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Developmental effects of economic and educational change: Cognitive representation in three generations across 43 years in a Maya community

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We studied the implications of social change for cognitive development in a Maya community in Chiapas, Mexico, over 43 years. The same procedures were used to collect data in 1969–1970, 1991, and 2012—once in each generation. The goal was to understand the implications of weaving, schooling and participation in a commercial economy for the development of visual pattern representation. In 2012, our participants consisted of 133 boys and girls descended from participants in the prior two generations. Procedures consisted of placing colored sticks in a wooden frame to make striped patterns, some familiar (Zinacantec woven patterns) and some novel (created by the investigators). Following Greenfield (2009), we hypothesised that the development of commerce and the expansion of formal schooling would influence children's representations. Her theory postulates that these factors move human development towards cognitive abstraction and skill in dealing with novelty. Furthermore, the theory posits that whatever sociodemographic variable is changing most rapidly functions as the primary motor for developmental change. From 1969 to 1991, the rapid development of a commercial economy drove visual representation in the hypothesised directions. From 1991 to 2012, the rapid expansion of schooling drove visual representation in the hypothesised directions.

Keywords: Social change; Culture; Cognitive development; Maya; Sociodemographic variables; Mexico; Chiapas.

Cognitive development is not static. It changes over time as societies change (Greenfield, Maynard, & Childs, 2003; Greenfield, 2004; Saxe, 2012; Saxe & Esmonde, 2005), influenced by variables related to modernisation (Gauvain & Munroe, 2009). How does social change impact individual development (Pinquart & Silbereisen, 2004)? This study is part of a larger project examining social change and human development across three generations of Zinacantec Maya people in Chiapas, Mexico. Up to now, Greenfield and colleagues have studied shifts in cognitive development over two generations in one Maya community, dating back to 1969 (Greenfield & Childs, 1977; Greenfield et al., 2003). This article introduces data from the third generation, studied in 2012.

Cultural change and cognitive development

Beginning in the 1970s and continuing into the 2000s, understandings of number and mathematics among the Oksapmin of New Guinea shifted in a coordinated way with sociodemographic shifts to a money economy and increases in formal schooling (Saxe, 2012). Oksapmin people changed their mathematical thinking and procedures by adapting their indigenous body-part system of

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Ashley Maynard did the main statistical analyses ~~for Generations 2 and 3,~~ supervised the coding and data inputting to SPSS for Generation 3, participated in data collection for Generation 3, and wrote the first draft of this article. Patricia Greenfield participated in conceptualizing and developing the procedure, participated in data collection for all three generations, participated in developing coding systems for Generations 1 and 2, supervised data inputting to SPSS for Generation 1 and 2, and was involved in contributing to and editing later drafts of this article. Carla Childs participated in conceptualizing and developing the procedure, participated in developing the coding system for Generations 1 and 2, participated in data collection and coding for Generations 1 and 2, and provided feedback on the first and later drafts of this article.

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counting and mathematics in order to carry out economic transactions.

Here, we use cross-temporal and cross-generational data to investigate how children adapt to a developing commercial economy and the expansion of formal schooling. We test Greenfield's (2009) theory of social change and human development by examining cognitive changes among Maya children in the same community across three generations. The relevant theoretical axiom is that sociodemographic change affects the child's learning environment, producing changes in cognitive development.

Theoretical background: from *Gemeinschaft* to *Gesellschaft*

Greenfield's theory is based on Tönnies's (1887/1957) concept of two idealised environments, *Gemeinschaft* (community) and *Gesellschaft* (society). At the sociodemographic level, *Gemeinschaft* environments are rural; education is informal and at home; the economy is founded on subsistence; and people are relatively poor. The *Gesellschaft* environment is urban; education occurs at school; the economy is based on commerce; and people are wealthier.

At the level of human development, cognition adapted to a *Gemeinschaft* environment is concrete and linked closely to context. Cognition adapted to a *Gesellschaft* environment is more abstract. Furthermore, in a *Gemeinschaft* environment, modes of thought follow tradition. In contrast, skill in dealing with novel stimuli is adaptive in a *Gesellschaft* environment. In this way, the sociodemographic level influences the level of human development.

Until this point, this is a model of the social environment under stable conditions. But sociodemographic environments are changing rapidly around the globe. Greenfield's theory predicts that these sociodemographic characteristics—commerce, urbanisation and schooling—all move human development toward abstract thinking and skill in dealing with novel stimuli. When sociodemographic characteristics change, cognition changes to adapt to the new environment. When social change moves in the *Gesellschaft* direction, the theory predicts that cognition will become more abstract and skill in dealing with novel stimuli will increase (Greenfield et al., 2003). An important corollary of the theory, tested in the present study, is that whatever sociodemographic variable is changing most rapidly in a particular time period will become the main driver of developmental change in that period.

Hypotheses and questions

We predicted that four decades of social change in the community of Nabenchauk—above all the economic transformation from agriculture to commerce, the expansion of schooling and exposure to urban environments—would produce in children more abstract cognition and increased skill in dealing with novel stimuli. Between 1969–1970 (Generation 1) and 1991 (Generation 2), the development of commerce was the main sociodemographic change in the community; as predicted, participation in commercial activities drove most of the cognitive changes observed between the first two generations (Greenfield et al., 2003). These changes included more abstract representation of textile patterns and greater skill in dealing with novel visual patterns.

Between 1991 (Generation 2) and 2012 (Generation 3), schooling and urbanisation were expanding most rapidly (Greenfield, Maynard, & Martí, 2009; Manago, 2014). We therefore predicted that they would be the most important forces for changes in cognitive development between Generations 2 and 3. We also predicted that the increase in abstract representation and comprehension of novel visual patterns that had occurred between Generations 1 and 2 would continue from Generations 2 to 3. We predicted that children would increasingly "go beyond the information given" in each generation to represent the most complex novel pattern; this task involved abstraction, as well as comprehension of novelty.

We also wished to examine the link between the subsistence activity of weaving and context-specific pattern representation—the detailed representation of woven patterns that would be required to actually weave them (Greenfield & Childs, 1977). We conceptualized a detailed representation of patterns as a cognitive adaptation to weaving, a *Gemeinschaft* feature of the environment.

METHODS

Participants

In 1969 and 1970, participants consisted of 90 children (39 girls) between the ages of 4 and 18 years ($M = 11.57$ years). In 1991, there were 113 participants (67 females) from the same families as in the first generation (children, nieces, nephews, god children and a few younger siblings of participants in the first generation), ranging in age from 5 to 22 years ($M = 11.57$ years). In 2012, there were 133 participants (75 females) from the same families (grandchildren, children, nieces and nephews, or godchildren of the first (1969–1970) or second (1991) generation. There were also a few younger siblings of participants in the second generation who were in the study. The age range of the 2012 sample was 4–22 years ($M = 11.27$ years). Although we included a few participants over 18 years in Generations 2 and 3, the mean age was between 11 and 12 years in all three generations. Each participant was in the study only once, in only one historical period. We recruited siblings as participants within all three generations; nuclear family membership was then a control variable in our statistical analyses.

Sociodemographic assessment

Our investigation is concerned with economic changes, urbanisation and the expansion of formal education in Nabenchauk since 1969, when the community was agricultural, to 1991, when many people in the community worked in commerce, and from 1991 until 2012, by which point Nabenchauk had transformed into a small city. Based on family interviews, we created a scale of work activities and consumer items that came with the commercial economy. Participants received a point for each of 15 activities or items:

1. Participating child buys/sells agricultural products (other than peaches)
2. Participating child sells peaches
3. Participating child sells flowers
4. Participating child works in a shop
5. Participating child works for wages
6. Participating child works as a carpenter
7. Father participates exclusively in a modern activity (commerce, construction and carpentry)
8. Mother sells peaches
9. Mother sells tortillas
10. TV in household
11. VCR/DVD in household
12. Radio, cassette player or stereo in household
13. Family owns a shop
14. Family runs a mill
15. Family owns a vehicle

This same scale had been used to compare Generations 1 and 2 (Greenfield et al., 2003). Items (such as VCR and DVD) not available in the first generation were scored 0 for all participants in Generation 1. We include family-level commerce in the analyses because participants participated in daily activities with their families, sharing commercial activities and products.

We also asked about the number of years of schooling of each participant and his or her parents. Schooling was available in each generation, although the participation and amount available varied. For the first and second generations, only primary school was available in the village or the broader Zinacantec community. By the third generation, a *telesecundaria* (television-aided junior high school) was available in the community; and high school was available in the neighbouring community and in the ceremonial centre of Zinacantán.

For purposes of this article, we considered urbanisation to be a variable that differentiated generations as a whole. The community grew from about 1500 inhabitants in 1970 to 3000 in 1991 to about 4500 in 2012. As the geographic area stayed the same, population density tripled.

Figure 1. The experimental situation. A 9-year-old girl places sticks in a frame to represent one of the contemporary Zinacantec woven patterns (© Lauren Greenfield/INSTITUTE).

While population growth was steady from 1970 to 2012, new urban characteristics began to appear after 1991: houses changed character from one room to two storeys with multiple rooms; many different kinds of stores appeared in the village; and a local taxi service was established. Because of these new features, the urban character of Nabenchauk accelerated between 1991 and 2012.

To examine cognitive effects of weaving, we asked girls about their weaving experience (in this culture, boys do not weave). We developed a scale based on typical woven items (0–5 items, including a skirt, a poncho, two kinds of shawls, and a placemat or "little weaving").

Procedure

To observe cognitive development, we measured ability to represent and continue visual patterns, using the same procedure in each generation. We included culturally familiar, woven-cloth patterns and novel patterns. In all generations, children were asked to place wooden sticks in a wooden frame to represent patterns (Figure 1).

In 1969–1970 and 1991, the first part of the experiment consisted of placing sticks in a wooden frame, to represent the red and white patterns found in contemporaneous patterns worn by men and women: the men's poncho and the women's shawl (Figure 1). In addition, participants in 1991 and 2012 represented the poncho and shawl from 1969, and participants in 2012 represented the poncho and shawl from 1991, which was still being woven and worn. Because the shawl pattern was most complex, it is the pattern analysed for the present article. Figure 2 shows the shawl patterns used in the experiment.

In the second part of the procedure, an experimenter began different striped patterns that were culturally innovative—patterns that did not exist in Nabenchauk—and asked the participants to continue

Figure 2. Examples of red-and-white striped textiles that were the focus of data analysis: 1969–1970 shawl (left). Note that the broad red stripe is actually composed of three narrow red stripes separated by two narrow white stripes. These complex broad red stripes are separated by simple broad white stripes. Representation of this configuration constituted a correct representation of the shawl pattern. The textile on the left was the contemporary model used for the first generation of participants (1969–1970). The 1991 shawl (right), the contemporary model used for the second and third generations of participants, had the same configuration of stripes but the proportion of red to white had increased, most notably in the reduction of the width of the broad white stripes. Red, white, pink and orange sticks in three widths, narrow, medium and broad were available to represent these woven patterns.

them. Before the continuation of each pattern, the experimenter made three repetitions of the sticks and said, "Now you place the sticks like this." The three patterns shown at the top of Figure 3 were used to test children in all three generations.

A fourth novel pattern was the most complex. We called it the growing pattern because it began with an alternation of a red and a white stick, and was followed by two red and two white sticks, three red and three white sticks, and four red and four white sticks (Figure 4). This pattern differed from the others because there were three possible correct ways to continue it. A participant could make the pattern progress (five red sticks and five white sticks, six red sticks and six white sticks, etc.). A participant could also mirror the pattern in the opposite direction (from four of each colour down to one of each). Lastly, a participant could repeat the pattern presented, copying what was already in the frame. We considered the growing or progressive strategy to require the most innovative thinking because the child had to "go beyond the information given" (Bruner, Goodnow, & Austin, 1956). Going beyond the information given also required abstraction in the sense of mental representation because the participant had to create stripes that did not exist in the experimenter's concrete model.

Recording the data

Across all three generations, the colour and the size of stick selections were recorded on paper for each test item. In the first two generations, Greenfield did all data recording. For the third generation, recording was done by both Greenfield and Maynard, so reliability needed to be established. Therefore, both the researchers recorded the first 29 participants' responses in order to test inter-observer reliability of the field recording. Agreement was 99.99% for size and 99.87% for colour.

Dependent variables

Representations of woven patterns

Participants used two overall types of representation—detailed (thread-by-thread) and abstract. A detailed thread-by-thread representation grouped narrow sticks to represent broad stripes, just as multiple threads are used to construct broad stripes in weaving. An abstract representation simplified by using a medium or broad stick to represent a broad stripe, losing the detail necessary to weave the pattern. A detailed, thread-by-thread representation was considered an example of *Gemeinschaft*-adapted cognition, used in a particular subsistence context, the task of weaving clothes for the family. An abstract representation was considered an example of *Gesellschaft* cognition, a form of cognition adaptive both in school and in the world of commerce, with its emphasis on arithmetical abstractions.

For this article, we evaluated the correctness and style of representation of the contemporary shawl because of its greater distinctiveness and complexity, compared with the simple red and white alternation in the poncho. In 1969 and 1970 (Generation 1), the contemporary shawl was the one shown on the left of Figure 2. In 1991 (Generation 2) and 2012 (Generation 3), we used an updated version of the shawl (right of Figure 2); its striped pattern had the

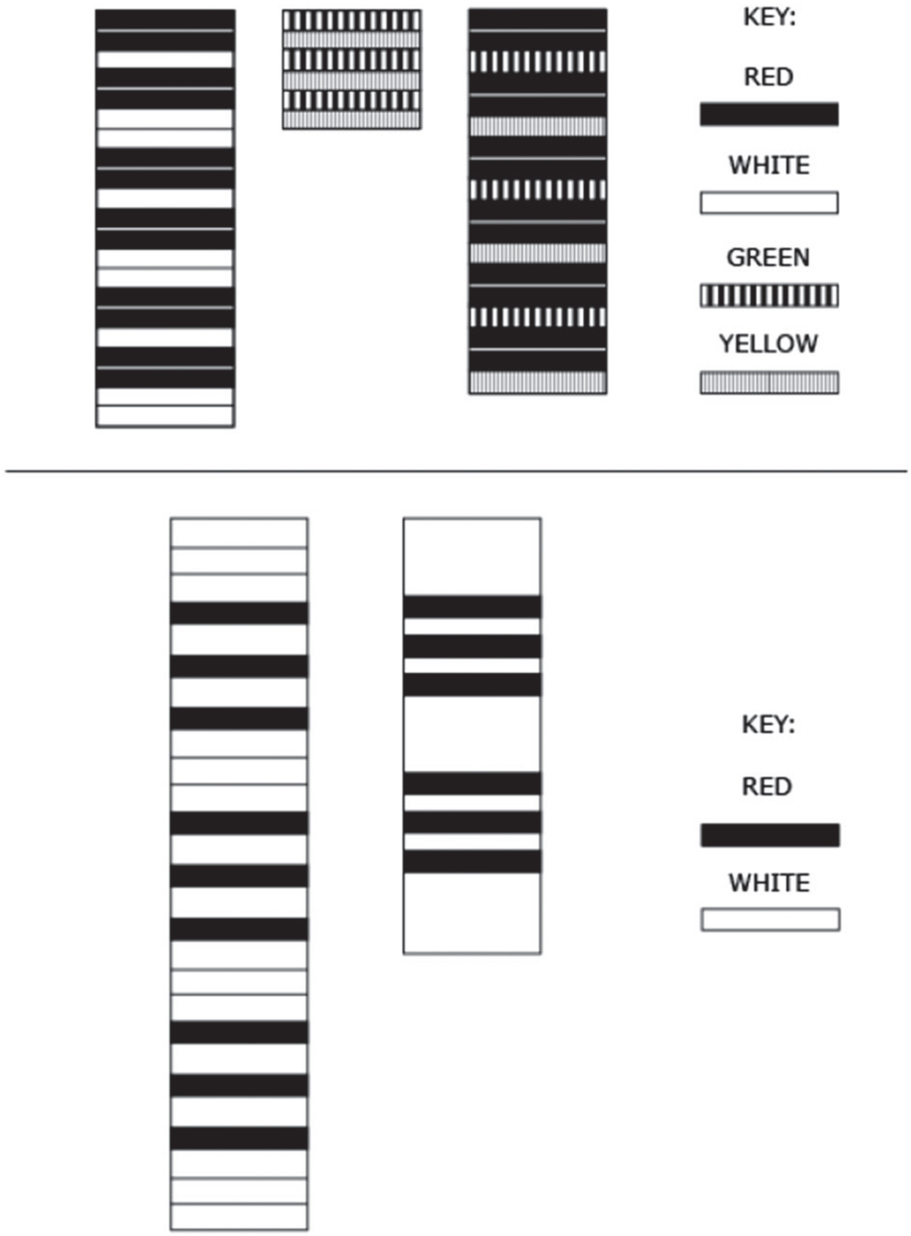

Figure 3. (top) Models for continuation of culturally novel patterns. Each model repeated the pattern three times. For the pattern on the left, narrow red, white, pink and orange sticks were available. For the pattern in the middle, narrow green, yellow, black and blue sticks were available. For the pattern on the right, narrow red, green and yellow sticks were available. (bottom) Detailed analysis (left) and abstract analysis (right) of a shawl.

same configuration of stripes (see details concerning this shawl in caption to Figure 2). We used the same shawl as a model in 2012 because it was still being worn by older members of the community and could be observed by our participants.

We counted any representation of the shawl as correct that constructed the configuration shown in Figure 2; examples are given at the bottom of Figure 3. Detailed representations comprised "thread-by-thread" responses using the narrowest sticks (bottom-left of Figure 3). Abstract representations included at least two medium or broad sticks included in the repeated pattern (bottom-right of Figure 3). The child's pattern had to repeat a correct, possible representation of the woven exemplar at least twice for it to be coded as a detailed or abstract representation.

Continuation of novel patterns

For the novel patterns shown at the top of Figure 3, we counted any pattern continuation as correct that had no errors. For the growing pattern, we counted any

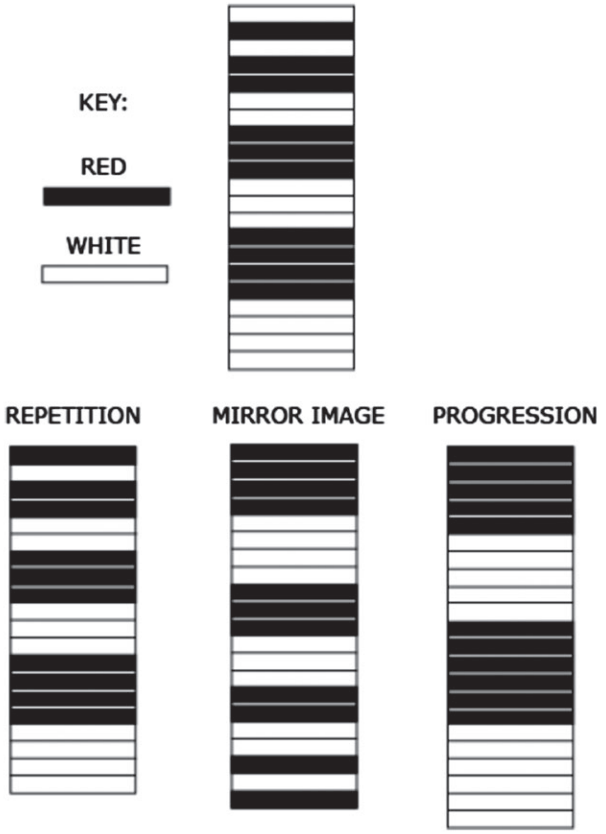

Figure 4. Model for growing pattern and three possible continuations. Narrow red-and-white sticks were available to participants for this item.

of the three possible strategies—progression, mirror or repetition—as correct that had from zero to three errors (Figure 4). We included some responses with errors because we were more interested in the strategy used than in its perfect execution.

Reliability

The 2012 data were coded by a rater unfamiliar with the hypotheses. The 1969–1970 and 1991 data were coded by the third author. The first author coded 20% of all the cases (i.e., all three generations) to determine the overall reliability with main coders. For the women's shawl, a reliability κ of .82 was achieved, a value that is considered "very good" (Altman, 1991).

For the novel patterns shown at the top of Figure 3, we calculated percent agreement; because the coding was simple and the agreement was very high, a κ-statistic would be misleading. From left to right at the top of Figure 3, percent agreement was 90%, 92.8% and 96.5%, respectively. For the growing pattern, percent agreement was also high, 96.5%. We resolved any differences in coding before progressing with the analyses.

RESULTS

Social change

Schooling

In each generation, children attended school for more years. Because the highest level in the village schools was 6th grade in the first and second generations and 9th grade in 2012, we selected out participants in the age of 13 years and above to examine rates and highest level of schooling achieved. We did not include younger children in this analysis to avoid reporting a skewed average number of years of schooling; younger children would have lowered each mean because many would have not completed their schooling. In participants ranging from 13 to 22 years, the average years of schooling increased from 1.00 in 1969–1970, to 1.94 years in 1991, to 4.88 years in 2012.

Commercial activity

In each generation, the families were more involved in commercial activity. On average, participants or their parents indicated that increasing percentages of items in the commerce scale applied to them: 2% in 1969–1970, 20% in 1991 and 27% in 2012.

Weaving experience

As more girls in the third generation went to school and stayed in school longer, weaving apprenticeship diminished. We base this analysis on girls of 8 years and above, because many girls in Nabenchauk in the first two generations were learning to weave by the age of 8. Aggregating the first two generations, we see that 75% of girls 8 years and above had already started to weave. By the third generation, the percentage had dropped precipitously to 42%.

Pattern representation

Woven patterns

For these analyses, we included participants at the age of 9 years and above, because 9 was the youngest age at which a child made correct abstract representations ($N = 228$ [129 girls]; mean age, 13.67 years). In each generation, abstract representation increased, as predicted. In 1969–1970, there were no correct abstract representations of the contemporary shawl. By 1991, there were two (1.8%) abstract representations of the contemporary shawl. By 2012, there were many more abstract representations: 29.2% of the participants at the age of 9 and above in the third generation used a correct abstract strategy to represent the contemporary shawl. A chi-square test showed that the distribution of strategies changed over the three generations ($\chi^2 = 39.06$; $df = 2$, $p = .000$, $N = 228$). Gender was not correlated with abstract representation.

There were differences in the associations of the macrolevel, sociodemographic variables between Generations 1 and 2, and between Generations 2 and 3. Because we expected a developmental difference, and in order to isolate the independent variables of commerce and schooling, we controlled for age in these analyses. From the first to second generation, controlling for participant's age, neither commerce nor schooling was correlated with abstract representation of the contemporary shawl. This may be because there was such a low rate of correct, abstract representations (from zero in 1969–1970 to two in 1991). However, from the second to third generations, controlling for participant age, schooling was correlated with abstract representation of the contemporary shawl ($r = 0.17$, $p = .03$), but commerce was not.

Whereas correct abstract representations were tied to schooling, correct detailed or "thread-by-thread" representations were tied to weaving experience. For this analysis, our sample was 152 girls of 8 years and older from all three historical periods. Eight was chosen as the minimum age because it was the youngest age at which any girl constructed a correct detailed representation. Among the girls who had woven all five of the items in our weaving scale, 55.5% constructed accurate detailed, "thread-by-thread" representations of the contemporary woman's shawl. Among the girls who had woven three or four of the items, 46.4% constructed accurate detailed representations. Finally, among the girls who had woven from zero to two items, only 13.7% constructed accurate, detailed representations. A chi-square analysis showed that the association between weaving experience and accurate detailed or "thread-by-thread" representations of the woman's shawl was statistically significant ($\chi^2 = 26.2$; $df = 6$, $p = .000$, $N = 142$).

TABLE 1
Results of Mixed Linear Effects Models.

Outcome measure	*Parameter*	*Estimate*	*Standard error*	*F value*	*p value*
Getting novel Patterns correct					
Generation 1 to Generation 2					
	Generation 2[a]	−0.59	0.25	5.31	.024*
	Age	0.10	0.03	10.05	.002**
	Sex	−0.09	0.24	0.16	.691
	School	−0.97	0.61	2.54	.116
	Commerce	0.14	0.06	6.02	.016*
Grouping variable: family relatedness (Wald Z = 0.441, *p* = .66)					
Model fit indicators: AIC = 333.34; BIC = 338.69					
Generation 2 to Generation 3					
	Generation 3[b]	−0.75	0.16	22.20	.000***
	Age	0.09	0.02	4.95	.027*
	Sex	−0.13	0.13	0.90	.343
	School	0.13	0.03	18.59	.000***
	Commerce	−0.11	0.46	1.367	.245
Grouping variable: family relatedness (Wald Z = 2.01, *p* = .045)					
Model fit indicators: AIC = 415.39; BIC = 421.51					

[a]Versus reference group, Generation 1. [b]Versus reference group, Generation 2.
*$p < .05$. **$p < .01$. ***$p < .001$.

Novel patterns

In each generation, children improved at representing the novel patterns. Participants in the second generation continued more novel patterns correctly (mean number correct, 1.98/4) than participants in the first generation (mean number correct, 1.46/4). Participants in the third generation continued the most novel patterns correctly (mean number correct, 3.59/4). In the first generation, boys completed significantly more novel patterns correctly, but there were no significant gender differences in 1991 (Greenfield et al., 2003). Similarly, there were no significant gender differences in 2012.

Using mixed linear effects modelling and controlling for family relatedness, we examined whether the relationship between historical period and correctly continuing the four novel patterns was statistically significant, and whether correct continuations differed with age, schooling, gender and commerce (Table 1). First, we compared Generations 1 with 2. The significant *F* test for generation indicates that there are differences between the two historical periods. Our prediction that commerce was the main driver of change between the first two generations was confirmed. Next, we compared Generations 2 with 3 on the same parameters (Table 1). Our prediction that schooling was the main driver of change between Generations 2 and 3 was also confirmed.

For the most difficult novel pattern—the growing pattern—the percentage of participants getting it correct doubled in each generation: Twelve percent of the participants continued the pattern correctly in the first generation; 24% continued it correctly in the second generation; and 49% gave a correct answer in the third generation. Of the participants who got the pattern correct, the most dramatic increase in making the pattern grow was from the first generation (18%) to the second generation (62%). However, contrary to prediction, only 52% of the participants who got the pattern correct in the third generation made the pattern grow.

DISCUSSION

We predicted that, as Nabenchauk moved increasingly in the direction of a *Gesellschaft* environment, there would be overall increases in abstraction and ability to deal with novel stimuli across the generations; these predictions were confirmed. Given that *Gesellschaft* environments can also be considered modern, our findings concerning novel stimuli are concordant with Gauvain and Munroe's (2012) finding that children's exploration of novel objects is positively correlated with societal modernity. At the same time, we found that weaving experience, a subsistence skill adaptive in a *Gemeinschaft* environment, was associated with detailed, thread-by-thread representations of the woven pattern, a cognitive strategy that is adaptive for the specific context of weaving.

We predicted that schooling would have a greater association with abstract representation than would commerce from Generations 2 to 3. This prediction was confirmed. We predicted that children would increasingly "go beyond the information given" in each generation to represent the growing pattern; this prediction was upheld only from Generations 1 to 2. However, as predicted, correct representations of this most complex novel pattern (using any of the three strategies) increased dramatically from Generations 1 to 2 to then 3. We predicted that gains in ability to correctly represent novel patterns would be associated with commerce from Generations 1 to 2, but with schooling from Generations 2 to 3; and we showed this to be the case.

Thus, an important tenet of Greenfield's (2009) theory was able to be tested and validated using this cross-temporal, three-generation design: Whatever sociodemographic variable is changing most rapidly between two time-points will be the one to drive developmental change. Commerce had been the main sociodemographic change between 1969 and 1991, and our results show that it was the main driver of cognitive change in that time interval. By 1991, commerce had become a constant, but schooling continued to change dramatically between 1991 and 2012. Correlatively, schooling had the bigger impact in the period from 1991 to 2012 on children's increasing ability to deal with novelty.

However, not all the intergenerational cognitive change is accounted for by our models. We speculate that the increasing urbanisation of Nabenchauk accounts for much of the remaining intergenerational change. However, because Nabenchauk provides the same basic community environment for all its residents at any given period of time, the influence of urbanisation is not amenable to statistical analysis.

Development is not a constant across historical time (e.g., Pinquart & Silbereisen, 2004). Changes in the macro-level environment affect cognitive development bringing losses as well as gains. For example, increased formal education promotes abstract visual representation. Our readers will undoubtedly consider abstraction to be useful and important; but when a girl is weaving, she needs a thread-by-thread understanding. The detailed view is adaptive in a *Gemeinschaft* world where weaving is a subsistence skill. In contrast, abstract cognition and being able to solve novel problems are adaptive in a *Gesellschaft* world of school-based learning and a commerce-based economy.

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