 and 1970, the next generation in 1991 and 1993. In the intervening two decades, the community, located in Chiapas, Mexico, was involved in a transition from an economy based primarily on subsistence and agriculture to an economy based primarily on money and commerce. A naturalistic study of weaving apprenticeship and an experimental study of visual representation showed that the ecological transition was linked to greater emphasis on independent cultural learning, abstract representation, and innovation, and, correlatively, a movement away from scaffolded guidance, detail-oriented representation, and imitative representational strategies. These changes constituted automatic adaptations with an implicit nature. In addition, historical variability in implicit modes of cultural apprenticeship predicted shifts in implicit processes of child and adolescent cognition. In sum, socialization and development are not fixed but adapt, in a coordinated way, to changing ecological conditions.

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Keywords: Historical change; Cultural learning; Representation; Culture; Cognitive development; Apprenticeship

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1. Introduction

Cognition and learning are adapted to the ecological environment, including the economic system. Such adaptations tend to be implicit and automatic rather than explicit or deliberate. However, the ecological environment can change tremendously over time. Will cognitive development and processes of cultural apprenticeship undergo implicit change in response to long-term economic change? Despite strong theoretical interest in the historical dimension of development (Cole, 1996; Scribner, 1985; Vygotsky, 1978), longitudinal study of historical change in cognitive development and the informal education that produces it has been lacking. Our research began to fill this gap by exploring whether or not processes of cultural learning and cognitive representation show implicit adaptations to long-term change in the economic environment.

Our exploration was guided by a theory of two cultural models of informal education (Greenfield & Lave, 1982; cf. Edelstein, 1999). In this theory, each model of informal education is associated with a particular style of cognition, which, in turn, is adapted to a different economic system. The theory makes some specific predictions about how learning and cognition will adapt to changes from one economic system to another.

The first model is a culturally conservative one: Apprenticeship is highly guided by the master and opportunities for error are therefore limited. This model is strengthened when the cost of error is very high (Greenfield, 1984; Rogoff, 1990) and apprenticeship is product-oriented (Renshaw & Gardner, 1990). Because the master's guidance limits learner experimentation, opportunities to innovate are also limited, and the apprentice therefore acquires an array of skills with little change from the master's set of competencies. This model is well adapted to producing items that express a constant cultural tradition.

The second model is adapted to cultural innovation rather than cultural conservation (Greenfield & Lave, 1982). Instead of guidance by a master, the emphasis is on trial-and-error learning by the novice. The frequency of error of course increases, as does learner independence. Trial-and-error learning intrinsically involves experimentation; innovative processes and products are a natural consequence of experimentation. This model is strengthened when the cost of making an error is relatively low (Greenfield, 1984; Rogoff, 1990), for example, when materials are inexpensive and easily replaced. Under such circumstances one need not be as concerned about preventing error in the final product.

Theory and evidence link subsistence and agriculture to a conservative cultural model, on the one hand (Collier, 1990; Edelstein, 1983); they link money and commercial entrepreneurship to an innovative cultural model, on the other (Edelstein, 1983; Lerner, 1958; McClelland, 1961). If a community moves from agricultural subsistence to entrepreneurial commerce, will processes of cultural apprenticeship change from the conservative to the innovative model? This was the question that drove Study 1.

Some support for this model of social change already exists. Both anthropology and psychology have produced evidence that a movement from agriculture to commerce in the economic realm is linked to the development of a more independent psychology. One example comes from India: Seymour's long-term ethnography indicated that increasing commercialization is associated with patterns of socialization that produce more independent individuals (Seymour, 1999). Another example comes from Guatemala: comparing two Maya communities, Loucky (1976) found a greater emphasis on autonomy from the extended family and generally greater perceived internal locus of control in a community involved in commercial cottage industry, compared with one that engaged only in subsistence agriculture. A third example comes from the United States: In Iowa, Elder, King, and Conger (1996) used a cross-sectional design to assess the effects of the historical movement away from agriculture in Iowa; they found greater independence in those participants who had not become farmers.

The second major question asked what effect a movement away from agricultural subsistence towards entrepreneurial commerce would have on cognitive processes. Edelstein theorizes that movement from the concrete barter of a subsistence-based community to market exchange produces more abstract cognitive processes. He contrasts the "concrete exchange of goods" with the "abstract exchange of symbolic equivalents" (Edelstein, 1983, p. 58). As our study community moved from subsistence agriculture toward commerce and entrepreneurship, we expected a corresponding movement from more concrete to more abstract modes of representation. We also expected these shifts in representational style to occur against a background of a general, unchanging sequence of representational development. Study 2 tested these hypotheses.

With respect to the predicted shift in representational style, *cross-sectional* research designs for studying change have indicated that movement from subsistence to a money economy affects representational processes (Beach, 1995; Edelstein, 1983; Saxe, 1999). For example, Saxe (1999), working in Papua New Guinea, compared shopkeepers at the most commercial end of the spectrum with subsistence farmers at the other end; he found evidence for an increasingly abstract system for representing addition as a function of commercial involvement. In Study 2, we present the first *longitudinal* evidence for a shift from a concrete, conservative to an abstract, innovative mode of cognitive representation as a function of commercial involvement.

At the same time, ecological change from subsistence to commerce often involves increased schooling (Seymour, 1999). Formal education is, in turn, often associated with abstraction (for example Greenfield, Reich, & Olver, 1966). To what extent are any observed changes from concrete to abstract modes of representation linked to schooling? Not only going to school, but also having a school-educated mother were possible factors that could mediate between general ecological change and specific changes in cultural apprenticeship and cognitive representation (e.g., Laosa, 1978; Zukow, 1984). Our studies explored the relevance of maternal and child schooling as well.

Finally, our overall theoretical model posited a connection between modes of apprenticeship and modes of representation. We hypothesized that a more independent style of apprenticeship would be linked with an abstract representational style and skill in constructing novel representations. On the other side of the coin, we thought that a more interdependent style of cultural apprenticeship would be linked with a more concrete representational style and less skill in constructing novel representations. This hypothesis was explored by correlating results of Study 1 on weaving apprenticeship with results of Study 2 on cognitive representation.

2. Historical research design and study site

To study the impact of social change on cultural apprenticeship and cognitive development in a rigorous, controlled way requires a particular kind of longitudinal research design. One must compare the socialization practices of parents in one generation, under one set of ecological conditions, with the socialization practices of their grown children, under a new set of ecological conditions (Study 1). One must also compare the cognitive processes of one generation of children with the cognitive processes of that generation's own children, growing up in a different historical epoch (Study 2). Unlike a traditional longitudinal design, our historical design compares parents and their children, holding procedure and participant age constant, while varying the historical time period.

Our study site was Nabenchauk, a Zinacantec Maya community in Chiapas, Mexico. We studied the first generation in 1969 and 1970 (e.g., Childs & Greenfield, 1980; Greenfield, 1974; Greenfield, Brazelton, & Childs, 1989; Greenfield & Childs, 1977); we returned to collect comparable data on the second generation in 1991 and 1993. The intervening period from 1970 to 1991 witnessed the acceleration of an ongoing economic transformation from a more subsistence, agriculturally-based economy to a more money-oriented, commercial economy (Collier, 1990). Equally important, social change had been uneven. Some families had remained much more involved in agriculture; others were involved in a wide variety of commercial activity, both as entrepreneurs and as consumers. Although schooling opportunities were provided by the same two elementary schools at both periods, some families had a greater tradition of sending their children to school than did others. This variability in economic participation and schooling allowed us to test whether commercial participation and schooling might be tied to any observed historical change.

In both periods, our studies of apprenticeship and visual representation centered on the domain of weaving. Weaving was the centerpiece of girls' informal education in Zinacantán. (Zinacantec boys do not learn to weave.) Weaving also became part of commercial entrepreneurship in the 1990s. Girls and women began weaving and embroidering tourist items for sale to outsiders and producing subsistence

items for sale to other members of their community. At the earlier period, weaving was more exclusively for the use of oneself and one's family, and weavers wove for other family members more out of a sense of social responsibility than for money (Haviland, 1978).

Along with the movement toward weaving commerce was a movement toward design innovation, as predicted by the theoretical model. Designs went from a standard stock of about four patterns in 1970 to, in 1991, an infinite number of brocaded and embroidered designs superimposed on the same basic garment plans. The infinitely varied Zinacantec designs of the early 1990s involved much more complex weaving than had existed in 1969 and 1970. But this complexity did not signal a devolution of Mayan culture. Because complex brocade weaving (as well as Zinacantec commerce) originated before the Spanish conquest, the changes in the woven textiles constitute in some important respects a return to pre-Columbian cultural roots.

3. Study 1: historical change in weaving apprenticeship — from interdependence to independence

3.1. Weaving apprenticeship in Zinacantán: the first generation

Our 1970 data on weaving apprenticeship in Nabenchauk conformed to the culturally conservative model. Using naturalistic video, Childs and Greenfield (1980) looked at the interactional processes involved in the transmission of weaving skill from one generation to the next. In 1970, weaving instruction was characterized by a relatively error-free scaffolding process, based on observation of models, obedience to developmentally sensitive commands, and use of help when needed (Childs & Greenfield, 1980; Greenfield, 1984). This mode of informal instruction was well adapted to the superordinate goal of preserving the traditional Zinacantec way of life (Greenfield & Lave, 1982). The absence of trial-and-error discovery was well suited to maintaining the traditional patterns. The processes of apprenticeship were similar in important ways to Maya patterns of guided participation with toddlers later found in Guatemala by Rogoff, Mistry, Goncu, and Mosier (1993).

3.1.1. Predicted changes

We predicted a movement from the culturally conservative model of highly scaffolded apprenticeship to the culturally innovative model of more independent learning, as Zinacantec society accelerated its movement from corn-based subsistence to money-based commerce. A corollary to this prediction related to the process of change. We predicted that change would be proportional to the involvement of mother and daughter in textile-related commerce. We also tested alternative factors: maternal education, learner education, and family involvement in general commerce.

3.2. Method

3.2.1. Participants

The participants were 72 Zinacantec girls, ranging in age from 3 to 19 years (mean = 11.8, median = 12) and representing two historically distinct generations of the same extended families in Nabenchauk. The first generation was studied in 1970; the second generation, in almost all cases their daughters and nieces, was studied in 1991 and 1993. The girls in each generational cohort ranged from first-time weaver to expert.

For our analysis of historical change in weaving apprenticeship, we first selected those participants who had little prior experience in weaving (no more than three different items). Forty-five of these beginning weavers had data for all variables relevant to our statistical analysis. Ages ranged from 8 to 16 (median = 10). Their teachers/helpers were most often mothers, older sisters, younger sisters, cousins, or young aunts.

Family tree cards made by the third author in 1969 and 1970 enabled us to track down the descendants of the earlier participants when we returned to the field site in 1991. Almost all were still living in the community, and all the direct descendants of the 1970 weavers who were old enough to weave agreed to participate.

3.2.2. Procedure

For both generations of participants, weaving videotapes were made, by appointment, in the courtyard (or occasionally in the house, if it rained). Our local assistant accompanied us to virtually every taping session and introduced us to the families. Both cohorts were told that we wanted to see girls learning to weave.

In 1970, the equipment was the first Sony portable black-and-white reel-to-reel video recorder, with an external microphone set up under the loom. In 1991 and 1993, we used a Sony Hi-8 color video recorder, with radio lavalier microphones worn by the weaving learner and her teacher or helper, if there was one. The language of the tapes (and of the researchers' interaction with participants) was Tzotzil Mayan. For both cohorts, participants were compensated with a polaroid photograph and payment.

In addition to the videotape, there were several sources of fairly elaborate demographic data: interviews by our research team (in both 1970 and 1991/1993) and a Stanford Medical School survey of the community done in the summer of 1991.

3.2.3. Coding of the videotapes

Videotapes from both cohorts were extensively coded by the third author, who was blind concerning the hypothesized relationship of textile commerce to style of weaving apprenticeship. The coder was also blind as to scores on the textile commerce scale and even blind concerning the nature and existence of the textile commerce scale. On the other hand, her knowledge of backstrap loom weaving, Tzotzil, and the families contributed to coding validity.

Dependent variables of interest in this paper include two measures of learner independence during the weaving process: learner independence while weaving and prevention and correction of errors by the learner.

Independent weaving is defined as the proportion of time the learner worked independently on the first part of the weaving, without any intervention or instruction from her helper or teacher. Approximately 10% of the tapes were coded by an independent reliability coder (the first author); the correlation between the two coders was .9987, $P < .001$.

Learner prevention and correction of errors is based on identifying 16 specific opportunities for error in the weaving process (e.g., placement of the bobbin.) Each potential error could then be prevented by the learner or by the teacher; or, in the absence of prevention, the error could occur. If the error occurred, it could be either corrected (by learner or by teacher) or not corrected by anyone. The variable, learner prevention and correction of errors, is defined as the percentage of preventions and corrections the learner made by herself, out of all the preventions and corrections that were made, both learner- and teacher-initiated. After the third author had coded the data for this variable, two independent coders who were familiar with weaving, but not with the hypotheses were trained as reliability coders. Because not all scale points were equally likely to be used, percentage agreement was used in preference to kappa to assess interrater reliability. Each reliability coder made 80 judgments on data from five randomly selected weaving tapes; the tapes represented nine different participants in all (i.e., one tape was coded by both reliability coders). One coder achieved 93% agreement with the coding standard; the other coder attained 90% agreement with the standard.

3.2.4. *Textile commerce scale*

In order to test our hypothesis that the movement toward more independent learning was related to the participants' involvement in textile-based commerce, we used data sources (interview and census data) to create a mother–daughter textile-commerce scale. Some examples of textile commerce activities are: selling weaving, winding thread for pay, and selling thread. The left-hand column of [Table 1](#) presents complete listing of the items. The main coder for these items was blind as to all hypotheses and to the coding of the weaving videos.

3.3. *Results*

We used structural equation modeling to understand the patterns of relationship among historical period, experiences associated with a changing ecology, and processes of cultural apprenticeship. Structural equation modeling allows one to describe the coherence among features at multiple levels, an important aspect of culture (Rogoff et al., 1993). Among several models that were tested, the best fitting model (based on Maximum Likelihood Estimation) is shown in [Fig. 1](#). The

Table 1
Items used in the commerce scales

Textile commerce	Non-textile commerce
Learner sells weaving	Participating child buys/sells agricultural products
Learner winds thread for pay	Participating child sells peaches
Learner sells thread	Participating child sells flowers
Mother sells weaving	Participating child works in a shop
Mother sells thread	Participating child works for wages
Mother weaves for others on order	Participating child works as carpenter
Mother sews for others on order	Father participates exclusively in a modern activity (commerce, driving, construction, carpentry)
Learner weaves for others on order	
Learner sews for others on order	Mother sells peaches
	Mother sells tortillas
	TV in household
	VCR in household
	Radio, cassette player, or stereo in household
	Family owns a shop
	Family runs a mill
	Family owns a vehicle

Note: Scores for each scale are calculated by dividing the number of affirmative items by the total number of items in that particular scale.

means and standard deviations of all of the variables used in the model are shown in Table 2.

In the model, historical period (top level of the model) refers to whether a participant was a member of the earlier generation, studied as children in 1970, or the generation of their daughters, studied as children in the 1990s. The statistically significant link (.37, $P < .01$) from historical period to textile commerce in the model shows that, from one historical period to the next, participation in textile-related commerce increased significantly. Older girls also participate in significantly more textile commerce (.36, $P < .01$).

An increase in textile-related commerce, in turn, is related to an increase in learner independence on two measures; this is seen in the significant link between

Table 2
Means and standard deviations of variables in the weaving model

	All subjects, mean (S.D.)	Historical period	
		1970 ($N = 9$), mean (S.D.)	1991–1993 ($N = 36$), mean (S.D.)
Textile commerce	0.20 (.24)	0.01 (0.04)	0.24 (0.25)
Age	10.16 (2.76)	10.56 (1.65)	10.06 (2.99)
Independent weaving	56.92 (31.29)	47.98 (34.12)	59.16 (30.64)
Learner prevention/ correction	80.62 (22.77)	77.89 (23.30)	81.30 (22.92)

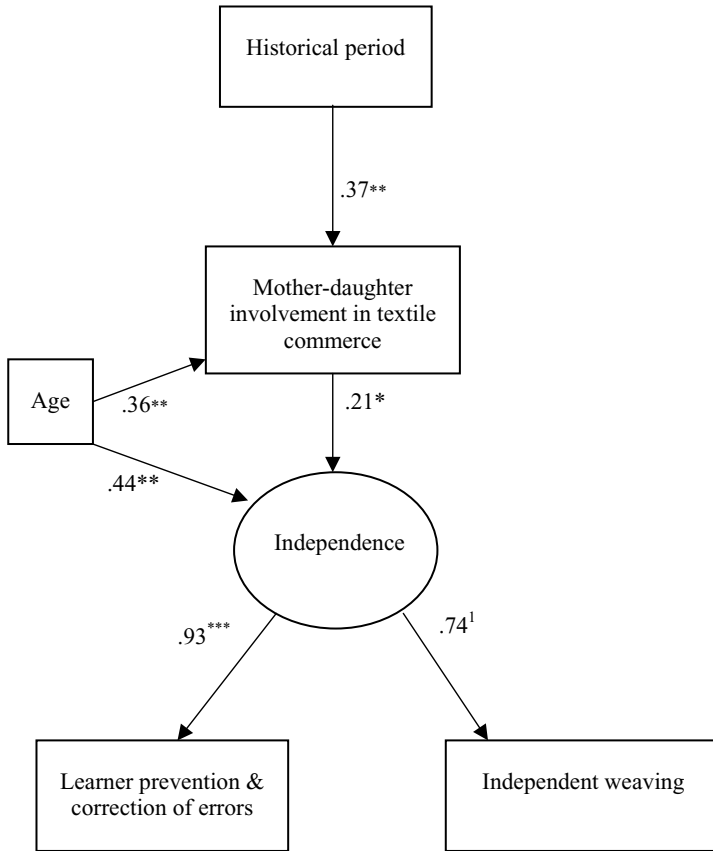


Fig. 1. Structural equation model of the historical change in weaving apprenticeship. Comparative Fit Index (CFI) = 0.973; $\chi^2(4, N = 45) = 5.606, P = .231$. (In structural equation modeling, a non-significant chi-square with a high, rather than the usual low, P level, indicates good fit to the model.) Significance levels of individual links: * $P < .05$; ** $P < .01$; *** $P < .001$; 1: path was fixed prior to running the model. Error labels are omitted for simplicity.

textile commerce and independence ($.21, P < .05$). Learner independence is a latent variable composed of two measured variables, independent weaving and learner prevention and correction of her own errors. Age of the learner is also related to independence in weaving; older girls, although they are not always more experienced as weavers, have more independence as they learn to weave; the link of $.44$ is reliable at the $.01$ probability level.

3.3.1. Alternative models

We tested a number of alternative models. For example, we reversed the link between textile commerce and learner independence. However, the model with

a path from learner independence to textile commerce did not fit as well as the reverse.²

We also tested two models that contained a direct link between historical period on the one hand and style of weaving apprenticeship on the other. Neither fit the data. Direct links from historical period to style of weaving apprenticeship were weak in these models because of the unevenness of social change in the 1990s. While some families had incorporated textile commerce into their way of life, others were not involved in making financial profit from the weaving enterprise. The passage of two decades was accompanied by more independent weaving apprenticeship only when mothers and daughters of the new generation were involved in textile commerce.

We also tested the specificity of the relationship between commercial involvement and learner independence. In addition to the textile commerce scale (already described), we developed a non-textile family commerce scale (right-hand column of Table 1 and described in more detail in connection with Study 2). This scale, composed of multiple interrelated features of the commercial way of life in Nabenchauk, included more general features of commercial activity. We tried substituting this non-textile commerce scale in the model; however, the model did not converge (i.e., did not work). In this way, we established that commerce relates to style of weaving apprenticeship through specific, relevant commercial activities, not through commercial involvement in general.

Other alternative models involved formal education. Because classroom teaching stresses pupils' initiative and speaking up, we thought that schooling might increase girls' independence. However, whether we added schooling (ranging from none to sixth grade) as a variable to the model in Fig. 1 (linking it to learner independence) or substituted schooling for textile commerce in Fig. 1, the model did not fit the data. We also tested maternal schooling (which ranged from none to third grade) and found that it could neither replace textile commerce nor add anything to the model.

We thought that weaving experience also might have played a role in girls' increasing independence. Whether we added weaving experience as an additional link to independence or substituted weaving experience for age, the model did not fit the data as well. Because girls become more expert weavers over a period of years as they get older, weaving experience and age were highly correlated ($r = .72$, $P < .001$). However, age may also be a carrier of an additional aspect of weaving experience, opportunities to observe weaving. Older girls have also had more opportunities to observe weaving, an important mechanism in traditional weaving apprenticeship among the Maya (Childs & Greenfield, 1980; Nash, 1958).

² In addition, we tested a bi-directional link between textile commerce and learner independence. This lowered the fit index to unacceptable levels, which could have been because of a change in degrees of freedom.

3.3.2. Summary

Processes of weaving apprenticeship changed from one generation to the next, moving from more interdependent to more independent learning. However, this change was not a uniform one; instead it was concentrated in those families where the learner and her mother participated more in textile commerce, for example, weaving or sewing for other Zinacantecs on order. One way in which textile commerce could relate to learner independence has to do with mothers' new commercial activities, which sometimes made them less available as weaving teachers. This hypothetical link exemplifies why we do not see changing modes of apprenticeship as conscious or intentional, but rather as an unconscious implicit adaptation to new conditions.

4. Study 2: historical change in cognitive representation

We wanted to link the historical shift in weaving apprenticeship to changes in cognition. We focused on the domain of visual pattern representation because visual patterns are an important byproduct of the weaving process. Corresponding to two models of cultural apprenticeship were two possible models of learning and cognitive development, applicable to the domain of pattern representation. The conservative model stresses learning to reproduce specific known patterns through observation and imitation; the innovative model stresses learning to create novelty and using abstract principles to transfer concepts and strategies to novel situations. Corresponding to the historical shift in models of apprenticeship found in Study 1, we predicted historical change in representational processes from concrete detail to abstraction and from the familiar or imitative to the novel. We also predicted that these changes would occur in the context of unchanging (and perhaps universal) patterns of cognitive development.

4.1. Pattern representation in Zinacantán: the first generation

We begin with the original study (1969/1970), presenting its results as background for the historical comparison of pattern representation processes in 1991. In 1969 and 1970, Greenfield and Childs collected data on the effects of weaving, formal schooling, and age on the development of pattern representation in Zinacantán (Greenfield & Childs, 1977). In the same article, we also reported data from a cross-cultural comparison group of female college students in Cambridge, MA, USA.

4.1.1. Representation of Zinacantec woven patterns

Participants were first asked to represent striped woven patterns by placing colored wooden sticks in a frame (Fig. 2). The woven patterns, a poncho and a shawl, were always visible as models in the experimental situation. These patterns furnished a baseline for assessing a shift toward a more abstract mode



Fig. 2. Pattern representation materials and experimental situation. Photo courtesy of Sheldon Greenfield.

of representation between 1969–1970 and 1991. The two woven patterns, omnipresent in Zinacantec textiles, are shown in Fig. 3. At adolescence, both schooling and weaving were associated with a more analytical approach to representing the woven patterns.

Fig. 4 shows an analytic representational strategy that was commonly used by teenage girls (all of whom were both unschooled and expert weavers) and schooled adolescent boys (none of whom knew how to weave). As can be seen by comparing Fig. 3 with Fig. 4, this strategy involves an accurate analysis of the basic configuration of single and triple red stripes in the poncho and shawl, respectively. In addition to involving accurate analysis, this strategy groups narrow white sticks together to create broad white stripes, just as individual threads are grouped in a weaving to make a broad stripe. We therefore called this strategy detailed or “thread-by-thread” analysis (see Fig. 4). Teen-age boys who did not go to school were less likely than either weavers or schooled boys to provide an analytic representation of the patterns and more likely to differentiate the patterns in a global fashion. They often ignored the basic configuration of red-and-white stripes, making the shawl pattern, for example, a simple alternation of two narrow red and two narrow white sticks (e.g., Marian 101, a 15-year-old boy).

Particularly relevant to our predicted historical changes were our cross-cultural comparison sample of U.S. college students, tested in this same period. Their most

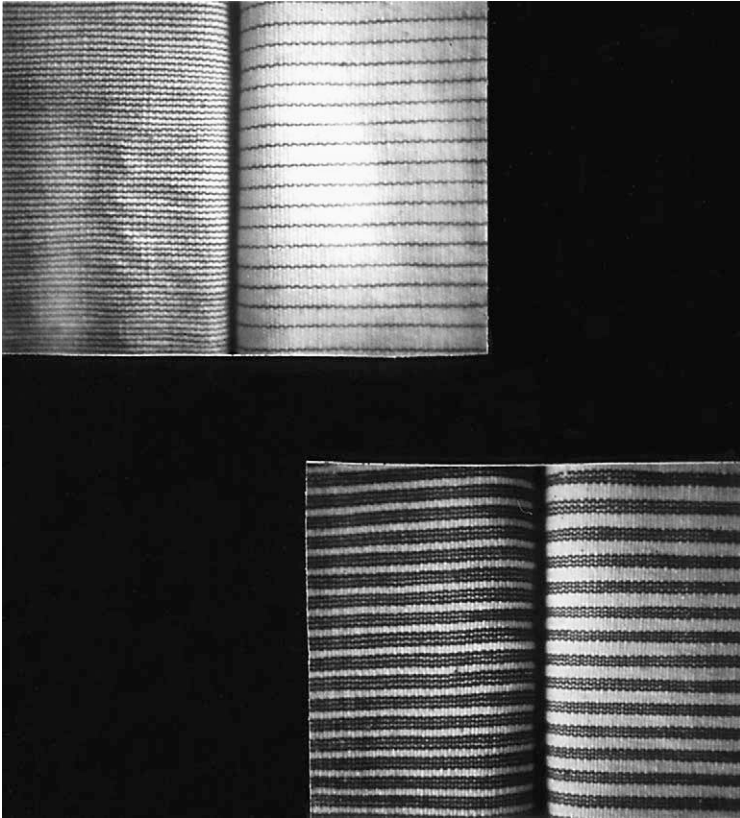


Fig. 3. Zinacantec poncho pattern (on top) and shawl pattern (on bottom) ca. 1969 and 1970. The dark stripes are red cotton; the light stripes are white cotton.

common representation is shown in Fig. 5. Like the representations of Zinacantec teen-age weavers and school-experienced boys, the representations of college students in Fig. 5 reflected an accurate analysis of the configuration of stripes in each woven pattern. However, the representations of these participants differed in an important respect. Instead of grouping narrow sticks to construct broad stripes, they used single broad sticks to represent the broad stripes. We termed this an *abstract* analytic strategy because it abstracted individual component threads into a single stripe, analogous to the way individual members of a category (e.g., my dog Rover, your dog Fido) can be abstracted into a single category (dogs). What these two different types of abstraction, one verbal and one visual, have in common is that they both eliminate concrete detail to form a superordinate unit.

We hypothesized that this abstract mode of representation utilized by the U.S. college students would appear in Nabenchauk in 1991, as a function of the

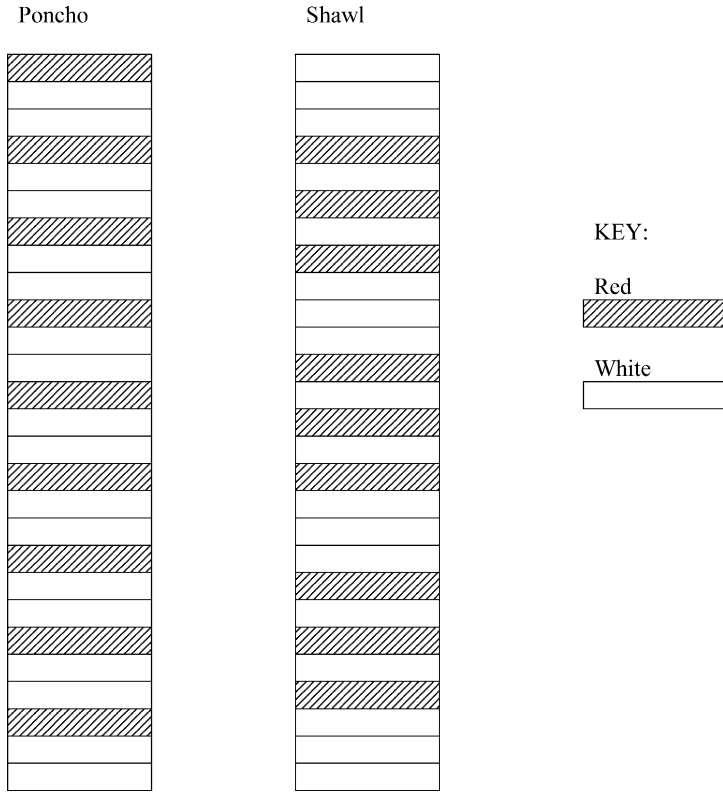


Fig. 4. Examples of detailed, thread-by-thread analytic representations of Zinacatec textiles.

economic shift away from subsistence and toward commerce. We thought this change would relate to (1) greater participation in the abstract exchanges of a money economy (money being a completely generalized medium of exchange), (2) exposure to more different patterns, including through television, and (3) in the case of one participant who had secondary education, a higher level of formal education. All three of these factors characterized our group of U.S. college students.

4.1.2. *Novel patterns: gender, schooling, and historical period*

When asked to continue culturally novel patterns modeled by the experimenter (and shown in Figs. 6 and 7), boys, in 1969 and 1970, performed better than girls across different age groups. This finding was attributed to the fact that boys traveled more, participated in agricultural commerce, and were exposed to a wider range of fabric patterns in the course of their travels (Greenfield & Childs, 1977). Similarly, Rogoff and Gauvain (1984) suggested that the lack of transfer from skill in weaving patterns to the representation of novel patterns in expert Navaho

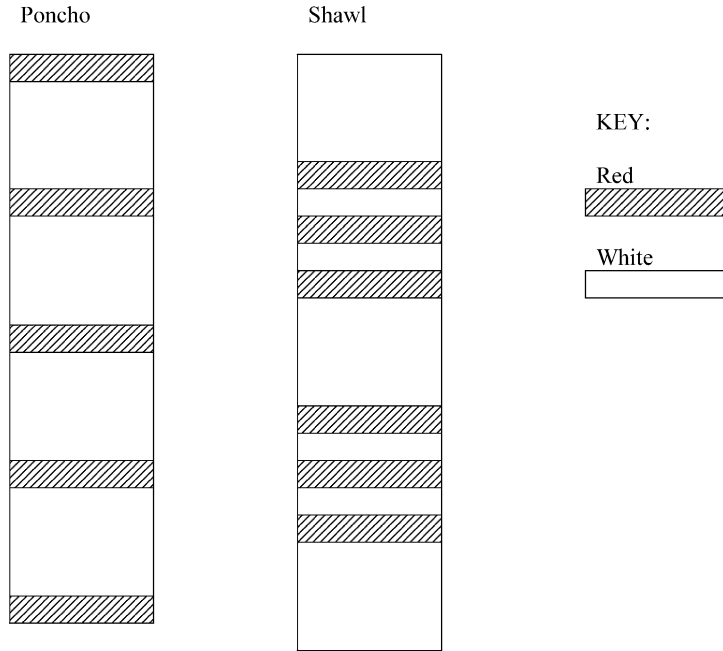


Fig. 5. Examples of abstract, analytic representations of Zinacotec textiles.

weavers (adolescent girls) occurred because of their exposure to but a few simple woven patterns. Because of Zinacotec girls' exposure to an infinite variety of woven patterns and their new participation in textile commerce in 1991, we expected the earlier male superiority in representing novel patterns to either decrease or disappear.

We predicted and found that, because of a new acceptance of innovation in the second historical time period, the variety of woven patterns increased. If increased cultural emphasis on innovation and exposure to a variety of patterns were also factors in the application of pattern representation skills to novel patterns (Guberman & Greenfield, 1991; Rogoff & Gauvain, 1984), then one would also expect an increase in skillful representation of novel patterns from one historical period to the next. We also hypothesized that greater involvement in commercial activity would entail greater exposure to novelty, which would, in turn, relate to greater facility in representing novel patterns.

4.1.3. Novel patterns: the "progressive pattern"

One novel pattern in particular held special interest because there was more than one possible "correct" continuation. We termed it the "progressive pattern," and it is shown in Fig. 7, along with three possible strategies for correctly continuing the pattern. To continue the pattern by making it progress (the rightmost strategy

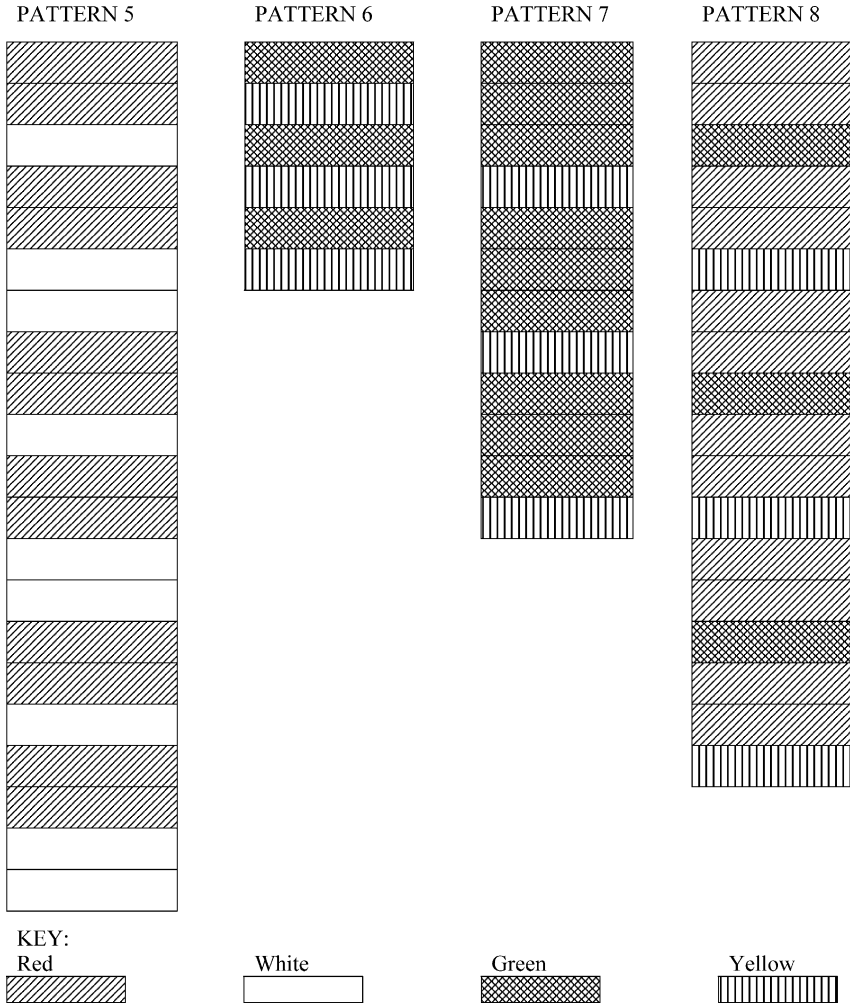


Fig. 6. Models for continuation of culturally novel patterns. For Pattern 5, narrow red, white, pink, and orange sticks were available. For Patterns 6 and 7, narrow green, yellow, black, and blue sticks were available. For Pattern 8, narrow red, green, and yellow sticks were available.

in Fig. 7), involves “going beyond the information given” (Bruner, Goodnow, & Austin, 1956) to create something slightly novel. The only participants in Nabenchauk who responded to the pattern with the progression strategy in 1969 and 1970 were boys with school experience (Greenfield & Childs, 1977). The higher rate of schooling in 1991 compared with the earlier period, as well as the greater value placed on innovation in an entrepreneurial environment, led us to predict more frequent use of the progression strategy in 1991.

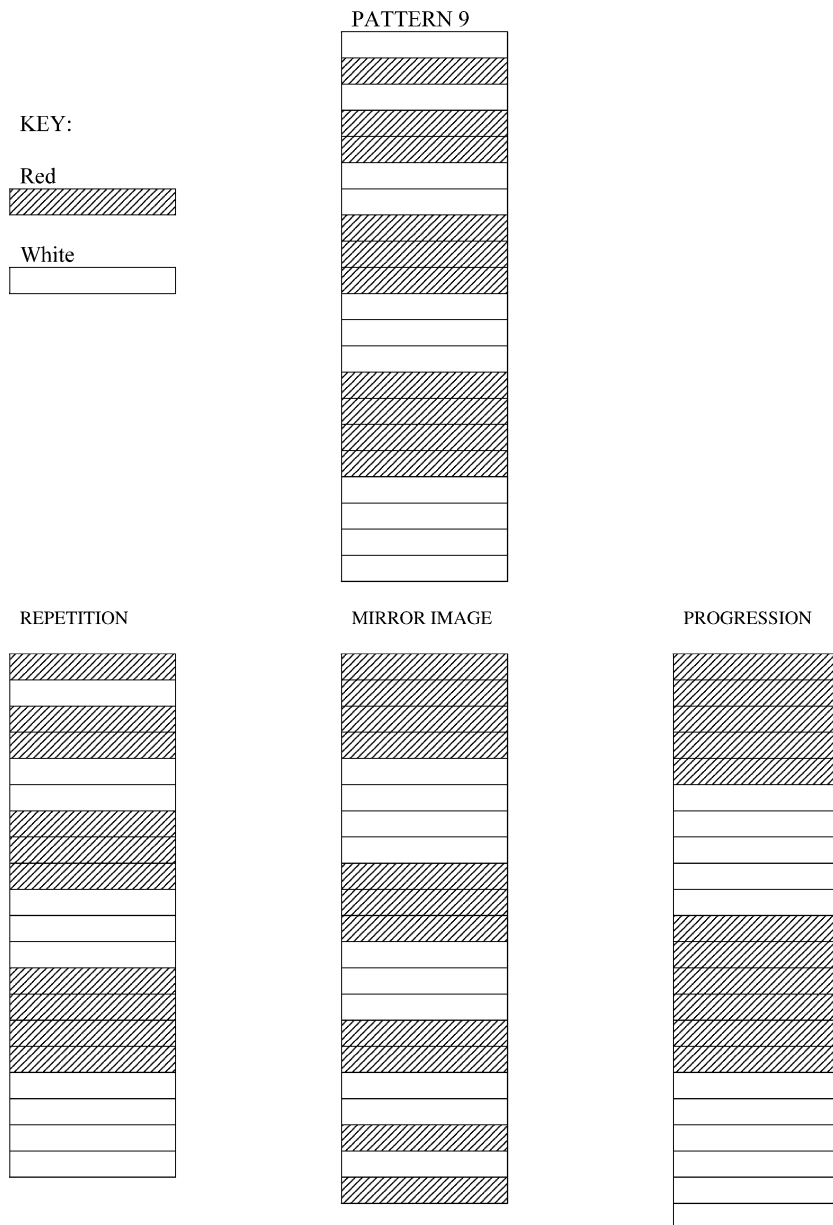


Fig. 7. Model for progressive pattern and three possible continuations. Narrow red-and-white sticks were available to participants for this item.

4.1.4. *Developmental patterns*

Consistent with [Werner's \(1948\)](#) developmental theory, seemingly universal developmental trends were identified in pattern representation. As Zinacantec children grew from age three to adolescence, their representations became increasingly differentiated and hierarchically complex ([Greenfield & Childs, 1977](#)). Children went from random placement of sticks at age four and five to binary differentiation of pattern parts in the 8- to 10-year-old group (e.g., Pattern 6, [Fig. 6](#), required a simple alternation of two colors), to hierarchically organized patterns involving complex subunits in the teenage group (e.g., Pattern 8, [Fig. 6](#), required combining two complex subunits; one subunit comprised two red and one green sticks, while the other complex subunit comprised two red and one yellow sticks). Insofar as differentiation and increasing hierarchical complexity characterized developmental progress in pattern representation, simplification of the more complex patterns characterized the nature of developmental errors ([Greenfield & Childs, 1977](#)). Consistent with the general universality of the progression from simple to more complex pattern representation, we expected no change in this developmental progression in 1991.

4.2. *Method*

4.2.1. *Participants*

Participants were 203 Zinacantec children, adolescents, and young adults, ranging in age from 3.5 to 22 with a mean age of 11.57 years. The mean age was precisely the same for both generations, one tested in 1969 and 1970, the second tested in 1991. Participants in this experiment included both boys and girls (97 boys and 106 girls). Most of the weaving learners whose apprenticeship was analyzed in the structural equation model ([Fig. 1](#)) participated in Study 2. This overlapping sample allows us to focus on the interrelations between style of weaving apprenticeship and the representation of visual patterns.

4.2.2. *Materials*

Materials included a wooden frame (inside dimensions of 9 in. × 16 in.) and sticks ([Fig. 2](#)); the same frame and sticks were used in both periods. The sticks were available in three widths: narrow (1/4 in.), medium 1 1/4 in.), and broad (2 1/4 in.) and in different colors (for more details, see [Greenfield & Childs, 1977](#)).

In addition, when asked to represent textile patterns, participants were shown examples of Zinacantec woven items, the poncho worn by men and boys and the shawl worn by women and girls, each with its own distinctive red-and-white stripe. Between 1970 and 1991, the configuration of striped patterns for the male poncho and female shawl had remained constant. However, the broad white stripes had become narrower. This change resulted in redder-looking garments; there was a greater preponderance of white in the older ponchos than in the newer ones. For this reason, we gave our 1991 participants two sets of woven models, one from the earlier period (to replicate the stimuli that had been used in 1969 and 1970)

and one from the later period (to equate the familiarity of the stimuli at both periods).

4.2.3. Procedure

Participants came to the home of a Zinacantec family to be tested. Childs and Greenfield were the experimenters for all of the 1969 and 1970 participants and for most of the 1991 participants. For a smaller number of participants, Greenfield was assisted by someone else, either from the U.S. or from Nabenchauk.

First the experimenter demonstrated how to place the sticks in the frame and had the participant try to do it. Each participant began by representing two patterns, the contemporary pattern for the poncho and the contemporary pattern for the shawl. In order to make the participants feel equally comfortable at both periods, the contemporary garments, including the participant's own poncho (as in Fig. 2) or shawl, were used as the initial stimuli in the procedure for both the 1969–1970 participants and the 1991 participants. For these items, red, white, pink, and orange sticks in all three widths were available.

In 1970, we oversampled representation of the culturally relevant woven patterns. Therefore, for a minority of the participants tested in 1970 ($N = 23$), the experiment ended at this point.

The remaining participants in 1969–1970 and all 1991 participants were asked to continue a series of seven patterns begun by the experimenter ($N = 180$). Patterns 3 and 4 were red-and-white striped patterns similar to the Zinacantec poncho pattern (and were not used in the historical comparison). Patterns 5–8 (Fig. 6) constituted the first four culturally novel patterns. Pattern 9, the “progressive pattern” (Fig. 7), was the last culturally novel pattern. In 1969 and 1970, the pattern representation procedure ended here. In 1991 only, Pattern 9 was followed by a task in which participants represented an old (1969) poncho and shawl that were shown to them.

Because the same pattern of historical change was found, whether we used the old patterns (which were last in the sequence of tasks) or the new patterns (which were first in the sequence of tasks) as our 1991 data point, we concluded that order in the sequence of tasks was not critical for our purposes. When we refer, in the Section 4.3, to representation of the contemporary woven patterns, participants from both historical periods were representing a striped poncho and shawl from their own era (first in the sequence of tasks in both eras). When we refer to representation of the old woven patterns, participants from both historical periods were representing a striped poncho and shawl from 1969 or 1970 (first in the sequence of tasks in 1969 and 1970, last in the sequence in 1991).

4.2.4. Non-textile commerce scale

In order to test our hypothesis that representational changes were related to involvement in commerce, we created the non-textile family commerce scale briefly described earlier and presented in the right-hand column of Table 1. As with the textile commerce score, family commerce scores are the proportion of the items in the right-hand column of Table 1 that apply. Almost all items could apply equally

to boys or girls. Note that this scale aggregates a number of interrelated changes, such as transportation (e.g., family owns vehicle), exposure to TV (TV in household), changing work opportunities for families (e.g., family runs a mill, family owns a shop), including children (e.g., participant works for wages). Each item could have effects on several levels; for example, it requires money and a commercial transaction to buy a TV; but TV further exposes viewers to many new stimuli, including commercials. Viewing commercials could be considered another layer of participation in a money economy, with its own further impact on consumerism. Note too that several of the items (e.g., virtual travel through television and real travel through available transport) entail exposure to diverse and varied fabric patterns. We cannot separate out such exposure from other features of the commercial complex, but it is certainly included within the commerce scale. The unifying conceptual thread running through all items is that each requires some type of participation in a commercial economy. No items from the textile commerce scale appeared in the non-textile commerce scale.

4.3. Results

4.3.1. Change in style of representing woven patterns

4.3.1.1. *Abstract representation.* We predicted a shift in strategy for representing the broad stripes in the woven patterns from a detailed, “thread-by-thread” approach to a more abstract approach. This hypothesis was explored in two ways. First, we looked among the oldest participants, the adolescents and young adults, for the abstract analytic strategy utilized by the U.S. college students (Fig. 5). As we had predicted, this style, totally absent in Nabenchauk in 1969 and 1970, was utilized by the next generation of participants in 1991. For example, among participants in 1969 and 1970, all of the analytic representations of the shawl were detailed (e.g., Fig. 4); in 1991, eight abstract analytic representations of the shawl appeared in the total sample: six abstract analytic representations of the old shawl and two abstract analytic representations of the new shawl (e.g., Fig. 5).

In order to utilize parametric statistics to assess this historical change, we developed a quantitative measure of abstract representation: the total number of medium and broad sticks (vs. narrow sticks) used in a representation of one of the Zinacantec textiles. (The array of sticks in three different widths can be seen in the photograph in Fig. 2.) This quantitative measure of abstraction was independent of accuracy in the pattern analysis (for example, the use of an alternation of broad red and broad white sticks for the shawl would count as abstraction, even though analysis of the complex red stripe was absent). Then we carried out multivariate analysis of variance with abstract representation of the contemporary textiles (contemporary to the respective historical periods) as the dependent variables and historical period as the independent variable.

Between the earlier period and the later, the rate of abstract representational strategies increased significantly ($F = 3.82$, $df = 2, 200$, $P = .024$) for both the contemporary shawl ($F = 7.23$, $df = 1, 201$, $P = .008$) and contemporary

poncho ($F = 7.23$, $df = 1, 201$, $P = .008$). For the shawl, the mean number of medium and broad sticks increased from 2.17 to 3.82. For the poncho, the mean number of medium and broad sticks increased from 2.38 to 3.81. (We did the same analysis with the old shawl and poncho (Fig. 3) as the dependent variables, with exactly the same pattern of results.)

When gender was added to the analysis, there were no gender differences in abstraction; nor was there any interaction of gender with historical period. Because boys do not weave, these results eliminate the possibility that the historical increase in abstract representation of the woven patterns is linked to a historical rise in the range of different patterns in one's weaving or embroidery repertoire.

We then used structural equation modeling to further explore the processes by which historical period, on the societal level, was connected to cognitive change on the individual level, more specifically the change from a more detailed to a more abstract mode of representation. Among several models that were tested, the best fitting model (based on Maximum Likelihood Estimation) is shown in Fig. 8. The means and standard deviations of all of the variables in the model are shown in Table 3.

This model confirms our hypothesis that the historical increase in the use of an abstract style of representation is related to involvement in commercial activity. In the model, historical period (top level of the model) refers to whether a participant was a member of the earlier generation, studied as children in 1969 and 1970, or the generation of their sons and daughters, studied as children in 1991. The statistically significant link (.67, $P < .001$) from historical period to commerce (next level of the model) shows that, from one historical period to the next, participation in non-textile commerce increased. This increase paralleled the historical increase in textile-related commerce in the first model depicted in Fig. 1. An increase in non-textile commerce, in turn, is related to an increase in the factor of abstraction (third level of the model); this is seen in the significant link between commerce and abstraction (.12, $P < .05$). Abstraction, in turn, is a latent variable composed of the number of medium and broad sticks used to represent the contemporary shawls and ponchos. With increasing age, according to the

Table 3
Means and standard deviations of variables in the pattern representation model

	All subjects, mean (S.D.)	Historical period	
		1969–1970 ($N = 90$), mean (S.D.)	1991 ($N = 112$), mean (S.D.)
Age	11.56 (4.07)	11.54 (4.32)	11.57 (3.88)
Commerce	0.12 (0.13)	0.02 (0.04)	0.20 (0.13)
Contemporary poncho: large/medium sticks	3.25 (4.47)	2.38 (4.25)	3.96 (4.54)
Contemporary shawl: large/medium sticks	3.08 (4.43)	2.17 (4.17)	3.81 (4.52)

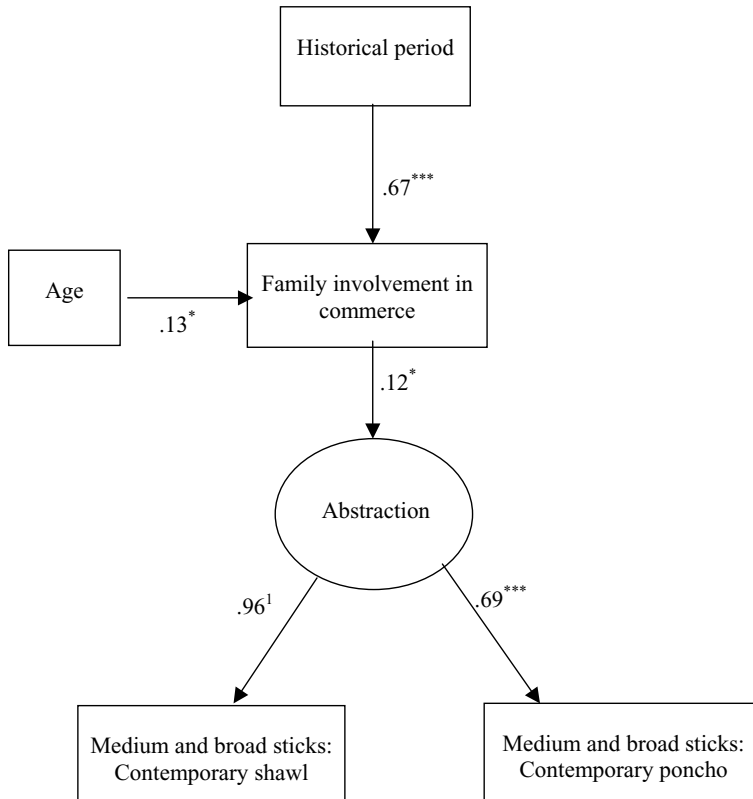


Fig. 8. Structural equation model of the historical change in abstract representation of woven patterns. We included only those subjects who had data for all the variables, yielding 202 out of the 203 subjects who participated in this part of the study. CFI = 0.995, $\chi^2(6, N = 202) = 6.181$, $P = .28898$. Parameter is significant at $* P < .05$; parameter is significant at $*** P < .001$; 1: path was fixed prior to running the model. Error labels are omitted for simplicity.

model (Fig. 8), comes increasing involvement in family commerce. In sum, this structural equation model confirmed our hypothesis that the historical increase in abstract representation would be related to the study participants' involvement in many facets of a money economy, from selling to transport to access to consumer electronics such as television.

4.3.1.2. Alternative models. Most basic in considering alternative formulations was to test the direction of the arrows in the model. From a theoretical perspective the only path that could possibly go in the other direction is the link between commerce and abstraction. An abstract cognitive style could be more favorable to participating in commercial activities. However, the model with a path from

abstraction to commerce did not fit as well as the one depicted in Fig. 8.³ Although we tend to associate formal schooling with the development of abstraction, neither children's schooling nor their mothers' schooling related to the historical increase in abstract visual representation. We also tested two models that included direct links from historical period to abstraction. Neither model showed a fit to the data, indicating the necessity of participation in non-textile commerce as a link between historical change and cognitive change.

4.3.2. Representation of novel patterns

We predicted that skill in continuing and representing novel patterns would improve from one historical period (and one generation) to the next. To test this prediction, we compared participants' skill in correctly representing the culturally novel patterns, Patterns 5–9 (Figs. 6 and 7), at the two time periods. Because the ability to represent patterns improves with age (Greenfield & Childs, 1977), we used age as a covariate in an analysis of covariance. We had predicted an overall historical change in getting novel patterns correct based on the development of entrepreneurial commerce, including exposure to a wider range of patterns. We counted as correct any pattern continuation that had no errors; for the progressive pattern, any of the three strategies shown in Fig. 7 was counted as correct for purposes of this particular analysis. Boys had performed better than girls with novel patterns in 1969 and 1970 (Greenfield & Childs, 1977). In order to test the predicted historical reduction in this gender difference, we also included gender in the analysis.

Our hypotheses were confirmed by this analysis: controlling for age, historical period had a significant main effect on the number of novel patterns that were correctly represented ($F = 4.384$, $df = 4, 173$, $P < .05$, $N = 178^4$); subjects in the later historical period correctly completed significantly more novel patterns (mean = 2.65, out of 5) than did those in the first historical period (mean = 2.19, out of 5). Controlling for age, the gender difference was also significant ($F = 4.337$, $P < .05$), with boys correctly completing more novel patterns (mean = 2.57) than girls (mean = 2.39). As expected, age was a highly significant covariate ($F = 80.925$, $P < .001$), showing improvement over age in number of novel patterns continued correctly.

As predicted, there was a reduction of the gender difference between the first and second historical period. Whereas boys correctly completed more novel patterns (mean = 2.50, out of 5) than girls (mean = 1.74, out of 5) at the first historical period ($F = 3.887$, $df = 2, 64$, $P = .053$), there was no significant gender difference at the second historical period. Indeed, the historical change was

³ In addition, we tested a bi-directional link between commerce and abstraction. This lowered the fit index to unacceptable levels, which could have been because of a change in degrees of freedom.

⁴ One hundred and eighty participants were given novel patterns to continue; one participant could not be used in the analysis because of experimenter error; another could not be used because of a missing age. The sample consisted of 84 boys and 94 girls.

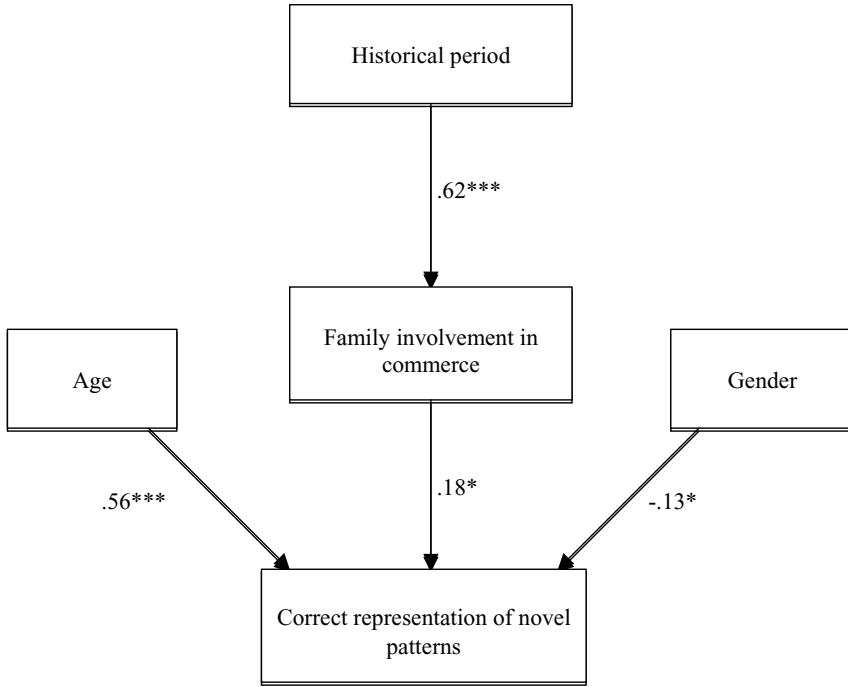


Fig. 9. Path model of the historical change in representation of novel patterns. CFI = 0.969, $\chi^2(6, N = 178) = 11.123, P = .085$. Parameter is significant at $* P < .05$; parameter is significant at $*** P < .001$. Error labels are omitted for simplicity. For the gender variable, boys (one), girls (two); the negative link from gender indicates that boys correctly represent more novel patterns than do girls.

concentrated in the girls ($F = 5.856, df = 2, 91, P = .018$). The girls improved from a mean of 1.74 (out of 5) in the first historical period to a mean of 2.66 (out of 5) in the second historical period. The boys' improvement (from a mean of 2.50 to 2.64, out of 5) was not statistically significant. In essence, by 1991, boys and girls were representing novel patterns with the same level of skill.

We again used structural modeling to further explore the mechanism by which historical period, on the societal level, was connected to cognitive change on the individual level, this time to improvement in the representation of novel patterns. Among several models that were tested, the best fitting path model (based on Maximum Likelihood Estimation) is shown in Fig. 9. The means and standard deviations of all of the variables in the model are shown in Table 4.

This model confirms our hypothesis that the historical increase in the representation of novel patterns is related to the participants' involvement in commercial activity. In the model, historical period (top level of the model) refers to whether a participant was a member of the earlier generation, studied as children in 1969

Table 4
Means and standard deviations of variables in the novel-pattern representation model

	All subjects, mean (S.D.)	Historical period	
		1969–70 ($N = 67$), mean (S.D.)	1991 ($N = 111$), mean (S.D.)
Age	11.37 (4.10)	10.97 (4.43)	11.60 (3.88)
Commerce	0.13 (0.13)	0.02 (0.05)	0.19 (0.13)
Novel pattern representation	2.48 (1.52)	2.19 (1.55)	2.65 (1.49)

and 1970, or the generation of their sons and daughters, studied as children in the 1991. The statistically significant link (.62, $P < .001$) from historical period to commerce (next level of the model) again shows that, from one historical period to the next, participation in non-textile commerce increased. An increase in non-textile commerce, in turn, is related to an increase in the correct representation of novel patterns (third level of the model); this is seen in the significant link between commerce and representation of novel patterns (.18, $P < .05$). In line with results from the ANCOVA just reported, there is a significant positive link from age to novel-pattern representation (.56, $P < .001$), as well as a significant link between sex and novel-pattern representation, with boys performing better than girls ($-.13$, $P < .05$; link is negative because male gender was coded as 1, female gender as 2). According to the earlier ANCOVA, this relationship between gender and novel pattern representation is due to the first generation only.

4.3.2.1. Alternative models. Most basic was to test the directionality of the relevant paths in the model. From a theoretical perspective the only path that could possibly go in the other direction is the link between family participation in commerce and skill in representing novel patterns. Skill with novel patterns could be favorable to the involvement in commerce. However, the model with a path from novel-pattern representation to commerce did not fit as well as the one depicted in the Fig. 9.⁵

We added a direct link between historical period and novel-pattern representation, leaving all other parameters as they appear in Fig. 9, and found the link to be non-significant. We thought that schooling might have played a role in the children's performance on the task and tested models that included mother and child schooling in several ways. Neither the children's schooling nor their mothers' schooling contributed to mediating the historical increase in the representation of novel patterns, either with or without commerce. We also tested an additional model that included a direct link from historical period to novel-pattern representation, eliminating commerce as a mediating variable. This model did not show

⁵ In addition, we tested a bi-directional link between commerce and novel-pattern representation. This lowered the fit index to unacceptable levels, which could have been because of a change in degrees of freedom.

a fit to the data, indicating the necessity of participation in non-textile commerce as a mediating link between historical change and cognitive change. In sum, our path analyses further confirmed our hypothesis that the historical increase in the ability to represent novel patterns would be related to participation in many facets of commercial activity.

4.3.3. *Change in response to the “progressive pattern”*

One of the five novel patterns analyzed in the prior section was the “progressive pattern.” This pattern is unique in that it has three alternative “correct” strategies. Whereas in the prior analysis all three correct strategies were counted as correct, we now turn our attention to analyzing differences in strategy choice. Our essential historical prediction was that, as part of the greater cultural value placed on novelty or innovation, there would be a shift in preferred strategy toward the “progression” strategy, in which the participant creates something a little novel, something that goes beyond the pattern that has been started by the experimenter (see bottom, right of Fig. 7).

In order to test this prediction, we compared the distribution of the three different strategies — repetition, mirror image, and progression (shown in Fig. 7) — at the two historical periods. As we were more interested in the nature of the strategy than in its perfect execution, we used strategies that contained up to three errors in this analysis. A chi-square test showed that the distribution of strategies had changed quite dramatically ($\chi^2 = 10.540$; $df = 2$, $P = .005$, $N = 37$). In 1969 and 1970, only 18% of the three strategies had been the progression strategy; the majority had been the repetition, an imitative strategy (bottom left, Fig. 7). In contrast, 62% of the solutions in 1991 went “beyond the information given” to make the pattern expand. Hence, the prediction that there would be an overall historical increase in the use of a more innovative, less imitative cognitive strategy was confirmed by an historical increase in the use of the progression strategy.

Schooling turned out to have the strongest relationship to use of the progression strategy. Controlling for age and commercial involvement, schooling was significantly correlated with the use of the progression strategy on Pattern 9 ($r = .46$, $P < .0005$, one-tailed). Conversely, controlling for age and schooling, commercial involvement was correlated with the use of the progression strategy, but at a lower level of significance ($r = .15$, $P < .03$, one-tailed). Here is the one place where the educational portion of social change is more closely related to changes in representational strategy than is commercial experience.

4.3.4. *Historical constancy in representational development*

These historical changes were set against a general (and perhaps universal) developmental trajectory toward representational strategies of increasing differentiation and hierarchical complexity with age. The five novel-pattern models (Figs. 6,7) can be arranged on a scale involving number of different pattern parts and their arrangement into hierarchically organized subunits. Patterns 6 and 7 are the simplest with two stripes or pattern parts each. Patterns 5 and 8 are next with

complex subunits (e.g., Pattern 8 required combining two complex subunits, each composed of two differentiated stripes; one complex subunit comprised two red and one green sticks, while the other subunit comprised two red and one yellow sticks). Pattern 9 (the “progressive” pattern) is organized into four subunits, each containing two differentiated stripes (e.g., red–white is a subunit).

This ordering of pattern complexity also predicted developmental ordering. The youngest age at which at least half the children got the simplest patterns, Patterns 6 and 7, correct was 7 years old. The youngest age at which at least half the children got the next most complex patterns, 8 and 5, correct was 10- and 12 years old, respectively. In no group did half the participants succeed in completing Pattern 9 perfectly. In sum, children become able to represent increasing pattern complexity as they grow older. This developmental pattern held across both historical periods.

Just as the positive side of representational development was the construction of increasing complexity with age, the nature of systematic developmental errors was (after the random stage of the very young children) the simplification of more complex patterns. These simplifying error strategies were also constant across both historical periods.

Fig. 10 presents examples of simplifying errors in representing Pattern 9 in both historical periods. The eight-part “progressive” pattern has been simplified to a two-part pattern by Maruch 53, a 15-year-old participant from 1969. Xunka 136, a 15-year-old participant from 1991, constructs a more complex representation (Fig. 10), but still greatly simplifies in comparison with the model. She transforms the pattern from an eight-part pattern with four complex subunits into a four-part pattern with two complex-subunits: Stripes of four sticks in each color alternate with stripes of three sticks. Most interesting is the consistency with which each of these participants approaches pattern construction across items. Their respective approaches to Pattern 9 reflects an upper limit to pattern complexity that is reflected in their other pattern continuations. Hence Maruch 53 (who constructs two pattern parts in constructing Pattern 9) fails with the two patterns, 5 and 8 (Fig. 6), that have more than two pattern parts and complex subunits. In contrast, Xunka 136, who has constructed Pattern 9 with two complex subunits, succeeds in the other patterns, where the maximum complexity is two complex subunits (Patterns 5 and 8, Fig. 6). While these two 15-year-old girls illustrate the historical constancy and developmental consistency of error strategies, they also illustrate the historical shift toward greater skill with novel patterns demonstrated earlier. Although they are of the same age, Xunka, our 1991 participant, is able to represent the more difficult patterns at a higher level of complexity than is Maruch, a member of the earlier generation.

4.3.5. Summary

The representation of visual patterns is a form of implicit, non-verbal knowledge. Our historical study indicates that it adapts quite automatically, without necessity of explicit instruction, to changes in the economic ecology. With movement from subsistence to commerce, we found a correlated movement from detailed to

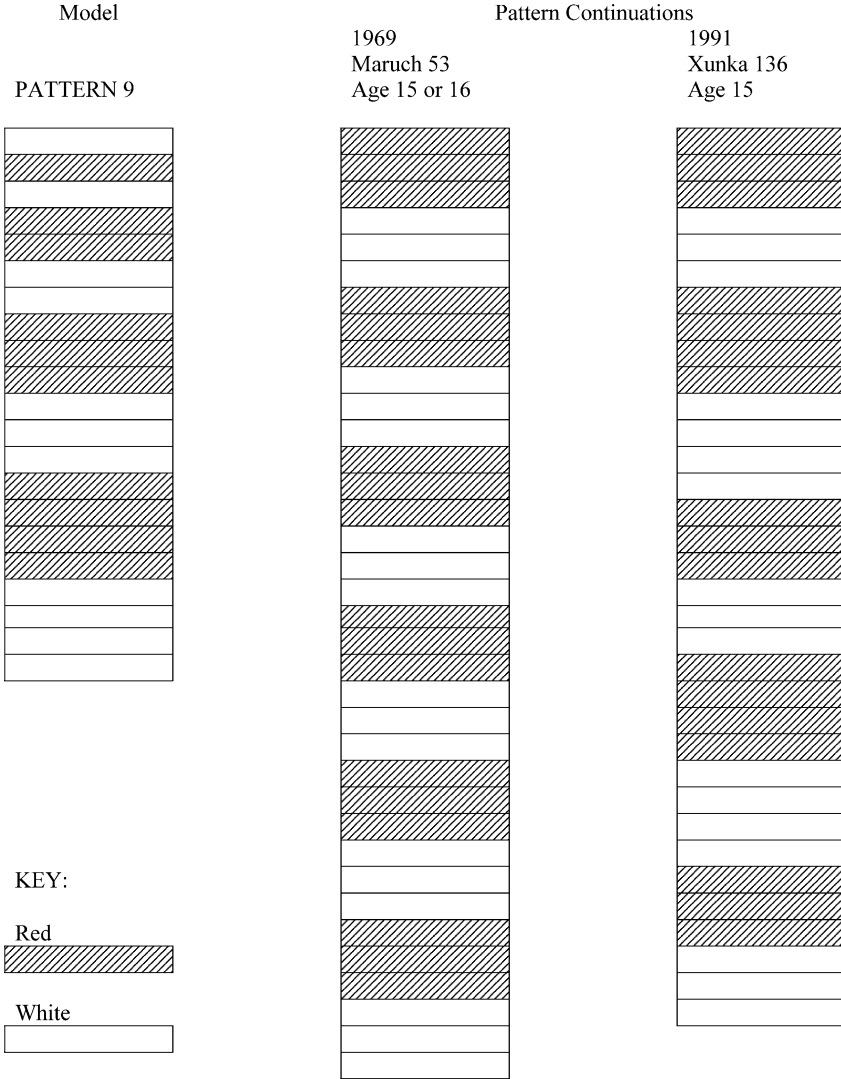


Fig. 10. Simplification error strategies in response to Pattern 9.

abstract representation, along with a movement toward greater skill in representing novel patterns. We also found that the explicit process of school education had an effect on implicit processes of pattern representation. In Nabenchauk, school aided children and teens to “go beyond the information given” to create “novelty”

with an ambiguous representational problem. These historically contingent shifts constituted automatic adaptations, not explicit knowledge. Such implicit processes of cognitive adaptation were founded on a constant and unchanging trajectory of representational development: toward increasing differentiation and hierarchical complexity of visual constructions with increasing age.

5. Connections between apprenticeship and cognitive representation

The theory behind the predicted change in weaving apprenticeship was that a more independent, trial-and-error style of apprenticeship would be adapted to an environment in which innovation was valued. On the cognitive level, our pattern representation experiment included a measure of skill in representing culturally novel patterns. We therefore explored the possibility of a link between a more independent, trial-and-error style of weaving apprenticeship and skill in representing culturally novel patterns. Using age as a covariate (because pattern representation improves with age), we ran correlations between the number of novel patterns correctly completed in the pattern representation experiment and the two apprenticeship variables, (1) independent weaving and (2) learner prevention and correction of errors (a measure of trial-and-error learning) used in the structural equation model. Our sample comprised weaving learners who had woven three or fewer items in the past (the same girls included in the structural equation model) and who had also completed the pattern representation experiment. Thirty-three girls met these criteria for inclusion in the analysis.

Our predictions were confirmed: Both measures of an independent, trial-and-error style of weaving apprenticeship — independent weaving and learner prevention/correction of errors — were positively correlated with skill in representing the culturally novel patterns in our cognitive experiment. Controlling for age, the partial correlation of learner independence in weaving apprenticeship with novel-pattern completion was .4538 ($P = .003$, one-tailed test); the partial correlation of learner prevention and correction of weaving errors with novel-pattern completion was .3348 ($P = .025$, one-tailed test).

6. Discussion

Against a background of general (and perhaps universal) processes of cognitive development, our data show that implicit processes of cultural learning and cognitive representation undergo historical transformation under conditions of ecological change. We do not see these ecological changes as linear progress. Nor did they start at the beginning of our study or end when our study ended. They are simply a slice of cyclical change that allows us to illuminate some interesting relationships between ecological niches, cultural transmission, and cognitive development.

In a society that has moved from agriculturally-based subsistence toward money-based commerce, we have found a series of automatic, coordinated changes in the cultural apprenticeship of weaving and the cognitive representation of cultural artifacts and novel patterns. These coordinated changes indicate implicit movement from a more conservative to a more innovative cultural model. The correlations between an independent, trial-and-error style of apprenticeship and cognitive skill in representing culturally novel patterns suggest that this style of cultural apprenticeship may reflect and sustain the innovative cultural model. Conversely, they suggest that a more closely guided form of apprenticeship may foster the maintenance of established cultural forms, the hallmark of a conservative cultural model. Moreover, the correlations between apprenticeship style and modes of visual representation indicate the generality of the conservative and innovative models across domains and the interrelationship of elements in a cultural pattern.

A study of weaving cooperatives, another form of textile commerce, in another Maya community in highland Chiapas, Chenalho, confirmed this relationship between textile commerce and a more independent weaving apprenticeship (Chen, 1991). The daughters of women in the cooperative learned to weave with a more independent style of weaving apprenticeship than girls whose mothers wove mainly to fulfill subsistence needs.

Pattern representation, our second domain of interest, also changed over historical time, becoming, first of all, more abstract in style. However, the Zinacantecs had taken just the first steps in the direction of abstraction; our earlier study suggested that Euro-Americans would have used this style almost exclusively, whereas the Zinacantec sample manifests a mixture of abstract and detailed styles of representation. Secondly, from one generation to the next, Zinacantec girls became more skilled at representing culturally novel patterns. The increased skill in representing and creating novel patterns in an experimental context seemed to have ecological validity: It was also found in the real cultural world of woven patterns, where constant innovation was a major feature of the 1990s, in contrast to the small, closed stock of patterns found in 1969 and 1970. The generality of this correlation between commerce and innovative artisanal designs was confirmed by ethnographic study in Tenejapa, another Mayan community in Chiapas and among Native Americans in the Santa Fe region (Greenfield, *in press*). At the same time, the fact that Zinacantec boys, even in 1969 and 1970, were skilled in representing novelty corresponds to the fact that the transition to commerce had already begun, and boys were traveling more than girls to market centers, helping their fathers to sell their corn (Greenfield & Childs, 1977).

Because the ecological changes have been uneven in Nabenchauk, we have been able to demonstrate that involvement in different types of money-based commerce is related to these historical changes. Our structural equation models showed that familial involvement in relevant commerce is related to increased independence in weaving apprenticeship, increased abstraction in representing woven patterns, and a greater orientation toward processing and creating novel patterns in the 1990s.

Formal schooling, another part of the transition from a subsistence to a commercial way of life, was most closely linked to “going beyond the information given” in pattern representation.

As one aspect of life — the economic — changed for the Zinacantecs, other aspects also changed. These findings indicate that macrochanges on the economic level are related to coordinated changes in socialization and development on the level of family and individual. In turn, these changes on the individual and family level provide the transformed human capital required by a new economic system. We find, in our study of weaving apprenticeship, that mothers do not necessarily raise their children as they were raised; instead, they raise them, not necessarily consciously, to adapt to the changed social conditions under which their children will function as adults. Similarly, our study of cognitive representation indicates that children’s representational skills do not necessarily replicate those of their parents. Instead, the patterns of cognitive development of a new generation change in response to a changing world, but always respecting constant patterns of basic cognitive development. We have reported one case study of one community in one social context in one slice of time. The results therefore constitute one particularization of the general principle that historical change brings coordinated changes in implicit processes of cultural learning and cognitive representation. Many other particularizations of this principle are also possible; they should be revealed by future research.

Author Note

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