MIND, CULTURE, AND ACTIVITY, *12*(3 & 4), 171–225

ARTICLES

Studying Cognition in Flux: A Historical Treatment of *Fu* in the Shifting Structure of Oksapmin Mathematics

Geoffrey B. Saxe and Indigo Esmonde
University of California Berkeley

This article extends a framework for the study of culture–cognition relations to problems of historical research and diachronic analysis. As an illustrative case, we focus on mathematics in Oksapmin communities located in a remote highland area in central New Guinea. The Oksapmin, like their neighboring Mountain-Ok groups to the West, traditionally use a 27-body-part counting system for number, and there is no evidence that Oksapmin used arithmetic in prehistory. We present a coordinated analysis of shifts in functions of a word form based on field studies completed in 1978, 1980, and 2001. These shifts are related to changing collective practices of economic exchange in which arithmetical activities are increasingly important. The word form *fu* has changed from its use as an intensive quantifier that means "a complete group of plenty" to one that means double a numerical value. We show how the analytic framework affords a multilevel inquiry into genetic processes of change in the Oksapmin case and argue that the approach is useful for understanding the interplay between cultural and developmental processes in cognition more generally.

PROLOGUE

In June 2001, four of us left Berkeley for two Oksapmin valleys located in the highlands of central New Guinea. This part of New Guinea remains remote; first contact was in 1938, and there are still no roads to the area. The trip for me[1] was a return to a special part of the world where I had spent time in 1978 and then 1980. During those periods more than 20 years ago, I was engaged with research on mathematical cognition among a people who use a 27-body-part counting system and who in traditional life did not engage in arithmetical practices (see Saxe, 1982a; Saxe, 1982b).

As a way station in our 2001 trip, we stopped in a mining town, Tabubil, about 100 km west of Oksapmin. In this town we met up with old Oksapmin friends who had come to seek West-

Correspondence should be sent to Geoffrey B. Saxe, Graduate School of Education, University of California, Berkeley, Berkeley, CA 94720–1670. E-mail: saxe@berkeley.edu

[1] As the narrative moves from Saxe's early work and developing conceptual framework to the studies that Saxe and Esmonde conducted together in Oksapmin communities in 2001, so does the use of first-person singular (reference to Saxe) and first-person plural (reference to Saxe & Esmonde).

ern-style employment. In the rapid flow of talk that cut across English and my limited understanding of Tok Pisin and even more limited Oksapmin,[2] our conversation shifted to mathematical topics, and at this point I heard an Oksapmin word that sounded like *fu*. *Fu* (or sometimes *tit fu*) was an expression that I had learned on my earlier visits, but now it was used in a way that puzzled me. I asked about *fu*, and our companions explained that when preceded by a body part name, *fu* meant to double the value of the body part. They noted, for example, that when one points to the nose (*aruma,* 14th body part in the Oksapmin sequence) and says *arum-hai fu*,[3] the meaning is to double the value of the nose (14), yielding a value of 28. Now this was perplexing. As an apprentice to the numerical practices of Oksapmin elders in 1978, I had learned that *fu* with fists raised meant a completion of all 27 body parts in a count. In fact, there were no arithmetical procedures for adding and subtracting body parts, and doubling body parts would have been a very foreign idea at the time. For me, a student of mathematical cognition, this was a remarkable turn of events.

These 2001 Tabubil conversations introduced the problem with which we engage in this monograph: How do new collective systems of representation and associated mathematical ideas arise in the social history of a social group? Was this *fu* a historical descendent of the earlier *fu* that I had learned long ago? Or was this a new word form, perhaps borrowed from a neighboring group? Did someone invent *fu* as a way to represent values greater than those permitted by the indigenous number system? If any of these processes fits the case, how did new uses of the word come to spread in the social history of Oksapmin communities?

This monograph, then, is about two histories. One portrays our own investigative history—the flow of our investigative activities in which we gradually came to frame a problem, produce observations, follow up leads, and produce a series of empirical studies that allowed us to reconstruct a partial history of a small piece of Oksapmin mathematics: *fu*. This became an engaging enterprise, much more complexly nuanced than I imagined at the outset. The other history that we trace here is a partial history of Oksapmin mathematics itself, from precontact times to the present, a history that is quite remarkable. These two histories are, of course, intertwined. The Oksapmin history necessarily reflects our own investigative frame and activities, enabling and at the same time constraining the view of Oksapmin history that we present. At the same time, our own investigative history—our series of investigative moves—took form as we adjusted our inquiry to information that emerged from our observations and a series of systematic empirical studies.

In the end, our empirical contribution to the history of Oksapmin mathematics is certainly very modest: the history of a single word form. However, the word form is a microcosm that permitted us to document a complex interplay between cognitive and sociohistorical processes. This interplay stands out in unusually clear relief in our analyses, and the dynamic processes that we document may be quite general, extending far beyond the boundaries of our inquiry into the Oksapmin case.

---

[2] Tok Pisin, sometimes referred to as Melanesian Pidgin, is one of Papua New Guinea's national languages, known and used throughout the country, except perhaps in the most remote regions. We occasionally use the expression *Tok Ples* which refers to the vernacular language of a specific cultural group in Papua New Guinea. In the case of the Oksapmin people, Tok Ples is the Oksapmin language.

[3] *Aruma* in Tok Ples means nose, and the nose is the 14th point in the body system (an ordinal). In Tok Ples, to turn this count position into a cardinal, one adds the suffix *hai*. *Arum-hai fu* thus stands for the cardinal value of 28.

SOCIAL HISTORY, COLLECTIVE PRACTICES, AND COGNITIVE PROCESSES: TOWARD A METHOD OF STUDY

We begin with a brief account of the construct of history in treatments of cognition, a construct that is not well represented in extant frameworks. We hope to make a contribution to this research literature in conceptualization and in empirical and analytic techniques.

History as a Construct in Treatments of Cognition

Analyses of cognition that are well-coordinated with historical analyses are few in number, despite the importance ascribed to historical perspectives by many prominent scholars (e.g., Cole, 1996; Damerow, 1996; Scribner, 1985; Wertsch, 2002). Most empirical studies that are concerned with culture–cognition relations and that make appeals to history as an important construct are not themselves historical. Many investigators have used Piagetian tasks to reveal whether there is cross-cultural variability in rates of development or whether some communities do not progress through Piagetian stage sequences (for an early review, see Dasen, 1972), and some have interpreted these data in historical terms, likening extant subsistence-oriented societies to earlier points in the history of Western technologically oriented societies (Hallpike, 1979). This modernist narrative—that human history is on a single Western-style trajectory—should be viewed with skepticism, especially as a method for linking transformations in human cognition with social history (see Cole, 2002; Wertsch, del Rio, & Alvarez, 1995). Indeed, such approaches can tell us little if anything about the interplay between historical and developmental processes.

An important trend that is more sensitive to issues of historical context takes a different orientation, often associated with Vygotsky's writings (Vygotsky, 1978, 1987) and sometimes ecocultural frameworks (Berry, 2003; Dasen, 2003). An important idea in the Vygotskian-inspired work is that individuals draw on cultural resources to structure and accomplish problems with which they engage in everyday socially organized activities (for contemporary treatments, see Cole, 1996; Saxe, 1991; Scribner & Cole, 1981; Wertsch, 1991). From such a perspective, researchers have situated analysis of cognition in the particular social and historical predicaments that marked the activities of individuals. In studies of dairy workers loading crates (Scribner, 1984), navy personnel operating a ship (Hutchins, 1995), and street children engaged with the sale of goods (Nunes, Schliemann, & Carraher, 1993; Saxe, 1988), investigators showed how the cognitive activities of individuals draw on properties of artifacts and the activities of others in structuring and solving local tasks. Though such studies pointed to the importance of historically situated activities in cognitive analyses, they did not focus on the dynamics of historical change itself and its relation to the conceptual activities of individuals. Further, many of these studies are not developmental. That is, they do not offer ways of understanding processes of peoples' developmental trajectories as they engaged with historically situated practices.

An approach that is more closely geared to an account of history and cognition is the cross-sectional study of single communities undergoing rapid social change. By sampling cohorts with different levels of engagement with newly emerging practices and assessing their performance on varied kinds of cognitive tasks, investigators seek to gain insight into the way historical shifts in practices may be interwoven with the cognitions of individuals (see Butler, 2000; Luria, 1976;

Saxe, 1982b). These studies themselves vary in the extent to which they adequately capture social history and development.

Luria, in studies of postrevolutionary Soviet Union, for example, made use of this method. Luria administered logical syllogisms and other similar tasks to five groups that had undergone different degrees of collectivization. He found that the reasoning of the groups differed, and that with collectivization, groups tended to perform in ways consistent with Western norms. Practices in everyday life and the cognitive problems that emerged in those practices, however, were left largely undocumented. As a consequence, the assessments are not informative about how local historical conditions might support particular kinds of knowledge and representations in individual activity.

Though an advancement over cross-cultural methods for historical analyses, even the best of such cross-sectional designs have their limitations. Without documentation of a significant stretch of historical time, we cannot follow particular strands of change—the way that ideas, conventions, and social organizations are brought forward and the way that these historically situated products may become transformed or fade over historical time in networks of interactions that are themselves shifting.

More recently, Greenfield employed a longitudinal method in a study of cognitive development, visiting the same site in Chiapas, Mexico, over substantial stretches of historical time (Greenfield, 1993, 1999; Greenfield, Maynard, & Childs, 1997). The longitudinal nature of her design enabled systematic analyses over the period from 1969/1970 to 1991. Over the 20-year period, the Chiapas community shifted toward greater commercialization, and Greenfield documented concomitant shifts in both the process of teaching and learning interactions involving weaving, and associated differences in weaving pattern–recognition skills in children.

Greenfield's study is an important and unique contribution in at least two ways: its longitudinal methodology and its contribution to our understanding of ontogenetic development in changing historical circumstances. Greenfield's study, however, is missing an account of the dynamics of change not only as individual activity takes shape in relation to history, but also as social history is shaped by individual activity. This is more than a simple omission. Rather, it reflects a particular way of framing problems that avoids analyses of the interplay between collective and individual activity in the production of a future or the reconstruction of a past. We see this as a feature of approaches that are often referred to as *sociohistorical* but focus on cognition in different historical periods. When problems are framed that render historical time as decoupled into separate contexts and then measured to be reconstituted through stochastic methods, it is not possible to recover the participation of individuals in processes of historical change. From a diachronic perspective, we would want to ask: Do some teaching interactions become valued and proliferate in communities under changing conditions? If so, how does this movement proceed over historical time? How do innovative practices—like weaving patterns—emerge and become valued over historical time to become, in turn, collective representations used by individuals in practices? In other words, how does the activity of individuals shape historical change, and, reciprocally, how does historical change affect individuals' practices?

To reorient the study of history in cognitive analyses requires a different way of framing analyses. This is a complex problem, indeed, and we consider it here in relation to the emerging methodological challenges that we faced in the field.

Methodological Challenges for a Diachronic Analysis

From Tabubil we took a much smaller aircraft to a dirt landing strip in Bak valley, a strip that had been cleared 2 years earlier (a 15-year effort by local people!) and about a 45-minute hike from some of my 1978 studies. About 3 weeks into our stay in the Oksapmin community, we were engaged with research issues related to Oksapmin mathematics. We had reunions with people I had known long ago and with many others who had become fast friends with Tom Moylan and Virginia Guilford, two resident anthropologists with whom I stayed in 1978; we had made observations in sites of interest—classrooms, trade posts, an air strip during vegetable exports; and we had almost completed a large and intense data-collection effort on practices of representation. At about this time, our inquiry became analogous to one of an evolutionary biologist, well captured by Stephen J. Gould in his account of the origins of a bird's wing (Gould, 1996). It is here that our entry into diachronic issues begins.

Gould (1996) asked, How could the wing have evolved? The question leads to a conundrum that often emerges in accounts of evolution. The precursory forms of a wing—those that did not afford loft—could not offer a survival advantage for flight. The discontinuity of function—from no flight to flight—is an evolutionary puzzle. How did proto-wings themselves emerge? Why did they endure? Clearly, the evolution of the wing could not be a story of continuous perfection of the flight function. A small fraction of a wing is not adaptive; it just doesn't allow a creature to fly. At the same time, a working wing is a complex anatomical structure and could not have appeared suddenly as a fully formed organ.

Like other evolutionary biologists, Gould (1996) argued that to understand the evolution of the wing, we must appreciate that evolutionary change is a complex of quirky shifts between anatomical forms and the functions that they serve. The wing's progenitor may well have offered organisms a selective advantage by serving a function other than flight. On this argument, the seeds of flight would have been born from the structural properties of these proto-wings that served other functions. Like other evolutionists, Gould points to thermal regulation as a likely candidate for the transitional function. Proto-wings that regulated temperature, by coincidence, may have supported a degree of loft, and the nature of the adaptive advantages that they afforded shifted, giving their possessors a novel selective advantage. This, in turn, led to new lines of evolutionary change and new ecological niches.

Though there is a world of difference between adaptations in the origins of species and adaptations of symbolic forms that have emerged in the social history of mathematics, we believe that the parallelism is instructive (for more on this view, see Croft, 2000; Hull, 1988; Werner, 1948). We explore its utility here, building on the framework elaborated in my prior work concerned with shifting relations between forms and functions in developmental analyses (Saxe, 1991; Saxe, 1999; Saxe, 2005) and extending the framework to the diachronic analysis of mathematics in communities. For us, the evolutionary conundrum, the origins of *fu* as double, poses three challenges for argumentation and evidence within a diachronic analysis.

Genetic continuity of form. The first challenge is to establish genetic continuity of form. In the case of the wing, how do we identify the progenitor form? The answer is not straightforward and is well represented in problems of cladistics. Consider, for example, the bat (a mammal) and the sparrow (a bird). The wings of both these creatures serve the function of flight, but evolutionary

wisdom has it that their genetic roots are quite different. In other words, though we find similarity of form and function in the wings of these creatures today, the progenitors of these forms and functions differed. In a similar way, we can ask, Are the early form and function associated with *fu* (in expressions like *tit fu* with its accompanying gesture) the progenitor of the current form of *fu* (in the sense of "double the value of a body part")? The problem is not trivial. It may well be that the two *fu*s are like bats and birds, spawned from quite different evolutionary lines that could be revealed in the linguistic analog to cladistic analyses. Perhaps they are linked by a common genetic lineage, and an understanding of that lineage would help us understand the origins and development of mathematical thought in this community. For us, the empirical challenge became a search for evidence that indicates whether the doubling *fu* had roots in the counting *fu*.

Genetic continuity of function. A second challenge is part and parcel of the first—to establish the genetic continuity of function. This is a complex analytic task. In the case of the wing, we noted that for Gould (1996) the evolutionary answer to the quirky shift problem is that the proto-wing could have evolved only if it afforded an adaptive advantage. Further, this adaptive advantage could not have been flight itself, because these appendages could not support flight in the ancestors of modern birds. The same argument applies to *fu*. A genetic perspective implies that the new function of *fu* that appears so radically discontinuous (its use as a multiplicative doubling operator) should exhibit transitional functions in activities of quantification, ones in which *fu* served nonmultiplicative functions that themselves were useful. The real challenge here, of course, would be to discover how novel multiplicative functions might emerge from other transitional functions. In other words, we seek to understand how discontinuity emerges through continuous change.

Changing niches and implications for genetic shifts in form–function relations. A third challenge for the evolutionary analysis concerns the idea of a niche. The analytic challenge is twofold: (a) to understand the conditions in which progenitor forms were viable and (b) to trace the shifts in properties of niches that support diverging evolutionary trajectories between parent and child forms and functions. Consider again the progenitor of the wing. Presumably, the ancient ancestors of modern birds were well adapted to their niches. Through environmental changes—such as a changing climate—particular mutations afforded new survival advantages. If the progenitor of the wing regulated temperature it might have conferred a survival advantage on the early ancestors of modern birds. Understanding the complex interplay between shifts in properties of organisms and properties of their niches is key to an evolutionary treatment.

In its broad contours, we can apply the same kind of analysis to questions about the genesis of *fu*. First, we would need to identify the sociohistorical niche equivalents in which earlier functions of *fu* were sustained, as well as conditions that led to shifts in properties of these niche equivalents relevant to form–function relations.

What might be the sociohistorical equivalent of the niche in the treatment of semiotic systems like mathematics? We argue that the construct of collective practices should be a strong candidate, and our analyses to follow are based on this argument. As we noted earlier, collective practices—such as economic exchange in trade stores—are semistable, socially organized activities in which individuals participate and communicate with one another, making use of varied cultural forms (language, gesture, body parts) to support communicative intentions. Further, changes in

collective practices, like those brought about by shifts toward a differentiated money economy, lead to the emergence of new coordination problems in activity (see Clark, 1996; Lewis, 1969), problems for which prior communicative approaches may be ill suited. Both continuity and discontinuity in these shifting practices, where some forms and functions may be more robust than others, provide an important focus of study.

We now turn to a selective sketch of Oksapmin history related to mathematics and collective practices of exchange. The history provides important background information for our exploration of our inquiry into *fu*. We first consider historical change of collective practices in Oksapmin and then move to an exploration of changes in individual practices related to mathematics and *fu*. We argue that, in the case of *fu*, historical change and individual development are tightly interconnected and shape each other. In the last section of the article, we close by considering how the case of *fu* illuminates processes of development more generally.

COLLECTIVE PRACTICES OF ECONOMIC EXCHANGE WITH CURRENCY FROM WESTERN CONTACT THROUGH 2001

The island of New Guinea is inhabited by over a thousand cultural groups that speak well over 800 natural languages. Near the center of the New Guinea island, Oksapmin is one of a mosaic of many distinct Mountain-Ok groups.

The Mountain-Ok share an overlapping material culture, including some patterns of dress, tools, weapons, cosmologies, and subsistence practices (Hyndman & Morren, 1990). Languages, however, differ across Mountain-Ok communities. Figure 1 depicts the geographical location of Mountain-Ok communities in New Guinea and the 7 related Mountain-Ok languages, including Ngalum, Tifal, Miyanmin, Telefol, Bimin-Kuskusmin, Faiwol, and Fetik. In addition to these closely related languages, some Mountain-Ok communities speak languages more distantly related to the core. Oksapmin is considered one of these language isolates, a member of the Trans-New Guinea languages (Wurm, 1983). Today, there are about 18,000 Oksapmin speakers.

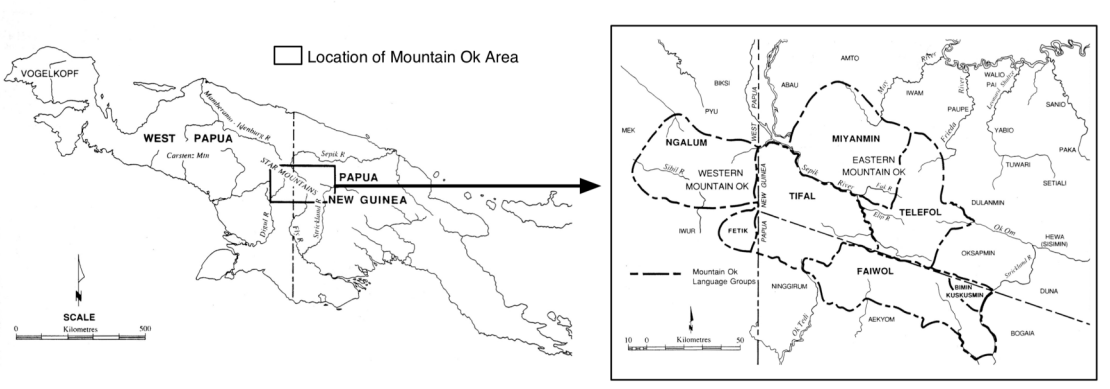

FIGURE 1 Location of Mountain-Ok communities in Central New Guinea (left) and languages of Mountain-Ok groups (right). Maps by Aub Chandica, in B. Craig & D. Hyndman (Eds.), 1990b, *Oceania monographs: Vol. 40. Children of Afek: Tradition and change among the Mountain-Ok of Central New Guinea* (pp. 211, 212). Sydney, Australia: University of Sydney.

FIGURE 2 Man in traditional dress (1978) smoking indigenous pipe in his taro garden.

The geography of the Mountain-Ok area is rugged and includes a number of distinct biomes with different conditions that support different flora and fauna. As in all Mountain-Ok groups, traditional subsistence practices in Oksapmin communities include cultivating taro and sweet potato, keeping pigs, and hunting with bow and arrow for birds and small mammals. People also collect other sources of protein, including various types of insects, worms, and tadpoles. Traditional dress is a grass skirt for women and a penis gourd and cane belt for men. Figure 2 shows a man in traditional dress, a friend I photographed 25 years ago.

The cosmology of all the Mountain-Ok groups is rooted in an origin myth of a magical woman (Uanku in the Oksapmin area but referred to as Afek by the Telefolmin and other Min groups). Uanku traveled long ago through the Oksapmin area from the east toward the western Mountain-Ok. She brought with her culture, including language (perhaps number), horticulture, and gendered roles for men and women (Brumbaugh, 1990; Brutti, 2000). Some believe that Uanku shifted languages as she encountered groups on her travels, accounting for the language differences among neighboring groups. All Mountain-Ok groups know of some version of the myth, though accounts of Uanku's travels differ (Barth, 1987). Initiation in some Mountain-Ok groups involves difficult challenges, and as these challenges are met progressively more secret knowledge is revealed, such as progressively deeper meanings of Uanku's activities (Brumbaugh, 1990).

Figure 3 contains a timeline for the historical period that is our focus of study—from just prior to Western contact through our fieldwork in 2001.[4] We find it useful to partition the history of economic exchange relevant to mathematics in the Oksapmin area into a precontact period and then three recent subperiods extending over about 60 years. The figure depicts a growing differentiation between subsistence and commercial economies, a differentiation depicted by the diverging lines. Height in the chart (the vertical axis) is our guesstimate of commercial economic

[4]Weeks (1981b) presents a more complete chronology of events related to contact in the Oksapmin area.

activity as indexed by export of vegetables, cash in circulation, number of commodities sold in Oksapmin trade posts, and proportion of people who participate in the cash economy. We have somewhat artificially marked the beginning of this divergence about 1960, though processes before the 1960s seeded a gradual differentiation. Though the line shows an upward trajectory in the amount of currency in circulation, note that it may not always continue to increase in the same way. When the Ok Tedi mine in Tabubil closes in several years as the ore is exhausted, Oksapmin communities will lose their principal market for vegetables as well as a source of employment for people from the community. At that time, remittances will probably decline.

Precontact

Archeology in the Telefomin area (Swadling, Mawe, & Tomo, 1990) shows that the Central New Guinea highlands were inhabited at least 17,000 years ago, with varying periods of activity since that time. Hyndman and Morren (1990) argue that the introduction of the sweet potato in the Mountain-Ok area about 300 or 400 years ago had a profound effect on life in the region. By their analysis, preceding the introduction of the sweet potato the principal staple for people in Central New Guinea was a type of taro that grew only at a limited elevation range; the people also raised pigs, an important source of protein. The sweet potato could be cultivated at a wider range of elevations. It became a principal staple for human consumption and was also used as fodder for pigs. The increase of food supply (both in the rise of the pig population and in the sweet potato) and the need for additional land to support the supply led to both population increases and outward expansion from a central core into alternative biomes.

Trade was central to life in prehistory in Mountain-Ok groups (Cranstone, 1990). Oksapmin obtained (a) stone axes from the north; (b) black palm, shells, and bows from the south; (c) salt from the east; and (d) kundu drums from the west (see also Weeks, 1981a). In precontact times, people traded commodities, which included shell valuables, a form of currency used across Mountain-Ok groups. Robbins (1999) provides a fascinating discussion of the function of such

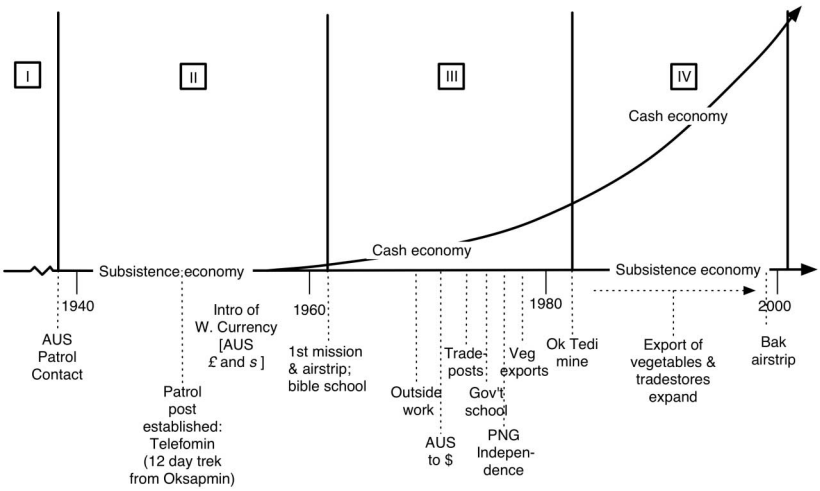

FIGURE 3 A growing differentiation between subsistence and cash economy in Oksapmin (1940–2001).

valuables in the case of the Urapmin, a group located near the Oksapmin. Figure 4 depicts known trajectories of commodities (from Craig & Hyndman, 1990b).

The Oksapmin's 27-body-part counting system has its origins in precontact times, but its history is unknown during this period. The system is depicted in Figure 5. To count as Oksapmin traditionally do, one begins with the thumb on one hand and enumerates 27 places around the upper periphery of the body, ending on the little finger of the opposite hand (Moylan, 1982; Saxe, 1981). To indicate a particular number, one points to the appropriate body part and says the body part name. For example, to indicate the number 12, one points to the ear which is the 12th body part in the sequence, and says the word for ear, *nata*. To count past the 27th body part, one continues up to the wrist, to the forearm, and on up and around the body. There is no distinction between the name for the 21st body part and the 29th body part; both are called *tan besa* (other forearm, indicating the forearm on the opposite side of the body from which the count was initiated).

With the completion of the little finger (27th body part), it was customary to produce a stereotypic gesture, raising one's fists, exclaiming, "*tit fu!*" (see Figure 6). The expression signals the completion of a count of all of the body parts. In 1978, when I took assiduous notes on properties of the Oksapmin count system, many members of the Oksapmin community used this expression. At that time, I had no inkling that *fu* would come to occupy a good deal of reflective and empirical analysis 23 years later.

In many respects the Oksapmin system, like its Mountain-Ok counterparts, appears well tailored to serve traditional needs in everyday life, as are many number systems across human communities (Crump, 1990; Menninger, 1969). It was (and to some extent still is) used in daily activities that involved counting valuables, measuring string bags (a common artifact), and indicating ordinal positions (such as ordinal relations on a path). Arithmetic, as Westerners know it, appeared to be nonexistent in traditional life.

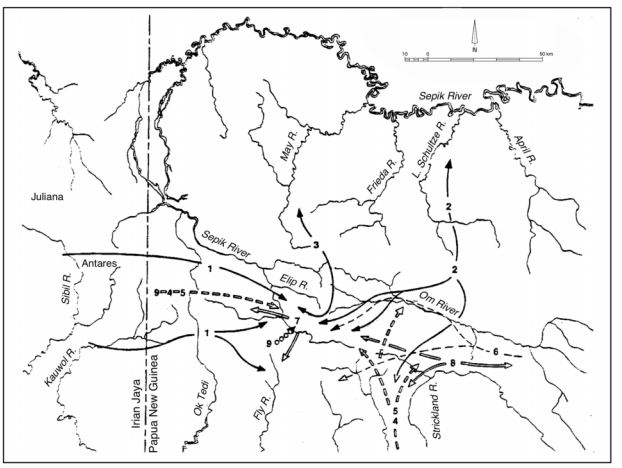

FIGURE 4 Movement of commodities through successive trades with neighboring groups in Mountain-Ok prehistory. Figure used with permission from Barry Craig, in B. Craig & D. Hyndman (Eds.), 1990b, *Oceania monographs: Vol. 40. Children of Afek: Tradition and change among the Mountain-Ok of Central New Guinea* (p. 248). Sydney, Australia: University of Sydney.

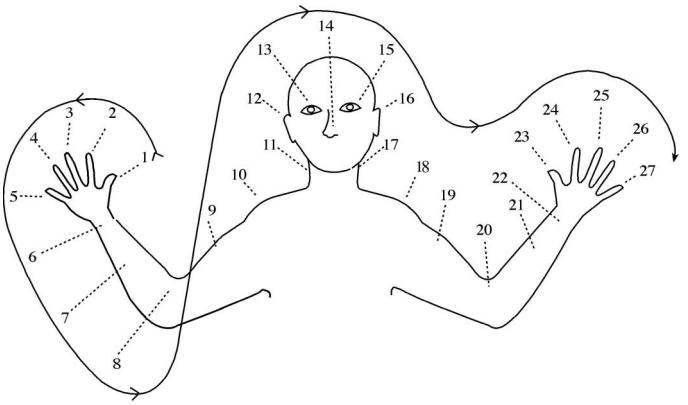

FIGURE 5 Body part count system with 27 distinct points. In order of occurrence: (1) thumb (TIP^NA), (2) index finger (TIPNARIP), (3) middle finger (BUM RIP), (4) ring finger (H^TDIP), (5) pinky (H^TH^TA), (6) wrist (DOPA), (7) forearm (BESA), (8) elbow (KIR), (9) biceps (TOW^T), (10) shoulder (KATA), (11) neck (GWER), (12) ear (NATA), (13) eye (KINA), (14) nose (ARUMA), (15) eye on other side (TAN-KINA), (16) ear on other side (TAN-NATA), (17) neck on other side (TAN-GWER), (18) shoulder on other side (TAN-KATA), (19) biceps on other side (TAN-TOW^T), (20) elbow on other side (TAN-KIR), (21) forearm on other side (TAN-BESA), (22) wrist on other side (TAN-DOPA), (23) thumb on other side (TAN-TIP^NA), (24) index finger on other side (TAN-TIPNARIP), (25) middle finger on other side (TAN-BUM RIP), (26) ring finger on other side (TAN-H^TDIP), (27) pinky on other side (TAN-H^TH^TA) [Saxe, 1981].

FIGURE 6 Woman reaching 27th body part and making stereotypic gesture of raised fists accompanied by the exclamation of *tit fu*!

Both close and more distant Mountain-Ok neighbors use the same 27 body parts, sometimes with slight variations in the order. For example, some groups west of Oksapmin do not start with the thumb, as the Oksapmin do, but instead with the little finger. This is true of the Sibilmin far from Oksapmin at the western-most part of the Mountain-Ok area (Brongersma & Venema, 1962), the Nekalimin in the border region with West Papua (Wesch, 2005), and the Telefolmin people (Healey, 1965). In contrast, the Asabano, allies and trading partners with the Oksapmin, use the same sequence of body parts (R. Lohmann, personal communication, January 2004)[5] and, like the Oksapmin, loop back around the body to count numbers greater than 27. All groups distinguish the first 13 body parts from their mirror-image last 13 by the use of a morpheme, but the more western groups cited use a suffix, whereas the Oksapmin groups use a prefix, *tan* (meaning roughly, "other side"). Further, the reports of the Sibilmin, Nekalimin, and Telefolmin counting systems do not describe the looping procedure. No reports of Mountain-Ok communities other than the Oksapmin document the punctuation of the completion of the 27-body-part count with the use of a specialized word form (*fu* in the Oksapmin case). Prior reports may well lack completeness, however, given that mathematics was not a focus of prior investigators.

Period I (1938–1960)

Westerners made first contact with the Oksapmin during the 19-month 1938–1939 Hagen–Sepik patrol. The Hagen–Sepik Patrol trekked through the Central New Guinea highlands in search of minerals and to establish a site for a patrol station. It was an enormous undertaking. Led by James Lewis and John Black, the patrol included 350 people who served as carriers and police from varied regions. In part because of the need to keep this enormous number of people fed, the patrol splintered in two early in its expedition. One party, led by Black, made first contact with the Oksapmin as it moved west toward Telefomin in June 1938. Several months into their journey, John Black's patrol segment traveled through Bak valley and established a base camp near Tekin, a part of the Oksapmin area that was a site of some of our work 40 years later.

Gammage (1998) provided a synthetic account of this patrol's first contact with Oksapmin people, an account culled from the extensive original patrol report and follow-up interviews conducted many years later with members of the patrol and with surviving people from the contacted groups. In a description of first contact, Gammage described a scene at Kunanap, an area on the periphery of Oksapmin. A member of the patrol, in an effort to appease local people for beginning to set up camp in their territory, offered a cowry shell as a friendly gesture to a large group of Oksapmin men who assembled with bow and arrow. The gesture was refused, and members of the Patrol killed Oksapmin men. A few days later the patrol entered the Tekin area. Gammage provided the following vivid portrayal based on reports pieced together from Oksapmin people.

> … the Tekin knew of the Kunanap killings, and heard that witches were eating the dead from the inside out, as witches did. They thought they too would be eaten and were determined to resist, clearing shooting lanes and stacking stones and clubs against an invasion. Allies came from as far as the upper Om to help. Six miles west an easy track led into the valley: that way a friend would come. Instead, as at Kunanap, the line crossed a steep range onto their rear. Yet only four spirits advanced [members of the Patrol]. The Tekin thought them easy meat. They would come from the bamboo, take them by the hand, slash out their eyes with a knife, and lead them away to be eaten. That was the custom. (p. 102)

[5]Concerning field notes dated April 18, 1994.

Based on John Black's field reports, Gammage noted the unintended inflationary effects of very early trades with Westerners.

> As at Hagen and Hoiyevia, people traded food for axes, salt, shell and beads, then at a profit bought food from neighbors to trade again. They were the "envy of people for miles," John noticed, "Travelers are already coming long distances to trade … no doubt paying toll to the local people for the privilege." (p. 108)

It was not until 1948—10 years later—that the Australian government established an outpost in Telefomin, about a 12-day trek from Oksapmin. Telefolmin people were traditional enemies of Oksapmin, and the hostility probably inhibited direct contact between Oksapmin and Western officers. Nonetheless, the presence of the patrol post may have been a source of the introduction of Western artifacts (including Australian shillings and pounds) through successive trading partners.[6]

Patrol reports from this era described initial contact with many different indigenous groups in the area who were often suspicious of the foreign element. Some reports make mention of early efforts to trade with local people for food and some of the difficulties encountered with kinds of items that were valued in barter. Patrol Officer Rogers (1949) wrote:

> From the experience gained during the patrol and from information gained by questioning natives on the station it was learnt that the best trade was tambu, salt, and large girigiri in that order. Unfortunately the patrol did not have any tambu and the girigiri held by the patrol was of the small variety. There is little interest and no demand for goldlip shell.
>
> The natives in the area are of course hungry for steel in the shape of tomahawks and knives. A few steel tomahawks have found their way into the area via native trade routes leading down into the Fly and Sepik rivers. The majority of the stone tomahawks held by the natives have also come to the area via these trade routes. A few stone tomahawks were seen that resembled the Mount Hagen type in design, these come from a trade route up the Om river … (p. 14)

Though we have not found patrol and missionary reports that discuss cash payments in shillings and pounds during this early period, there may have been some, and if so, perhaps some currency made its way to the Oksapmin region through successive trades.

Period II (~1960–1980)

More sustained contact with members of Oksapmin communities was initiated in the early 1960s with the building of a patrol post (June 1961) and then a Baptist mission in Tekin (for a detailed chronology of contact-related events in Oksapmin based in part on patrol and mission reports, see Weeks, 1981b). Over the history of Western contact, some traditional practices have been sustained, others have been modified, and new practices have emerged.

We surveyed early patrol officers' reports from archival records, with special concern to learn about early exchange practices. John S. Hicks, one of the first patrol officers posted at Oksapmin, made notes of special interest to us. He reported his experiences on multiweek patrols for which

[6] At that time, Papua New Guinea was a territory of Australia, and the currency in use was denominated in shillings and pounds.

his purposes were activities like locating a site for a landing strip or producing a census of local populations. For each patrol, Hicks needed to recruit and compensate carriers. In his narrative for Patrol Report #3, Hicks (1962b) wrote:

> No permanent carrier line was attached to the Patrol but little difficulty was experienced in gaining sufficient carriers in walks from group to group … Carriers were paid in salt or matches depending on the distance carried and the nature of terrain. (p. 10)

Hicks also described a practice of paying people in salt for sweet potato and other vegetables:

> Except for a small group at UANMIN where extremely acidic podsol makes the growing of staple foods difficult, food was available at all times and much of that offered far exceeded the requirements of the Patrol. Sweet potato, ginger, pit pit and some leaf vegetables were all bought at different times, payment being effected in salt. People especially from the Upper Valley, offered to follow the Patrol with food but were discouraged on the grounds that each group was made to feel, to some extent, responsible for the support of the Patrol. (1962b, p. 10)

Later in the same report, Hicks wrote about the distribution of new kinds of seed to local people. These seed were not only intended for local consumption but became food sources for patrols.

> During the first section of the Patrol lettuce, cabbage, bean and tomato seeds were distributed and it was gratifying to see, during early November, these growing vegetables attended and thriving in gardens previously given entirely to the production of sweet potato. Corn seeds given out by Mr. W. T. Brown's patrol have also been carefully nurtured and many gardens throughout the valley boast small plots of this welcome addition to the staple. (1962b, p. 12)

Particularly noteworthy are forces that began to shift from traditional trade practices to a cash economy involving Western currency of pounds and shillings (see Figure 7). Hicks's practice of trading salt, matches, and other Western artifacts for food and work began to give way to cash with the opening of a mission trade store. In Patrol Report #2, Hicks (1962a) writes:

> The people's interest in trade items, in spite of the use of such items throughout the Patrol, is waning. There were many instances of people, although accepting salt in payment for food, preferring money. The cause of this elementary and somewhat historic change in the economy of the people of the TEKIN Valley can be attributed to the opening, at OKSAPMIN Patrol Post, of a Baptist Mission Trade Store which has been in operation for three months. They have found, not unnaturally, that all types of useless and un-

FIGURE 7 Australian shilling and pound (20 shillings was the equivalent of 1 pound).

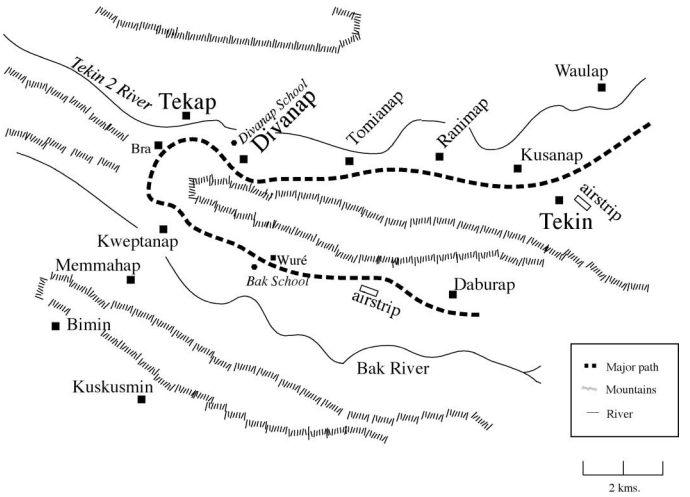

FIGURE 8 Map of Oksapmin area, 2001.

necessary items can be purchased for varying amounts of money and that such luxuries cannot be bought in exchange for what is all they have to exchange—food and their labour. Such is a normal and necessary development, and perhaps they are becoming fed up with a salt economy anyway. (p. 10)

The first mission (Baptist) and accompanying landing strip were built in 1962 in the Tekin area, depicted in the local map in Figure 8. The missionaries brought with them a host of concerns, for the most part related to the conversion of local people to the Baptist faith. These concerns also included change in dress, translating the bible, teaching Tok Pisin language, eliminating warfare with neighboring groups, shifting living practices, and ending Oksapmin initiations (a rite of passage in which in some Mountain-Ok group boys learned progressively deeper meanings and facets of the origin myths and other sacred knowledge accomplished through a series of sometimes painful rites of passage [Brumbaugh, 1990]). The hamlets closest to the mission were perhaps most immediately affected by the evangelical concerns of the missionaries.

The first substantial influx of currency to the area came when plantations in neighboring provinces began recruiting Oksapmin for 2-year stints of work. Recruitment began in the mid-1960s. The Oksapmin men were exposed to Western-style commerce during these stints, and they were paid for their work. Many of them learned to speak and count in Tok Pisin through contact with other peoples as well as expatriate administrators. Most men returned to Oksapmin when their period of work was complete, investing their cash wealth in commodities like bags of rice and cans of fish that they sold to community members. Figure 9 contains a photograph of one such trade store.

Guilford (1994) provided an analysis of the trade store as a source of storage of surplus wealth based on her fieldwork in 1978–1979. She argued that the traditional practice of sharing surplus wealth was adaptive in a community in which surplus was best stored through a web of social obligations and allegiances produced through giving. This practice of building social relations

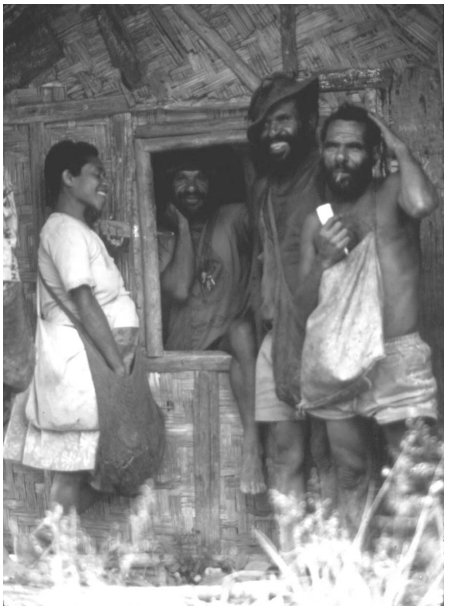

FIGURE 9 A trade store in 1978. The window and the door are one and the same. The interior functions as a storage place for goods.

through sharing is well documented throughout highland communities. An alternate way to store the wealth brought in from outside work, Guilford argued, was to build an enclosed space to store commodities that one would trade for cash to members of one's local community. This process further supported currency as a medium of universal exchange. Weeks (1981a) reported that in 1967 there were only two mission-run trade stores. Guilford (1994) reported that in 1980 there were more than 100 licenses for trade stores.

There were additional sources of cash for the community. Missionaries, like the patrol officers before them, distributed new types of seed to some Oksapmin people, and these new crops contributed to the increase of cash in the local economy. In the 1970s, missionaries encouraged some people to grow these new vegetables, offering to buy the produce back from them. In turn, missionaries sold the vegetables to outside markets, exporting the vegetables on small missionary aircraft.

The material tokens for currency were also changing during this period. Australia adopted dollars and cents for its currency in the late 1960s, shifting from shillings and pounds. Later, in the 1970s, Papua New Guinea gained independence and introduced kina and toea. Figure 10 shows common coins in circulation in the Oksapmin community in 2001.

Currency in its various forms introduced new quantification problems that reached some significant sectors of the Oksapmin community through the 1960–1980 period. For example, identifying the various denominations of currency as elements of varying values, identifying numerical equivalences between values, and adding and subtracting the values necessary in exchanges were foreign practices that became important as some sectors of Oksapmin communities engaged in economic exchanges with currency. How were such communicative and mathematical problems

accomplished? In trade stores, we suspect that people drew on available forms, tailoring them to the local conditions at hand in idiosyncratic ways. Some who had been outside the area and learned some Tok Pisin could draw on that language form in communications with one another, making use of Tok Pisin's Western-style register of number words. However, people had various levels of facility with Tok Pisin, and many who participated as customers of the new stores had no knowledge of it at all. Many local pragmatic solutions must have been created to enable people to communicate with one another about currency; some of these local solutions may have become more widespread throughout the community.

During this same period, the mission and then the national government opened schools in the region. Students who attended these schools had the opportunity to learn English and Western-style arithmetic, which may have offered alternative ways to solve the arithmetic problems found in trade store exchanges.

In sum, during this period, there was (and continued to be) a remarkable heterogeneity in Oksapmin people's experiences with quantification and economic exchange. People differed in the extent of their participation in exchange practices linked to age, region within the Oksapmin subdistrict, amount of schooling, gender, travel outside of Oksapmin, and role within the burgeoning cash economy. Multilingualism also differed among people. During this period, all elders and many members of younger cohorts were monolingual, speaking only Oksapmin. Not all children went to school, but those who did often became more or less trilingual, speaking Oksapmin, English, and some Tok Pisin.

Period III (~1980–2001)

In the early 1980s, active work on Ok Tedi copper and gold mine commenced. Tabubil, the small town constructed to support the workings of the mine, grew rapidly into a small city with many features to attract expatriate administrators and related industries (for an analysis of the effects of

FIGURE 10 Common currency in circulation in 2001 included 10-toea, 20-toea, 50-toea, and 1-kina coins as well as the 2-kina note.

Tabubil and the Ok Tedi mine on local communities, see Hyndman, 1990).[7] Many Oksapmin men and women found work in the mine or in the supporting industries, and many who found work sent remittances back to family in the community. Many others who remained in Oksapmin sold vegetables every week to local vegetable brokers, who sent large quantities of vegetables to Tabubil.

The vegetable business also grew and was no longer operated solely by the missionaries. Vegetable brokers in 2001 were Oksapmin men who bought from local subsistence gardeners and sold to buyers for the mine and other large stores in Tabubil. A report of exports in 1990 and 1991 indicated that 3 metric tons per week were exported out of the Oksapmin community to Tabubil (Bourke et al, 2002).[8] In 2003, an estimated 6 to 10 tons of vegetables were exported each week from the Oksapmin area (Lawrence, personal communication, September 2003). There were also local vegetable markets where Oksapmin (usually women) sold small quantities of vegetables to one another. Figure 11 (top) shows vegetables prepared for shipment to Tabubil. In Figure 11 (bottom), people are paid for vegetables that brokers sold to the Ok Tedi mining company in Tabubil.

The influx in cash led to the expansion of trade stores. The first trade stores were very small structures. Stores' inventories were typically limited to just two items: tinned fish and bags of rice. Though trade stores in 2001 varied in size and selection of commodities, most carried a wide variety of items, including nonperishable foods, clothing, school supplies, and household goods such as soap and batteries. A few stores had generators that ran coolers to store perishable food items, most frequently frozen chickens, which were a luxury item that most people could rarely afford.

In 2001, the language used in quantification practices was quite varied. One source of the variation was due to the effects of schooling. Many of the young adults in Oksapmin were fluent in Tok Pisin and spoke reasonably good English; these young people were likely to use Tok Pisin words for number and currency. A study of records kept by trade storeowners and clerks revealed that elders typically used indigenous methods for quantification whereas younger people, especially those with schooling, typically used Tok Pisin as their principal or exclusive method of quantification (Saxe & Esmonde, 2004).

The number of Oksapmin people who were employed outside of the region increased dramatically in this period, as did the number of trade stores within the region and local participation in the cash economy. Money was needed to buy clothing, to pay school fees for children, and for building supplies. Although at the time of our 2001 visit most of the food in the area came from subsistence gardens and most houses were still made almost entirely from traditional materials, virtually every Oksapmin person participated in the cash economy in some way. This is not to say that elements of the traditional economy had entirely vanished. Robbins (1999) provided a fascinating analysis in Urapmin, a nearby Mountain-Ok group, of the side-by-side practices of traditional shell money (*bonang*) with a cash economy.

STUDIES ABOUT THE GENETIC ROOTS OF *FU*

The historical sketch of shifting collective practices in Oksapmin communities sets the stage for our observations and inquiry into *fu*. In our account, we bring forward our concern with the three challenges of genetic analysis previously identified. These include establishing (a) continuity of form (Challenge 1), (b) transitional functions of the form (Challenge 2), and (c) the organization of

[7] Tabubil was the town where we first heard the new use of the word *fu*.

[8] One metric ton (or tonne) is equivalent to 1,000 kg or 2,204 pounds.

FIGURE 11 (top) Vegetables to be loaded on a twin-engine plane at Tekin airstrip in 2001; (bottom) money being paid to people for their vegetables sold for export.

collective practices that support shifting relations between form and function (Challenge 3). To support our analyses, we draw on studies conducted in 1978, 1980, and 2001. We also draw on records and fieldwork of others and archival records of exchange in Oksapmin communities. To introduce these analyses, let us return to our narrative of the work with which we were engaged in 2001.

Recurrence of *Fu* During Our Studies on Mathematics

The observations and conversations about *fu* during our brief stay in Tabubil had piqued our interest, particularly the origins of *fu*'s multiplicative meaning. It was some time after our arrival in the Oksapmin area, however, that questions about the meaning of *fu* emerged in occasional conversa-

tions. These conversations, to our disappointment, did not reveal anything about origins or any continuity between uses of *fu* now and early use documented in 1978. *Fu* was simply a way of using the body system (and doubling the value of a body part) in quantification. As a result, we began to doubt that there was an identifiable link between current uses and early uses of this form (challenge 1). Curiosity about the genetic history of *fu* was set aside to give priority to an exploration of collective practices of exchange and to pursue a host of issues central to understanding quantification practices and their transformation over social history. Possibilities for exploring *fu* were only shifted to the background, however. They were kept alive by some vague intuitions that no single person may know the genetic history of *fu* and further that individuals may not be aware of their role in the production of historical change.

Keller (1994) offered a traffic jam as a simple illustration of collective human activity that arises through unintended consequences of purposeful actions: Cars are proceeding on a crowded freeway at 65 mph, and the first one in a line inadvertently slows down to 60 mph. The driver immediately behind, on seeing the brake lights of the car in front, adjusts her speed, overcompensating slightly, reducing the speed not just 5 mph but with an added safety margin of 5 mph to 55 mph. All the drivers operate with the same maxim—"adjust your speed in accord with the car in front with a safety margin"—and the maxim leads to an eventual standstill at the *n*th car. Keller pointed out that the traffic jam is the product of human actions, actions that were all purposeful and concerned with not bumping into the car in front. The intentions were unrelated to the final product, however, and the makers of the jam are unaware of their contribution to it. Keller argues that a wide range of collective human products can be understood as analogous to a traffic jam: A structure emerges as epiphenomenal to the intentional actions of participants.

Of course, traffic jams are not collective systems of representation and bear little relation to them. Nonetheless, historical linguists like Keller find this general idea useful in thinking about historical change in systems that appear to be products of intentional design. How might the traffic jam metaphor be relevant for our analysis of historical shifts in collective systems of representation like the Oksapmin's?

As individuals engage in communicative acts related to similar problems, they may produce variations on ways to solve such problems as the representation of currency. Such variation includes the uses of idiosyncratic pragmatic devices (such as the use of known words in new ways) as people make efforts to communicate their intended meanings. In this process, one person may take up another's idiosyncratic production. The uptake, in turn, has a twofold consequence: first, it supports communication insofar as the word now has a precedent for a new function in the face-to-face interaction; second, it also introduces a local solution to a coordination problem. This solution may be carried forward in subsequent interactions if similar communicative problems recur. Just as the members of Keller's traffic jam do not know of their complicity in the jam, no one individual may be aware of his or her contribution to the changing structure of conventions that serves local needs. Here we have systems that emerge well adapted to shifting local conditions and personal predilections, but of which no single person is conscious. Indeed, design of a collective system would emerge out of the unintended consequences of local communicative activity. We will have occasion to return to these ideas as we consider sociohistorical issues in mathematical cognition in relation to the dynamics of historical change.

With this initial framing of collective practices and genetic processes and with an eye toward historical change, we move to our 2001 return to Oksapmin communities with a particular concern for understanding relations between social history and mathematical thought.

Leading Observations

In a single day, we found an important lead for an account of form–function shifts in the use of *fu*. By serendipity, we had occasion to chat with three people separately in a single day: an elder (perhaps 65), an older man (in his 50s), and a middle-aged man (about 35). In these conversations, we were concerned with understanding some varied properties of their mathematics, and in each case, the conversation included some discussion about *fu*. However, instead of beginning with questions about the origins of the meaning *to double*—a gambit that had led to dead ends in previous conversations—we began with queries about their knowledge of the position of *fu* on the body, an effort to find evidence of the meaning that Geoff had learned long ago. We found three accounts that were important clues to a continuity of form and shifting functions of the form. These locations are depicted in Figure 12.

The discussion with the elder corroborated the early 1978 observations. He offered an account of *tit fu gon a*. This is a multiword expression that we had not yet heard in 2001, but one that I had learned back in 1978. *Tit* is a conversational word meaning "one," *gon* referred to "all" or "complete" and *a* was a demonstrative, like "this" or "that." Thus *tit fu gon a* is an expression that communicates "one complete round (from thumb on one side to the pinky on the other)." He also demonstrated that to count beyond 27, one loops back around from the little finger on the second hand to the wrist.

The older adult used *fu* but used it to refer to either of two alternate positions. One meaning was similar to the one the elder had communicated and that I had learned in my own early apprenticeship in 1978: a complete round of twenty-seven, ending with the pinky. The other meaning was a puzzle: He said that *fu* also referred to the elbow on the other side (the 20th position). Why the elbow (20)? Was this an idiosyncratic use to be treated as noise in our early efforts to piece together a genetic history?

The interview with the middle-aged man provided independent corroboration of the 20th body part as the referent for *fu*. Unlike the older adult and the elder, however, he claimed that *fu* did not refer to the 27th at all—only the 20th.

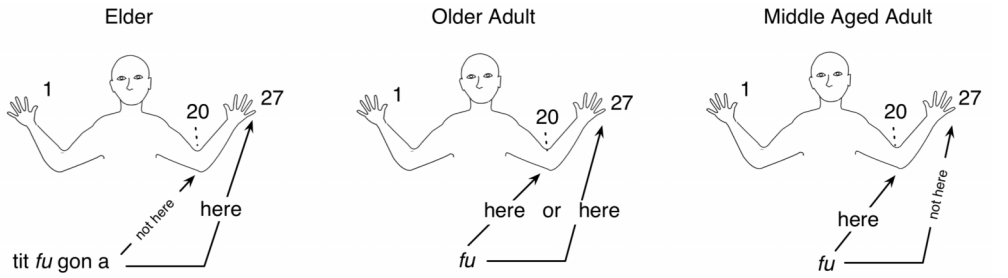

FIGURE 12 Three accounts of the positions of *fu*.

Observations made in 1978 and 1980 related to exchange with currency were a possible lead to making sense of the 20th position. Indeed, they turned out to be the key to resolving the apparent contradiction that *fu* was at once used by some to indicate the pinky (27), others the elbow (20), and still others both positions. The early observations also paved the way for a genetic analysis of the multiplicative meaning of *fu* used today, a genetic history replete with Gould's (1996) quirky shifts in function as well as shifts in the lexical and gestural forms associated with *fu*.[9]

More Pieces of the Puzzle: The 20th Body Part in 1978/1980

In my 1978 and later 1980 visits to Oksapmin, I found that a relatively small number of people—like trade store owners and men who returned from plantations—created new and idiosyncratic adaptations as they used the body system to handle currency transactions (Saxe, 1982b). Recall that three waves of currency systems penetrated the Oksapmin area from the time of contact through 2001. It turns out that the structures of these three waves are consequential in our genetic analysis. For ease of reference, we have listed in Figure 13 the dates of issue and retraction of currencies that have penetrated the Oksapmin area and principal equivalence relations within systems that were consequential in Oksapmin exchanges. We will have occasion to refer to these systems repeatedly throughout our narrative.

Though Australian shillings and pounds had been taken out of circulation in 1966, the legacy of the shilling–pound system[10] was still evident in 1978 and 1980. Even in 2001 a typical way to refer to K2.70 was *wan faun* (1 pound) *bes-hai*, or "1 pound and forearm (7)." In talk a 2-kina note is often called a *faun* (pound) and the 10-toea coin is often called a *siling* (shilling). These denominations are often counted with the body system. Rather than conceptualizing K2.70 as two 1-kina units and seventy 1-toea units, the Oksapmin treat this value as a modification of one 1-pound unit and seven 1-shilling units, or one 2-kina note (1 pound) and seven 10-toea coins (7 shillings). This practice is associated with a truncation of the body-count system, where people count shillings up to 20 (a *faun*) and then start over. This truncated body-count system (see Figure 14) was already evident in 1980, used by a relatively small proportion of the community, mostly trade store owners and clerks. The use of the 10-toea coin as a principal unit of currency was supported by the pricing structure of items in Oksapmin trade stores, where prices were all multiples of 10 toea.

[9] Only after our return from our 2001 trip to Oksapmin did we gain access to a dictionary of the Oksapmin language compiled by Marshall Lawrence (Lawrence & Snyder, 1993). Lawrence includes an entry for *fu,* spelled "pu" in the dictionary. Lawrence's entry corroborates our own interviews. He includes three entries for *fu*: "pu {n} 1. a unit of counting once up one arm around the body and down the other arm, making 27, 2. twenty; 3. a unit of two kina." Lawrence's dictionary was compiled through extensive conversations with a small number of informants.

[10] In 1966, Australia issued dollars and cents, a decimal currency system. A pound was converted to a 2-dollar note (other notes of different values were issued as well) and a 10-cent coin replaced the shilling. Thus the 1:20 equivalence relation between pounds and shillings was retained in the correspondence between the 2-dollar note and the 10-cent coin. We suspect that the 2-dollar note and 10-cent coin came to be called and treated as their pound and shilling equivalents by many (*faun* and *siling*). Support for this conjecture was the treatment of a new issue of currency in 1975 when Papua New Guinea became an independent nation and issued its own currency. Similar to the Australian issue, the new currency included a 2-kina note and a 10-toea coin. In 1978 (and in 2001) these denominations retained the early names (*faun* and *siling*) and have been incorporated into Tok Ples. In the remainder of this article we occasionally make use of the Tok Ples terms, *siling* and *faun*, to refer to the 10-toea coin and the 2-kina note, respectively.

Currency System	Dates of issue and retraction	Key Equivalence Relations
Australian shillings and pounds	Pre-contact through 1966	20 shillings = pound note
Australian dollars and cents	1966-1975	20 10¢ coins = 2-dollar note
Papua New Guinea kina and toea	1975-present	20 10-toea coins = two-kina note

Note. In Tok Ples, "pound" and "shilling" are pronounced "faun" and "siling," respectively

FIGURE 13 History of Western currencies used in Oksapmin area, dates of issue and retraction, and key equivalence relations.

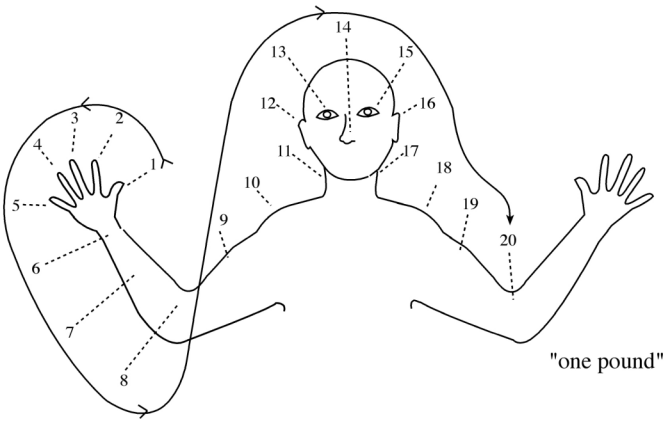

FIGURE 14 Truncated body-count system in which the 20th position (*tan kir*) was treated as a *faun* (pound) because 20 shillings was equivalent in trade value to 1 pound.

As an illustration of the lasting importance of the unit of 1 shilling—now taking the form of the 10-toea coin—consider a 1980 interview with an Oksapmin trade store owner in which he demonstrated how he solved an arithmetic problem, "1 kina 60 toea take away 70 toea." In the interview, the trade store owner transforms expressions of kina and toea into their shilling equivalents. Figure 15 presents a schematic of the man's solution to the problem.

One way of representing 1 kina, 60 toea, in shillings is depicted in Figure 15a. The figure shows a representation of ear on the other side, the 16th body part in the Oksapmin system, or 16 shillings (or sixteen 10-toea coins, the equivalent of K1.60). The owner, however, chooses a different tack, one adapted to the solution of the problem at hand, although still making use of the 10-toea coin (shilling) as the unit. He represents the sixteen 10-toea coins with two registers. Ten of the 16 are represented on one shoulder (10) of one side and the remaining six are represented as wrist (6) on the other (Figure 15b). The useful function of treating the 10-toea coin as a unit is further illustrated in the man's solution to the problem. To subtract 70 toea from the representation of

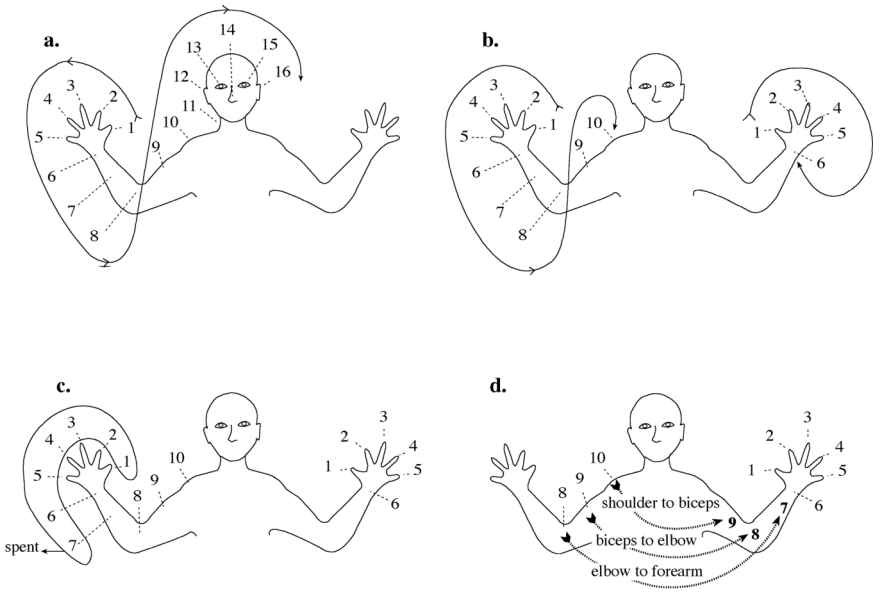

FIGURE 15 The solution of K1.60-70t by a trade store owner in 1980. (a) A representation of 16 using the body system. (b) An adaptation to represent K1.60 to frame an arithmetical calculation of K1.60 – 70t = *x*. Each body part is used to represent a unit of 10 (or 10-toea coins). (c) Spending 70 toea (seven units of 10), leaving the elbow (8th), biceps (9th), and shoulder (10th) on one side and the first six body parts on the other. (d) Adding on to the wrist (6th) by moving the remaining three body-part positions on the left (elbow [8], biceps [9], and shoulder [10]) to the body-part positions on the right (forearm [7th], elbow [8th], biceps [9th]), resulting in biceps (9) as the cardinal value of nine units of 10 (nine 10-toea coins), or 90 toea.

1 kina and 60 toea, the man indicates that 7 of the 10 on the right side are spent (Figure 15c): This leaves the elbow (8), the biceps (9), and the shoulder (10) on the left side. The owner then moves the remaining body parts across registers: The elbow (8) goes to the forearm (7, the body part that follows the existing six body parts on the right side), the biceps (9) to the elbow (8), and the shoulder (10) to the biceps (9), showing that 9 (or 90 toea) is the solution to the subtraction (Figure 15d). In sum, by manipulating the equivalents of shillings (10-toea coins) as body parts in the conventional system, the owner creates an efficient means of accomplishing the solution to the problem expressed in terms of kina and toea.

Additional documentation of early importance of the *siling* as a unit came in the form of a story told to us by one of our informants in 2001. The story tells of a storeowner who was no longer alive. He would sell only to customers who came with 10-toea coins or shillings. The owner thereby avoided arithmetical computations involving the composition of multidenominational units using kina and toea. Although this anecdote perhaps should not be taken too seriously, we find it consistent with our observations in trade stores today. The *siling* was a key and stable unit of exchange in the context of shifting currencies and multiple denominations.

Might the truncated use of the body system (terminated at the elbow [20]) have spread further through the Oksapmin communities subsequent to my last visit to Oksapmin in 1980? Might *fu*

have come to replace the pound (or *faun*) as a marker for the 20th body part? If so, why? It was through such questions and reflections that we initiated a new set of studies.

Systematic Studies on Positions of *Fu* and Its Varied Meanings

Our plan was to collect systematic information on the meaning of *fu*. With the truncated adaptation in mind, we moved quickly. We formulated, field tested, and then back-translated a series of interview prompts.[11] The queries were about the position of *fu* on the body, the meanings of *fu*, and its role in the representation of currency. We interviewed 20 elders, 20 middle-aged unschooled adults, 19 middle-aged schooled adults, and 15 adolescents. In addition, in a separate study with 33 third-grade children, we touched on some of the same issues; we include these data here for comparative purposes.

Inquiry into shifting locations for fu on the body. In our questions about the location of *fu*, we inquired about whether interviewees knew a position of *fu* on the body. We followed up this prompt with questions about whether they knew of other locations for *fu*. If someone gave more than one location for *fu,* both responses were recorded and coded. Consistent with our prior conversations with the three men, we found that both the elbow (20) and the pinky (27) were privileged locations, though some people did not know of any position at all. Notably, the position chosen and knowledge of a position differed over cohorts.

Figure 16 depicts our findings. We found four principal types of answers that varied in their frequency of occurrence over our five cohorts. The majority of the (unschooled) elders' responses (55%) indicated that the little finger (27) was the location for *fu,* and 20% indicated that elbow (20) was the location. Twenty percent of responses indicated some other body part. In contrast, for unschooled middle-aged adults, the relationship was reversed. Seventy percent cited the elbow (20), whereas only 30% cited the pinky (27). Three of these people cited both the elbow and the pinky as locations for *fu*. Only about 10% of the responses indicated a different body part. The pattern for schooled adults was similar to the pattern for unschooled middle-aged adults, though there was an increase in the number of people who stated that they did not know a position or referenced a different body part. Almost all of the adolescents responded that they did not know the position of *fu*. Eleven out of 31 children indicated that they knew of *fu*, and all of these children stated a body part other than the little finger or elbow. Most of these either said fist (5) or shoulder (10), perhaps identifying these with the stereotypic gesture (fist; see Figure 6) or a multiunit value (shoulder, or 10) in a base-10 multiunit count system.

Taken as a whole, these findings on the location of *fu* on the body indicated that the elbow (20) as a position of *fu* was widely used, as our early conversations suggested. The use of *fu* to point to the elbow was widespread through the middle-aged cohorts, though the link to *fu* with particular positions on the body is rapidly disappearing in the younger generations that we sampled. Our inquiry into the meaning of the Tok Ples word *fu* that we describe next provided important clues to the social history of the shift in position.

[11] In this article, we simply summarize the findings. The details of the interviews and the methods will be reported in a forthcoming monograph.

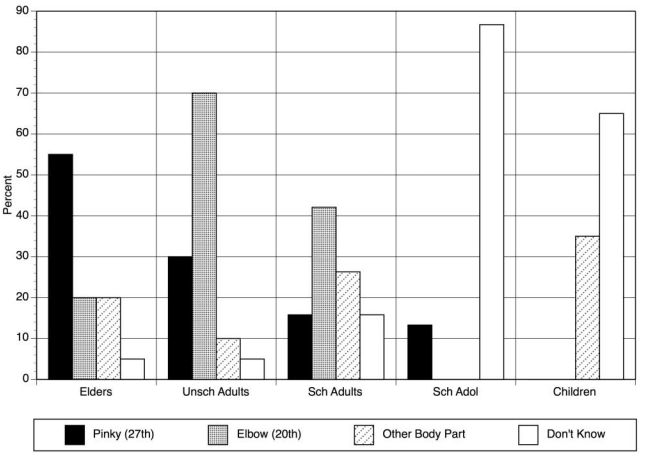

FIGURE 16 Percentage distribution of judgments about the location of *fu* on the body as a function of cohort.

Inquiry into shifting meanings of fu in ordinary language. We inquired into traditional meanings of *fu* with a separate set of questions. We asked whether the interviewees knew of the meaning of the word *fu* in Tok Ples and engaged them in conversation about this meaning. Although our informants in Tabubil had insisted that *fu* meant to double, only one of the participants in this study referred to this meaning for *fu.* We suspect that this discrepancy was due to our focus on traditional meanings for the expression. In broad sweep, responses were of three types. One was the simple statement, "I don't know." We take such statements to mean that the word is simply not used much if at all, in the history of the respondent. The second type of response was much more substantive. Many individuals' responses can be paraphrased as indicating that *fu* refers to a complete group of "plenty of things," a meaning that has no single word analog in English. The third type of response was simply a reference to *fu* as a particular body part (a number in Tok Ples) or a number in Tok Pisin. Left uncoded were miscellaneous responses, like the interpretation of *fu* in Tok Ples as a unit of currency.

Figure 17 contains the percentage of responses coded with these three categories by population group. The figure shows a progressive decline in reference to a complete group of plenty and a corresponding increase in a lack of knowledge of the meaning of *fu*.

The way in which respondents described the sense of "plenty," "complete," or "complete group of plenty" became an important source of data for us.[12] Sometimes our informants made reference to traditional activities that conveyed a qualitative sense of plenty and completeness. These references were varied. One elder said that *fu* is used when referring to clans (a unit of social organization in Oksapmin communities): "When referring to one clan of people call it *moh tit fu* and then another *moh tit fu*." Another referred to the nuts or seeds (that are smoked and eaten) that grow in a pandanus tree. The pandanus nut is similar to a sunflower in the sense that it is filled with

[12]People's responses quoted in the excerpts are very approximate translations. The interviewees were responding in Tok Ples, and their talk was translated into English by our research assistants. We make use of these translations here because they communicate some of the sense of the meanings of *fu*.

many edible seeds. The individual said, "In olden times, *fu* refers to pandanus nuts that will be divided. Before dividing, they are referred to as *fu*." Another unschooled adult related *fu* to different kinds of artifacts, stating "*tit fu* is plenty of valuable things from old times—like stone axes or bows and arrows." Another unschooled adult indicated that *fu* could refer to a place: "*Fu* alone means a bad place that's not easy to walk in —say for example a garden that has lots (plenty) of stones and vines and sticks everywhere, and you can't walk there." Several participants said that *fu* means a group of things that is put together, using the example of a clan's payment of bride price. When paying bride price, "You put a heap of things together; if it is plenty it is *fu*—you then say something like *fu bilong yu* when you give it over" (trans. "This is your *fu*.") These explanations have varied family resemblances.

A number of participants gave examples that illustrated how these global uses of *fu* could be related to counting activity and currency. We interpret such extensions as indexing gradual shifts in functions of *fu*. One person said, "*Fu* is used when you count up to plenty, like plenty of *kau kaus* (sweet potatoes) or taros." Another was more precise, offering an illustration that linked "plenty" and "complete" in the act of counting, saying that "*fu* is when you count all the way around your body and it is *fu*; do it again and it is *yot* (2) *fu*; again and it is *yetir* (3) *fu*."

Inquiry into shifting meanings of fu in relation to denominations of currency. Some people used *fu* to apply to money. For example, one elder said, "*Fu* is plenty of money." Another included in his extension a reference to counting currency: "It is a word used when counting money in Tok Ples." Other people were more precise in the extensions of *fu* to currency. It was in discussions of the relation of *fu* to currency that a key clue emerged in our inquiry.

One unschooled adult said "If you count *silings* (10-toea coins) to *tan kir a* (20), this is 2 kina. It is also called *fu*." Here was a plausible thesis to explain the shift in function of the word form *fu,* from an original meaning of plenty or complete, to one that perhaps led to a meaning of doubling.

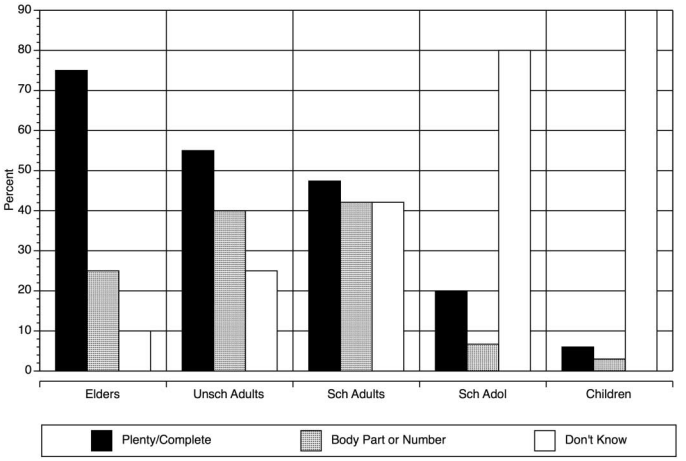

FIGURE 17 Percentage distribution of judgments about the meaning of *fu* as a function of cohort.

The meaning of *fu* may well have been appropriated in the count of 10-toea coins (which are referred to as *silings*) to a completion of the first major unit of currency, a 2-kina note (frequently referred to as *fauns*). Thus perhaps 2-kina notes were *fu*s—the equivalent of a complete group of 20 shillings (10-toea coins). Consider the implications: If a person referred to a number of 2-kina notes using *fu* in an act of reference, then the number of *fu*s would represent half the value of kina. Reciprocally, the value in kina of any number of *fu*s (2-kina notes) would be twice the number. For example, three 2-kina notes (*bumrip-hai* (3) *fu*) would carry the value of 6 kina.

There are additional sources of convergent support for the conjecture that *fu* came to mean the complete set of 20 *silings*/10-toea coins that makes up the major unit of currency, the pound/2-kina note. One kind of support comes from the findings presented in Figure 16, in which we find many adults indicating that the 20th body part is a *fu*. Additional support came from another unschooled adult who explicitly linked *fu* with 2 kina. He said that *tit fu* was "the same as *tan kir* (20) or 2 kina."

In sum, we took these convergent lines of evidence as leading toward a view that *fu* at some earlier point in the social history of exchange had come to be used to express a complete group of *silings* or a *faun*. The meaning was also extended to a complete group of 10-toea coins or a 2-kina note. Figure 18 represents equivalence relations in the system of pounds and shillings as well as the system of kina and toea; it also represents *fu* as a mediating link between the equivalence relations of each system.

Thus, the pieces of our genetic puzzle were beginning to fit together into a plausible account. Two leads in particular needed to be followed up. First, we needed further corroborative support for the idea that at some point in recent social history, *fu* was linked to a count of 20 *silings* (either shillings themselves or 10-toea coins). Second, we needed evidence that the count of 20 *silings* is regarded as a complete count, a completion defined by the *faun* (the pound or the 2-kina note). To find out, we conducted another interview study, in which we presented people with an array of kina and toea of all denominations from the 1-toea coin to the 20-kina note, asking them to select currency that showed *fu*. We found considerable support that *fu* was used by some Oksapmin people to refer to the 2-kina note. Figure 19 shows the frequency with which cohorts selected the

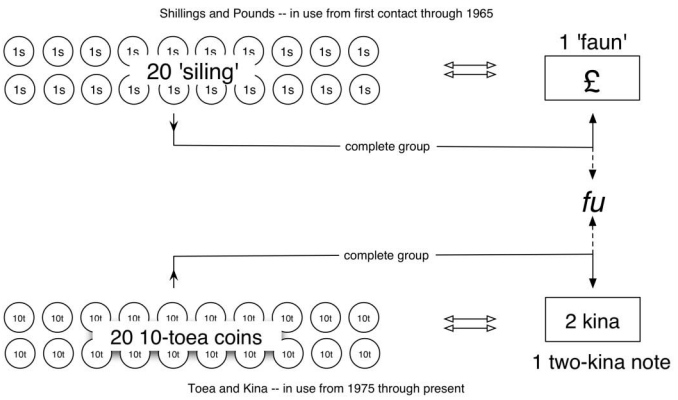

FIGURE 18 *Fu* as a mediating link between equivalence relations in the system of pounds and shillings and the system of kina and toea.

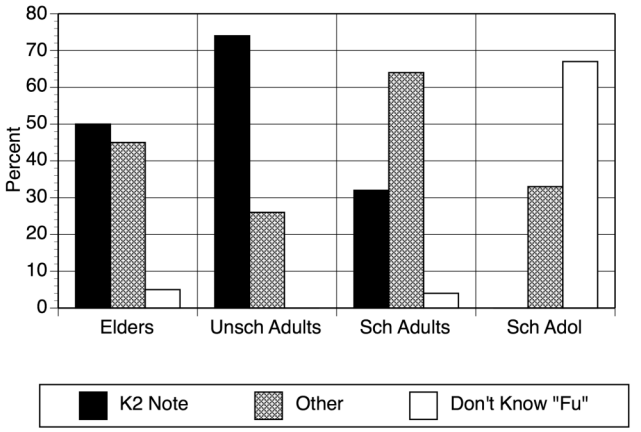

FIGURE 19 Percentage distribution of instances in which people identified various currency units as *fu* by cohort.

2-kina note. One half of the elders, the majority of the unschooled adults, and one third of the schooled adults selected this denomination.

Some of the identifications other than the 2-kina note are noteworthy. Some of the elders and unschooled adults identified the 20-kina note as *fu*. *Kat-hai* (10) *fu* is a common name for the 20-kina note in talk today, and it may well be that these identifications were linked to the presence of *fu* in such expressions. None of the schooled adolescents selected either the 2-kina or 20-kina notes as a denomination (only about 30% offered a choice at all).

Like our other analyses, respondents' comments about the rationale for their selections were instructive. A few elders used the qualitative meaning of *fu* in their identification of currency, saying, for example, that all of the units of currency together constituted a *fu* (perhaps a complete group of plenty). Another said that all of the denominations together were not enough to be called a *fu*. Others, however, made an explicit link between *fu* and a count of 20 *silings*. For example, one person identified the 2-kina note as *tit fu* because it is *wan faun,* explaining that the 2-kina note is *fu* and *tit* means one. Another identified the 2-kina note and justified his choice by a count of imaginary *silings* inside the note to elbow (20), calling it *tit fu*. Another elder linked the 2-kina note to a body part, saying that the 2-kina note means elbow (20th). Still another person explained that the 2-kina note is *tit fu*, that the 10-kina note is called *hanen* (5) *fu*, and that the 20-kina note is called *kat-hai* (10) *fu*, clearly illustrating the doubling function of *fu*.

References to the 2-kina note as a *fu* are suggestive about early extensions of the word to currency. *Fu* may initially have had a single referent: the complete set of twenty 10-toea coins that comprise 1 *faun* (or 2 kina). For some people, this complete set may have had a particular numerical value—the equivalent of a 2-kina note. As one person explained, however, at some point *fu* came to mean any amount of currency equivalent to 2 kina, not simply 20 shillings or the 2-kina note. This man remarked that the 2-kina note was a *fu*, but there were also other possibilities. As an example, he collected a 1-kina coin and two 50-toea coins and said together they constituted a *fu*.

The findings that we have reported so far offer a broad outline that supports a genetic analysis of *fu*, one replete with shifting relations between form and function over Oksapmin social history. We have established that *fu* has taken on the function of referring to 2-kina notes. However, *fu* also occasionally appeared to have other nuances of meaning; some people indicated that *fu* could be used to refer to collections of currency adding up to a value of two kina, not simply the 2-kina note or a count of twenty 10-toea coins. Might this generalization—from the embodied value in a specific currency note to a numerical value itself—be common in practices of quantification? If so, how is it distributed across population cohorts?

The Use of *Fu* in the Quantification of Stones and Different Values of Currency

To analyze the practices of quantification that people used or were capable of using in Tok Ples, we conducted an additional study in which we interviewed people from each of three cohorts: community elders, middle-aged adults with little or no schooling, and middle-aged adults with at least a 6th-grade education. In this study, we presented the respondents with to-be-quantified objects and asked them to indicate their value using the body system. We included three types of materials and five values within each type (variations on values of 4, 6, 11, 21, and 29; see Table 1). We suspected that the different materials and values might well reveal different practices. The materials and particular values used included stones, currency of lesser value, and currency of greater value. The values enabled us to produce comparisons across materials, holding what we regarded as a root value constant (e.g., 4 stones, 40 toea, and 4 kina).

With each presentation of to-be-quantified objects, we asked the interviewee to use the body system to tell us how much was presented. The quantification practices we observed were fascinating. Here we focus only on occasions in which *fu* was used in the final representation.

Figure 20 contains the mean percentages for which our respondents used *fu,* as a function of cohort. These findings point to the broad spread of *fu* through multiple strata of Oksapmin communities: All cohorts used *fu* frequently for greater values of currency, especially when those values were at least 21 kina. Indeed, for values of 11 kina, 21 kina, and 29 kina, at least two thirds of all middle-aged interviewees, both schooled and unschooled, used *fu* in their expressions. Among the

TABLE 1
The 15 Stimulus Conditions Used in a Study of Quantification Practices.

Material	*Value*				
Stones	*4 Stones*	*6 Stones*	*11 Stones*	*21 Stones*	*29 Stones*
Currency of lesser value	K.40 (2 20t coins)	K.60 (6 10t coins)	K1.10 (2 50t coins and 1 10t coin)	K2.10 (3 50t coins and 3 20t coins)	K2.90 (2 K1 coins, 3 20t coins, and 3 10t coins)
Currency of greater value	K4 (2 K2 notes)	K6 (6 K1 notes)	K11 (3 K2 notes and 1 K5 note)	K21 (1 K20 note and 1 K1 coin)	K29 (2 K10 notes, 4 K2 notes, and 1 K1 coin)

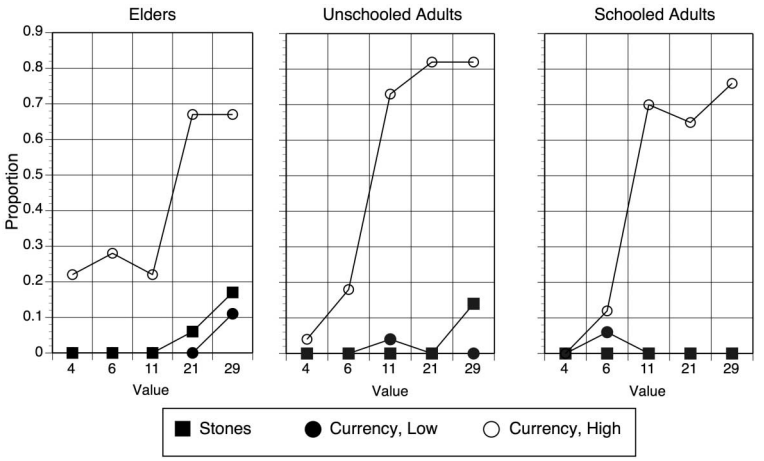

FIGURE 20 Mean proportion of interviewees using *fu* in oral representations for five values across three conditions (stone, low currency, and high currency) as a function of cohort.

elders, at least two thirds used *fu* in their expressions for 21 kina and 29 kina. *Fu* was infrequently used to express the lesser values or to count stones, and it was especially rare among schooled adults.

Figure 20 provides further evidence that *fu* had come to take on a generalized meaning for a value of 2 kina and was not restricted to a count of twenty 10-toea coins or to a 2-kina note. Consider representations for 21 kina, which was presented as one 20-kina note and one 1-kina coin. Over 60% of our participants used *fu* in their response, although no 2-kina notes or 10-toea coins were present.

Analysis of the distribution of the use of *fu* over cohort and types of materials is important for understanding how extensively a form has spread through interlocutors in a community. Nevertheless, it is limited with regard to understanding variations in the function of *fu* in these expressions. Further inspection of how *fu* was used in quantitative expressions provides more information on variant functions. We partitioned uses of *fu* into two categories: (a) unary representations in which the entire expression is used to refer to units in which there is no distinction between denominations, and (b) multiunit representations in which there is reference to more than a single denominational value.

Unary expressions involving fu. Some of our informants used *fu* as a marker for either a complete group of 27 or a complete group of 20. For example, one elder counted the 29 stones, producing the representation *tit fu gon hama it bes-hai*. This representation itself is modeled on the elder's count—one in which she counts the first 27 stones with all of the traditional body parts reaching 27 (called *fu*) and then continues on to the wrist (28) and forearm (29) for the last two stones. At this point she states that the value is *tit fu gon hama it bes-hai*. Literally this means one (*tit*) complete round (*fu gon hama*) and (*it*) forearm (*bes hai*; the suffix *hai* indicates that *bes* is a cardinal number). The translation must be interpreted in context of the production of the trajectory on the body, which is depicted in Figure 21.

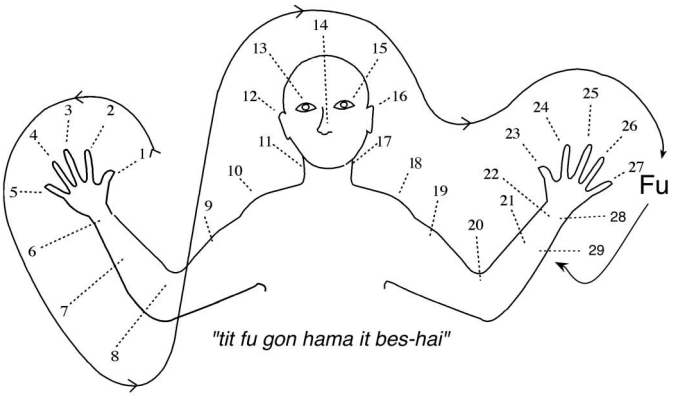

FIGURE 21 The use of *fu* in the representation of 29 stones. The elder counts the stones past the 27th body part to the 29th body part and in her representation uses *fu* to mark the route past the 27th body part.

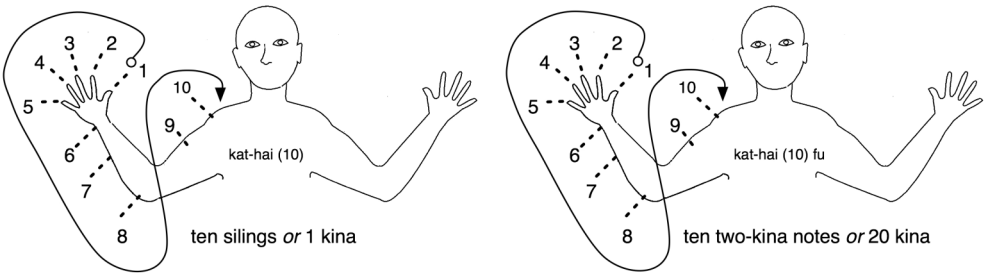

FIGURE 22 To represent K21 (one 20-kina note and one 1-kina coin) an informant produces the representation *kat-hai hat forhan kat-hai fu* (or shoulder [10] and shoulder [10] *fu*). We make one cautionary note here: In these interviews, we presented people with currency, recorded their responses, and later reconstructed their meaning. This technique necessarily involves some (educated) guesswork on our part and leaves us with some lingering questions. For example, in general, our data did not allow us to distinguish between informants who used *fu* as a unit of 2 kina and those who used *fu* to double a unit of 1 kina. Even in simple examples, like using *kat-hai* (10) *fu* to represent 20 kina, there are several possible meanings. The speaker could mean a count of ten 2-kina units (10 *fu*s), or the speaker could mean double a count of ten 1-kina units. Most likely, our respondents conceptualized the units of currency in a variety of ways, so the same response may take on different meanings in the quantitative activity of different people. (Of course, these are microgenetic constructions, and the answer lies in the microgenetic lineage in an individual's production of meanings.)

Multiunit expressions involving fu. Another elder, also counting the 29 stones, made use of the truncated system and created a multi-unit expression using *fu*. This person used elbow (20th position) to mark a *fu—tit fu hat forhan towat-hai tit si.* This representation makes use of the truncated system by representing 20 stones as *tit fu* (one *fu*) and then the additional 9 stones as biceps (*towat*, 9). The additional morphemes embellish the representation (*hat forhan*: "added to"; *tit*: conversational language for "one"; *si*: demonstrative, "these").

We found many examples of *fu* being used to refer to the value of 2 kina. For example, when six 1-kina coins were presented, a number of people quantified the coins and indicated the value was *bumrip-hai fu* or *yetir fu*. Both representations mean "three *fu*"—*bumrip* is the third body part, and *yetir* is the conversational number word for three. Because no 2-kina notes are present, the meaning of *fu* becomes either a reference to nonpresent 2-kina notes or simply a reference to doubling three, resulting in the value of 6 kina.

When *fu* is used to represent odd numbers of kina in expressions, people must produce special accommodations, because any initial value produced with *fu* that serves a doubling function is necessarily an even value. Informants combined the use of different forms to express values smaller than *fu* (or 2 kina). All strategies involved multiunit expressions. Several principal types were common in our corpus.

One type is a multiunit expression in which two body parts are used. One body part has *fu* as a suffix, where *fu* is used to double the number of kina represented by the body part. The second body-part value indicates the number of 10-toea coins it would take to make up the remainder of the total value. In many of our examples, this number is generally *kat-hai* (10), which is used to signify ten 10-toea coins, the equivalent of 1 kina. For example, Figure 22 displays the expression used by a man to quantify a 20-kina note and a 1-kina coin as *kat-hai hat forhan kat-hai fu*. This translates in English as 10 ten-toea coins and ten *fu*. This hints at a multiunit system whose principal units are *silings* and *fauns* (or *fus)*. Notice that this man used an expression involving two units: 10-toea coins and 2-kina notes, even though neither of these particular denominations were present.

We have provided evidence of various functions of the term *fu* as it is used in counting activities, especially when counting and naming currency. It is clear that the meaning of *fu* has shifted over time through its appropriation and use in collective practices involving currency. In the next section, we draw together the evidence to present a coherent picture of the shifts in meaning of *fu* over the social history of Oksapmin communities.

A DIACHRONIC ANALYSIS OF SHIFTING FORMS AND FUNCTIONS OF *FU* IN COLLECTIVE PRACTICES

Figure 23 contains a schematic of our analysis. The figure incorporates the timeline previously used to illustrate the emerging differentiation between subsistence and cash economies (see Figure 3). We use diagonal right-moving arrows to represent new functions of *fu* along with their genetic roots in prior functions. The figure also contains two types of horizontal lines, each of which varies in thickness. The solid lines show our rough approximations of shifting proportions of Oksapmin people using *fu* to serve an associated function over historical time (greater thickness signifies greater proportion of Oksapmin people using *fu* to serve the respective function). Similarly, the dashed lines depict shifting proportions of the use of important mediating material and symbolic artifacts that we argue are important for understanding the genetic history of *fu* (e.g., currency systems, Tok Pisin).[13] Finally, the elongated rectangle at the right is used to represent the time interval during our 2001 visit to Oksapmin—the period in which we conducted the varied empirical studies

[13]Note that we do not distinguish in this chart between an approximation of relative frequency of use of a particular function from the existence of use among a population cohort.

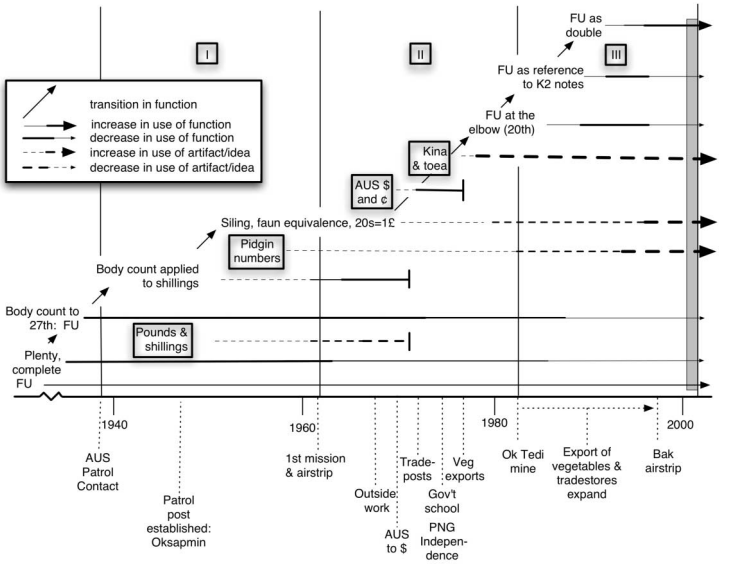

FIGURE 23 A timeline depicting probable shifting form–function relations of *fu* linked to shifts in the practice of currency exchange.

that we have summarized in this article. We begin with the cross-section of Oksapmin social history marked by the rectangle, and we then review the emergence of varied functions and meanings of *fu* revealed in our observations linked to practices of exchange.

In the early summer of 2001 (depicted by the grayed rectangle in 2001), *fu* was used as a suffix of a body-part expression. Our informants in Tabubil told us that *fu* was used to indicate that a listener was to take double the value of the specified body part. We later found that this was true in the Oksapmin area as well.

Had we understood more about practices and knowledge at that time, we would have found that for other segments of the Oksapmin population (and perhaps even the people we knew in Tabubil) some other functions of *fu* were known and used and that these functions were distributed unevenly through Oksapmin cohorts. They include the use of *fu* to refer to the 2-kina note, the use of *fu* to mark the completion of 27 body parts, and the use of *fu* to mark the completion of 20 body parts, as well as the traditional meaning of a complete group of plenty. Through our cross-sectional methods and earlier studies and observations in 1978 and 1980, we came to understand that the varied functions we observed in 2001 had their genesis in prior historical periods. The forms of expression in which *fu* occurred are linked in complex ways to the functions that *fu* served over historical time. Notably, we found no single person who was knowledgeable about what we now regard as the historical links between these forms and the varied functions of *fu*. In fact, many people we talked to were unaware that their peers had different meanings or functions for *fu*.

With Figure 23 as a representation of our conjecture of the genetic history of *fu*, we now return to the challenges that we posed earlier. We argue that there is considerable warrant to identify the

use of *fu* to double the value of a body part with early uses of *fu* as a global sense of a complete group of plenty (Challenge 1). Further, the relation is not one of a simple extension in which the word form was simply appropriated, extending the value of the body system. Indeed, our analyses point to many quirky shifts in function that we can specify with some detail in Oksapmin communities (Challenge 2). Finally, extant functions of *fu* and emerging functions are often linked to changing practices of economic exchange. These collective practices are niches in which *fu* takes on functions in communication and serves instrumental ends as problems are framed and accomplished. Thus, the collective practices both sustained particular functions and gave rise to new ones (Challenge 3). The differential participation in collective practices contributes to variation in form–function shifts across segments of Oksapmin populations. We offer a summary of the substance of the argument that follows, using Figure 23 as a map, for the general argument organized by historical period.

Precontact Period

We noted earlier that archeology in the Telefomin area documents human activity 17,000 years ago. Thus, the long history in this area is for the most part unknown and not recoverable. We do know that Oksapmin made use of two number systems before Western contact: the conversational number words (*tit* [1], *yot(a)* [2], *yetir* [3], *yota yota* [4], and *hanen* [5]), and the 27-body-part counting system. How these two systems originated is subject to speculative analysis based largely on the kinds of cross-group considerations we presented earlier. We bring forward some of those speculative concerns now with special regard for the shifting functions of *fu*.

Shift from fu as a complete group to the completion of a count to the 27th body part. During precontact times, *fu* was used in ordinary language to connote a complex of meanings involving "plenty," "group," and "complete." A complete count of 27 body parts became known as *tit fu*, in an expression that unites the 27-body-part counting system with the conversational number word *tit*.

There may well have been considerable heterogeneity in representational practices in prehistory. One example of this heterogeneity is the existence of different methods for counting numbers higher than 27. Today we find two ways reported by elders, both of which have some support as precontact methods for counting. Some elders in both 1978 and 2001 reported that to count beyond the 27th body part one moves on a trajectory that proceeds from the little finger (27th) back to the wrist (28th). In this method of counting, we find no recursive structure. In contrast, another elder reports a method of counting values beyond 27 that incorporates *fu* as signifying a multiunit value. After one round to the pinky (27th) position, one proclaims, "*Tit fu*!"; after another, one proclaims, "*Yot fu*!" and the count proceeds, making use of *fu* and the conversational numbers to mark multiunit values.

Because we have both reports for early counting, we suspect that this blending of systems may have been distributed unevenly through the Oksapmin population. Or a single person may have used both systems, depending on the representational needs of the participants in an interaction. Such variations undoubtedly had their own prehistory to which we have no access.

Postcontact: Period I

Body count applied to shillings and pounds. Sometime during the first postcontact period, Australian shillings and pounds entered the area through patrol officers and missionaries. We suspect these units of currency were targets of counting by some Oksapmin people. In such quantifications the body system (and *fu*) would probably have been applied irrespective of the denominational units of currency. The idea that there was a precise ratio of value between currency units (e.g., shillings and pounds) is very unlikely; these must have been quite foreign Western conventions and of little use. Trade store owners and clerks in 2001 reported that some of their elderly customers were unfamiliar with equivalence relations between currency denominations; those customers believed that more coins meant more money, regardless of the value of each coin. The story we were told about the trade store owner who accepted only 10-toea coins hints at the difficulties people must have had in quantifying the relationship between the various currency denominations.

Introduction of Tok Pisin/English numbers and terms for currency. With increasing contact with early patrol officers and missionaries, Tok Pisin and English were introduced, providing a new language for number. During this early period only a small portion of the Oksapmin population interacted with missionaries and patrol officers, and it is likely that few of them became fluent in the new languages through this early contact. Indeed, in 1978, Tok Pisin or English was spoken by a minority of Oksapmin people, primarily those who attended school (English) or who had worked outside of the area on plantations (Tok Pisin).

Postcontact—Period II

Pound–shilling equivalence and the elbow (20th) as a faun (pound). During Period II many Oksapmin engaged in currency exchange. Some began equating a count of 20 shillings with a pound, and thus a pound came to be associated with the elbow (20th position). This equivalence marks a shift in the functional relations between the body-counting system and these denominations of currency. Such an equation may well have been occasioned by the rise in the circulation of currency through the Oksapmin communities, through payments for plantation work and the start of trade posts.

Further, the trade posts presented arenas for sustained engagement with arithmetical manipulations of multiunit currency values by some—especially by owners of trade posts and people who frequented trade posts as customers. Such knowledge was distributed unevenly in the Oksapmin communities; those who participated regularly in exchanges of currency were likely to have been engaged with emerging problems where such knowledge was useful (see Saxe & Esmonde, 2004).

From Australian pounds and shillings to Australian dollars and cents to Papua New Guinea's kina and toea. In the late 1960s and again in the late 1970s, currency in the Oksapmin region changed from pounds and shillings to dollars and cents and then to kina and toea.

Although the currency systems changed, the denominations of bills and coins closely matched each other, and it is probable that some Tok Ples language for currency stayed the same. For example, the words *faun* (pound) and *siling* (shilling) are still commonly used to denote 2-kina notes and 10-toea coins. Over time, a complex system of language for currency evolved, combining body-part number words, conversational number words, and ordinary Tok Ples words that are used to name currency.[14]

Post Contact—Period III

With the striking influx of currency and increased exchange during Period III, we find varied linguistic devices to represent quantity in everyday activities, some based on Tok Ples and the body system and some on Tok Pisin and English. *Fu* is one of the varied devices used in Tok Ples.

Fu as the elbow (20th body part) and 2-kina note. We believe that the association between the 20th body part and the *faun* was an important precondition for *fu* to take on a new meaning in quantification. The *faun* marked a complete count of (plenty) *silings* at the elbow (20th). *Fu* had been used to mark a complete count of 27 body parts, but with the use of shillings and pounds as countable objects, *complete* took on a new meaning. The shift from the 27th to the 20th body part for a *fu* seems quite natural. In this way, it appears that *fu* took on both the meaning of elbow as a complete count of the body parts that constituted a *faun* and the meaning of *faun* (2-kina note) itself, as a complete group of *silings*.

Fu as double the value of a body part. The function of *fu* as the completion of a count of twenty *silings* became a useful way to refer to larger values of currency, and the generalization of *fu* to refer to a value of 2 kina may have occurred relatively quickly in the transition. This meaning has taken root and spread so that today when people represent large values of kina in Tok Ples, *fu* has acquired the meaning of double the value of a body part. When they count noncurrency units, such as stones, *fu* has maintained its meaning for some people as the completion of the last body part in the Oksapmin counting system.

Throughout this historical development, there was much heterogeneity among Oksapmin people in how exchanges were accomplished in trade stores. Though we argue that the doubling function of *fu* is the last in a chain of shifting functions, in fact, very few of our informants referred explicitly to the doubling function of *fu*. This may be because of competing conceptualizations of the currency system. For some, the currency system is thought of as a multiunit system with 2 kina and 10 toea as the principal units: A value of say, 14 kina is conceptualized as 7 pounds or 7 *fu*. In this framework, *fu* is not conceived as performing a doubling function. However, people with more schooling or more experience with English language for currency may consider 1 kina and 10 toea to be the principal units of the multiunit system. This orientation may lead individuals to interpret expressions like *bes-hai fu* as 7 kina times 2, yielding 14 kina. For still others, particu-

[14] In 1978 and in 1980, I did not observe or learn of anyone using *fu* to serve a doubling function. If this function of *fu* was already used during this period, it was not widespread.

larly those in Tabubil, *fu* meant simply to double the value of a body part. In 2001, we found evidence of many varied ways of describing and counting currency, often linked to an informant's level of schooling, language preference, age, or position within the money economy.

DYNAMICS OF CHANGE: MICROGENETIC, SOCIOGENETIC, AND ONTOGENETIC PROCESSES IN RELATION TO SHIFTING COLLECTIVE PRACTICES

To some readers, the Oksapmin case of *fu* will be taken as a testament to the cultural diversity of mathematical thought and the historical contingencies that support some quirky genetic trajectories. Indeed, our narrative illustrates how particularized in cultural and historical circumstances mathematical thinking is. Though we value the Oksapmin case for its special properties, we now take a different tack.

What can be abstracted from the Oksapmin case? Are there principles and constraints inherent in the development of mathematical thinking in the social history of communities? In our efforts to render this question tractable, we have treated the Oksapmin case of *fu* as a microcosm, one in which the dynamics of stability and change in patterns of human thought over social history are accessible for analysis. To explain the dynamics of change, we now turn to a framework that has served as both a guide and a product of our efforts.

Orienting Framework

The framework that we used to guide our analysis has largely been implicit in our descriptions in prior sections (for prior discussions of the framework see Saxe, 1991, 1999, 2005). We now make use of the framework to consider the interplay between Oksapmin social history and the development of new forms of mathematical thought.

The framework is cultural in that we elevate collective practices, recurrent socially organized activities that permeate daily life (themselves undergoing change), to a principal arena for our analyses. In practices, collective problems become constituted, solved, and reconstituted on a regular basis.

To illustrate our meaning of a collective practice and the constitution of mathematical problems in practice-related activities, consider the exchange of goods for currency as it occurs in 2001 in an Oksapmin trade store (Figure 24). The interrelated actions of customers and clerks working with cultural forms like currency, the body system, and Tok Pisin quantifiers create and re-create a pattern of social organization constituted by norms, values, and routines that endures over many years, even though the particular actors change. This is the "cultural stuff" that constitutes a common ground for interpreting one another's intentions in collective life (Clark, 1996).

At the same time, individual storeowners and customers are engaged in exchanges as distinct actors with their own understandings and motives. In their joint activity, differences in individuals' own understandings, beliefs, and positioning in particular roles lead to variations in how labor is distributed in joint activity. In the give and take of exchange about joint problems, each customer and each storeowner constructs and accomplishes his or her own mathematical goals. In this process, we find differences in their cognitive work as they transform cultural forms like the

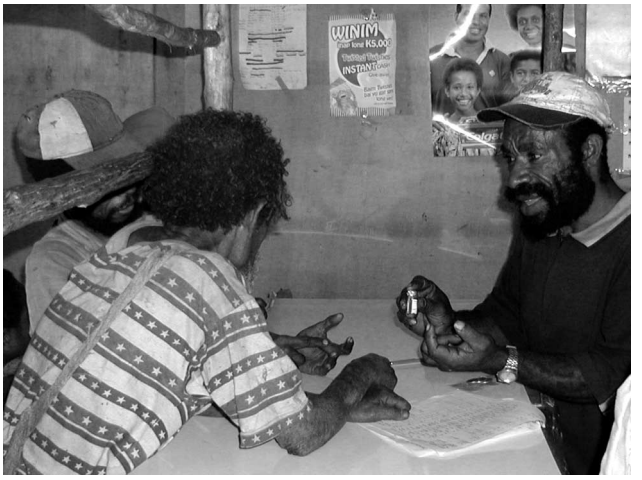

FIGURE 24 A trade store owner sells pig medicine to a customer in 2001.

body system, currency, or written numerals into varied means to accomplish what may be quite different emerging goals.

Of course, as we pointed out previously, interactions take form in relation to (and themselves are partially constitutive of) broad economic and political processes. For example, more distal events such as issues of new currencies and the availability of far-off markets have implications for the character and frequency of local exchanges. At the same time, collective practices at a local level constitute broader economic processes in the region at large. They are contributors to cash flow, inflation, and shifting market conditions. In these dynamics of collective practices, as they emerge and shift in cultural life, we locate our treatment of cognition. Further, collective practices shift in organization over historical time. We already noted marked historical changes in collective practices of exchange. Before Western contact, before Western currency was used or even known, Oksapmin participated in exchanges with neighboring cultural groups. In the Mountain-Ok area, trading partners often spoke different languages, though they used the same 27-body-part counting systems. Today, exchanges in trade stores and vegetable exchanges are mediated by currency; norms, values, and routines of exchange are much different than traditional activities.

As the foregoing comments show, our approach is also developmental. We focus on three strands of development as people create and accomplish emerging goals in practices (see also Saxe, 1991, 2005). These three strands of development are microgenesis, sociogenesis, and ontogenesis. Each strand involves interplay over time between cultural forms (e.g., the Oksapmin body-count system) and functions, the purposes for which those forms are used (e.g., to determine a cardinal value or to solve an arithmetic problem).

Microgenetic developments involve regularities in the moment-to-moment constructions of representations, occasions in which people make use of specific cultural forms to serve particular functions in activity. The use of the body (form) to create a numerical representation of coins (function) is an example. For instance, in 1960, when Australian shillings and pounds were used in the Oksapmin area, a woman might establish a one-to-one correspondence between a succession of six body parts (in a conventional order) and 6 shillings and then indicate that the value of the shillings is wrist, the

sixth body part in the series. Forms (with the function they afford) contain no inherent numerical meaning: A wrist itself is simply a physical entity. In microgenetic activity, individuals turn forms like the body into numerical means in relation to their emerging goals.

Sociogenetic developments involve regularities in the propagation of forms or functions as the form–function relations are reproduced and altered within a community. For example, we will argue that as people make efforts to work through communicative problems they make use of prior forms (such as the body system) to serve new functions (such as the use of body parts to solve arithmetical problems linked to new patterns of exchange with currency). In such idiosyncratic constructions, the public display of one microgenetic construction (e.g., a way of referring to the value of a coin) may be appropriated by other people and used in subsequent interactions as similar problems recur. With successive interactions, some developments are sustained and new developments take form as they crisscross over time through networks of individuals. New and idiosyncratic efforts to communicate intended meanings become semistable conventions.

Ontogenetic developments consist of trajectories in individuals' development. For example, young Oksapmin children in 1978 knew the names of body parts as well as the conventional sequence of the body parts in counting. However, many did not use body parts to serve numerical functions. With age, children's body parts take on numerical functions. Thus a child who has previously used the wrist to serve as a signifier for a body part may begin to use that signifier to refer to an ordinal position in a series. Such shifts in form and function both are products of microgenetic and sociogenetic processes and enable subsequent ones.

Micro-, Socio-, and Ontogenetic Processes in Relation to Shifting Collective Practices

Each strand of development represents a domain of genetic inquiry. An analysis of historical change in mathematical thought, however, requires a coordinated treatment of these processes relative to shifting collective practices. Indeed, individuals' microgenetic constructions in collective practices are moments in the sociogenetic reconstruction and propagation of forms and functions. Thus microgenetic constructions take form in relation to processes of sociogenesis. Such microgenetic and sociogenetic constructions are also moments in ontogenetic trajectories, taking form in relation to individuals' prior understandings and affording the possibility of new developmental trajectories. Furthermore, insofar as micro- and sociogenetic processes are occurring at moments of ontogenetic time for interlocutors, ontogenetic processes figure into both the production of mathematical communications and what individuals take up from communications with others. This general orientation to genetic analysis of activity provides a frame for considering processes of historical change in the use of *fu*.

Microgenesis[15]

Cultural forms such as *fu,* units of currency such as kina and toea, and material objects such as a pile of stones contain no intrinsic meaning, mathematical or any other. We have made this point—albeit indirectly—throughout our article. Forms like *fu* and currency take on a plurality of meanings

[15] *Microgenesis* has come to be used in two ways in the conceptual and empirical literature on cognitive development. The first meaning dates back to Vygotsky's work in the 1930s (Vygotsky, 1987) as well as to the later writings of Werner

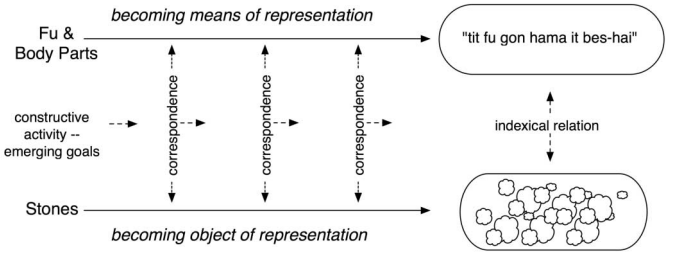

FIGURE 25 A depiction of a microgenetic construction of 29 stones over a moment in time where body parts and *fu* become a means of representation and the stones become an object of representation.

in Oksapmin everyday life, and some have no quantitative significance. For instance, in our interview about the meaning of *fu*, one elder said that *fu* was the sound one makes when one blows on a fire. Others offered more conventional meanings, though again they differed—"a complete group," "plenty," "the completion of a count to a pinky (27th)," "the completion of a count to the elbow (20th)." Similarly, units of currency can be treated as objects in themselves, with no intrinsic exchange value. This is clear in Tok Ples, where the terms for currency may well be vestiges from early contact. For instance, 1-kina coins in Tok Ples are literally referred to as "flat things with hole." Coins in general are referred to as "the sound of rustling stones." And one of the varied expressions for a 2-kina note is translated from Tok Ples as "a flat leaf." Similarly, a group of stones can be treated as a pattern, projectiles used in a slingshot for hunting birds, or other kinds of objects without quantitative significance.

If body parts, word forms such as *fu*, material objects such as stones, and cultural artifacts such as currency have no intrinsic meanings, how do they become imbued with mathematical properties? We argue that it is through a microgenetic process in which individual speakers organize cultural forms, such as the Oksapmin body system, to serve particular numerical functions (Saxe, 1999). Let's consider a couple of illustrative examples.

A microgenetic construction of 29 stones. Let's reconsider the elder's count of 29 stones presented in Figure 21. At face value, this count seems simple enough. The woman counted the stones with body parts that began at one thumb (1), proceeded to the pinky of the opposite hand (27, *fu*), and then went back up to the forearm (29), announcing the count as *tit fu gon hama it bes-hai*, roughly translated as a complete round and the forearm (see Figure 21 for the trajectory). What occurred in this act of counting that enables the elder to treat her representation as a numerical one? In this regard, we find three dimensions of activity, and we offer a schema for these in Fig-

---

and Kaplan (1963). These authors regarded microgenesis as a developmental process of schematization, either perceptually or conceptually—individuals move from relatively diffuse to more articulated perceptions or conceptualizations over short durations (see also Saxe, Dawson, Fall, & Howard, 1996). More recently, some authors have made use of *microgenesis* or *microgenetic methods* to refer to the study of shifts in children's strategies or cognitive structures over very short periods through repeated presentations of similar problems (see, e.g., Miller & Coyle, 1999; Siegler & Crowley, 1991). In this set of studies, we use the first meaning.

ure 25. One includes the body parts and *fu,* which become in this case a vehicle of representation; another dimension includes the stones, which become in this case an object of representation; the third dimension consists of a correspondence that becomes established between successive body parts and discrete stones—the mathematical basis for the numerical representation. The production of these three dimensions of activity (a vehicle of representation, an object of representation, and a correspondence between the two) constitutes a microgenesis of number.

First, consider the elder's treatment of *fu*. The word form becomes a means of specifying a particular ordinal position in an enumeration of body parts. Recall that in her count, the elder enumerates body parts, passing the left forearm (7th) and the right forearm (21st), and then progressing back up the body, ending on the right forearm (29th). In the final oral representation, *fu* becomes a means of marking the trajectory of the count. This trajectory passes over both the left and right forearms and then back up past the wrist (28th) to reach the right forearm once again (29th), as signified by *it bes-hai*. Thus *fu* becomes a means of marking an ordinal position along a trajectory, supporting the mathematical coherence of the number of one-to-one correspondences produced (29) with the final representation of the wrist (distinguished from 7th and 21st ordinal positions, also denoted by a forearm). In this sense, *fu* is a means of accomplishing the goal of representing a particular cardinal value, and that value is positioned in relation to other body-part values within the system itself.

Second, consider the elder's treatment of the stones. The stones themselves vary in their physical properties, like texture and size. In the count, however, the elder ignores these differences, instead treating the stones as units that are differentiated only by their ordinal position relative to one another. In this act, the stones become a group of discrete objects, each contributing a unit of one to a sum.

Third, consider the elder's generation of the body-part representation and the stones themselves. Not only do body parts and stones become treated as numerical entities in activity, but a particular relation is generated: A particular body-part expression, *tit fu gon hama it bes-hai*, indexes the particular number of stones. This relation depends on the establishment of a correspondence from one system to another. Indeed, by producing a one-to-one correspondence between an ordinal set of body parts and a discrete set of objects, the elder takes the last body part of the enumeration to index the cardinal value of the stones.

A microgenetic construction of 29 kina. Of course, *fu* can serve other kinds of mathematical functions, and these other functions are based in different kinds of correspondences created by a three-stranded process. Consider the use of *fu* in the representation of two 10-kina notes, four 2-kina notes, and one 1-kina coin, a total value of 29 kina. When we presented this currency amount, one elder produced the representation *arum-hai fu hama tan-kin-o temsi tana*, which can be translated as "nose" (14) *fu* and then one 1-kina coin (the "flat-with-the-hole") on the "eye on the other side" (15th position; see Table 2). In this case, *fu* serves a different mathematical function. Rather than to mark a place in a trajectory, it is used to refer to a value of 2 kina, and this reference

TABLE 2
A Representation of K29: Two Ten-Kina Notes, 4 Two-Kina Notes, and 1 One-Kina Coin

arum-	*hai*	*fu*	*hama*	*tan-*	*kin*	*-o*	*temsi tana*
Nose (14th body part)	Cardinal number marker (changing ordinal to cardinal)	*FU*(pound or K2 note or double body part value)	and	Other side of body	Eye (15th body part)	that one	Hole flat (the K1 coin)

carries a many-to-one correspondence relation: For every currency note there are 2 kina. Thus the nose (14th) is used to represent the value of fourteen 2-kina notes, the equivalent of 28 kina, and the 1-kina coin is placed on the eye, which is the 15th body part and comes after the nose, to represent an additional kina resulting in a value of 28 +1 = 29.

In each of these two examples, *fu* serves numerical functions for the elders. From a numerical perspective, however, the logic of these correspondences is quite different. In the first case, the correspondences are one-to-one, established between body parts and stones. *Fu* marks a point in the trajectory of these correspondences, correspondences that become treated as a sum in the representational activity. In the second case, the correspondences are both many-to-one between values of 2 kina and body parts and one-to-one between the eye-on-the-other-side (15th) and a 1-kina coin. In this case, *fu* as a trajectory marker is barely visible—only prior knowledge of its complex social history would provide a hint of its origins as a marker of the 20th shilling in a count of currency.

Though the correspondences implicit in the two representations are different, the activity of each elder reveals a particular mathematical coherence. It is this coherence—or efforts to establish it—that regulates the microgenetic constructions. Indeed, when people encounter trouble in their representational activity, appeals to such coherence serve as a constraint that guides repairs.

To illustrate the importance of mathematical coherence in quantitative activity, consider the case of the stones. On many occasions, we found that informants repaired their initial counts, and these repairs were regulated by a concern for the logic of correspondence relations. Were the woman inadvertently to skip a body part and be aware that she did so, we might imagine that she would judge her final count to be wrong. Of course, she might, in turn, create an idiosyncratic procedure by compensating through subtracting one from her final representation for the body part skipped. If she had skipped a stone and were aware that she had, she might create a different idiosyncratic procedure by adding a body-part value to her final count. Or she might not take either course and instead produce a recount or let the matter lie, unconcerned about precision. In any case, she makes use of one-to-one correspondences as a criterion both to guide and to repair her numerical activity.

In a similar way, in the representation of 29 kina we find that a respondent might engage in similar adjustments, though the adjustments would be organized by reference to many-to-one correspondences and thus be rooted in a different kind of coherence. In representing the kina the woman might miscalculate, indicating that the kina presented were *nat-hai fu hama tan-kin-o temsi tana* (ear [12] *fu* and flat-with-the-hole on the eye [13]), an expression that would be the equivalent of 25 kina. Were she to check the representation, we might imagine that the basis for the check would be the adequacy of the ear (12) as a representation of 28 kina, or a 2:1 relation between body parts and kina.

Of course, mathematical representations may be created in many circumstances seemingly with no regard for mathematical coherence. As examples, consider "mindless" counting, an automatic process regulated by habit. Our claim here is that in microgenetic activity, people may encounter problems in producing and interpreting representations, even when the production of a mathematical representation is not consciously guided by principles of correspondence or its entailments (e.g., commutative, associative, additive properties). In repairing their productions and interpretations, people evaluate representations with respect to the process of their production—the creation of one-to-one correspondences themselves as well as their logical entailments.[16] Thus issues of mathematical coherence as a constraint on microgenetic processes can

[16]Leont'ev (1981) pointed to this movement in his discussion of back-and-forth shifts between conscious actions–goals and automatic conditions–operations dimensions of activity.

seem invisible until problems arise, at which time these constraints enable repairs and reconstructions in ways that mitigate or solve problems.

In our sketch of microgenesis, people turn cultural forms like the body system into means for accomplishing representational and strategic goals. Although there are many constraints on microgenetic processes (e.g., memory, perception), one important regulative constraint in representational activity is rooted in the coordination of mathematical relations. By their very nature, microgenetic activities always have aspects that are innovative and aspects that are reproductive. They make use of extant forms, whether cultural or material. At the same time, they generate (and thereby innovate) meanings.

The analysis of microgenesis is fundamental for understanding the generation of mathematical reference. Nevertheless, microgenetic analyses cannot account for the complex of semistable communicative forms that have emerged and been taken up in different ways by people as such forms propagate through networks of interlocutors over social histories. To understand such processes of propagation and uptake requires different kinds of analyses, ones linked to the microgenesis of activity but not reducible to it. We next consider processes of sociogenesis and then ontogenesis.

Sociogenesis. In prior sections, we documented in some detail the shifting relations between the word form *fu* and the mathematical functions that it has served. Since Western contact, the meaning of *fu* changed from an ordinary language meaning for a qualitative sense of completeness or plenty to a precise meaning of double. This change occurred through multiple transitional phases, vestiges of which are apparent in community life today. We now focus on ways to account for the emergence and propagation of these diverse forms and functions.

We pointed out earlier that one approach to understanding the cultural evolution of forms and functions is through a model of independent invention. On this view, individuals themselves invent new functions, constrained and enabled by autoregulative principles like the equilibration of action schemes as explicated by Piaget (1970, 1977).[17] Though we find merit in the centrality of individuals' constructive activity in accounts of mathematics, such a thesis is unsatisfactory in its strong form. So much appears haphazard and idiosyncratic in the serendipitous events that we have described leading to the multiplicative function of *fu*. Indeed, though the Oksapmin system and the use of *fu* may at first blush call for an intentional design explanation, the facts as we have described them indicate that there was no such intended design. Indeed, the doubling function of *fu* appears much like what Keller (1994) refers to as a phenomenon of the third kind—an artifact produced by collective actions, with individuals pursuing intentions and goals unrelated to issues of design of a representational system. Indeed, the evolution of *fu* is an emergent process, something resulting from collective activity but not intended by it.

We take the view that a more adequate framework for understanding shifts in *fu* must involve a coupling of a microgenetic model with a commensurate sociogenetic model. This framework targets communicative activity in collective practices as a critical nexus for analysis, a view similar to that held by some historical linguists in treatments of language change (see, in particular, Croft, 2000).[18]

[17]We take up issues of individuals' own genetic histories in our subsequent section on ontogenesis.

[18]Sperber's general treatment of the epidemiology of representations is relevant to our treatment as well (Sperber, 1996).

The approach that appears to fit the Oksapmin case of *fu* argues that individuals operate with varied conversational maxims of action (Grice, 1989; Keller, 1994). Keller proposes maxims such as "Talk in such a way that the other can recognize your intentions" and "Indicate your intentions in such a way that the other can recognize them" (p. 98). The maxims are aspects of local rational activity and may well act to regulate and capture speakers' efforts when people are trying cooperatively to accomplish an economic exchange.

Consider Grice's well-known maxim of quantity as one such communicative constraint that may support a sociogenetic process. The maxim is that, in conversation, individuals make their contributions "as informative as is required for the current purposes of the exchange" and "do not make contributions more informative than is required."[19] The maxim leads to the expectation of a two-stranded process when interlocutors refer to novel objects for which they lack standard forms of reference. Let's take the introduction of a novel currency denomination, a coin, into the Oksapmin area as an illustration. Because the coin is new, there are no established conventions for referring to it. Further, knowledge of currency as a system of denominational values is distributed unevenly over the population.

The first strand of the sociogenetic process is synchronic, distributed over many locations in a community (such as the many Oksapmin trade stores). It is a source of variation in a population of utterances to serve similar functions in Croft's (in press) evolutionary treatment of language change. To provide sufficient information to orient a listener to, say, the novel 1-kina coin (in accord with a maxim of action), a speaker may make reference to the coin with merely a pointing gesture in a communicative act. In this deictic gesture, speaker and audience both orient to a common object through this motion in the give-and-take of communicative moves.

In other interactions, we might observe different communicative moves that also lead to joint orientation to a 1-kina coin. A speaker at a separate location might refer to the coin by a descriptive phrase that captures material features of the novel object, such as *tana* (flat), because the coin has a flat surface. This communicative move involves a term known to both speaker and audience, and it orients the audience and the speaker to the same object much as the gesture does. In another interaction, an interlocutor may refer to another 1-kina coin as *temsi*, the one with a hole (see Figure 26 for a representation of the 1-kina coin, distinguishable by the hole at its center), similarly orienting an audience to a descriptive term that marks a particular object and potentially affords reference in the coin's absence. We suspect that these initially idiosyncratic acts may vary in many ways from one another (describing the coin's texture, color, animals imprinted on a side, etc.). In this regard, they may become the germs of the sociogenesis of new forms and functions.[20]

---

[19] Grice (1989) contended that the Cooperative Principle and its associated maxims were universal. Others have argued otherwise (e.g., Spencer-Oatey & Jiang, in press). For our purposes here, we simply contend that some conversational constraints operate that are akin to Gricean maxims that lead to particular conversational dynamics with reference to mathematical representations.

[20] In fact, the use of descriptive phrases in what were initially idiosyncratic references is a very general phenomenon in Oksapmin. We note a few such references that have become stable communicative forms. For example, *kwekor,* the word for coins, literally means "the sound of rustling stones." *Haben tan*, a word for 2-kina notes, literally means "a flat leaf." Other word forms, like *gangasi,* an expression for a 50t coin that is the shape of a heptagon, literally means "with corners" (see Figure 10). Still other forms do not capture the material aspects; instead, they are metaphorical constructions that reflect prevalent ideas in the Oksapmin community that capture a thematic property of an object. Thus, to refer to the 20-toea coin, we find that *gamantan* is used, a term that literally means "marriage of flats." Here, the reference is to a marriage between what are today two 10-toea coins—the unit linked to the earlier prominence of the shilling coin.

The second strand of the process of change is diachronic, occurring as individuals' activities take form over time as they move through varied networks of other interlocutors. As interlocutors encounter recurring problems in communicative exchanges, the quantity maxim would lead them to make use of one another's means of reference through repeated uptake and repair in the back-and-forth of interaction. This maxim operates, in effect, to select for a particular way of referring to an object out of possible variations —again, a process consistent with Croft's (2000) evolutionary account of language change. In these communicative activities, individuals select, take up, and repair particular idiosyncratic constructions to solve recurring problems, adjusting their talk in relation to others' knowledge. Through such a process and in accord with the maxim, individuals create forms of reference that are "as informative as is required for the current purposes of the exchange" and "do not make contributions more informative than is required." The result—over the course of many interactions—would lead to semistable forms that are used, modified, and reused as interlocutors move through varied sites of collective activity. In essence, processes of variation and selection parallel evolutionary accounts of language change.

What data do we have to support claims of such a diachronic process? One approach to finding support would be to consider whether in talk today we have vestiges of idiosyncratic constructions that have become stable forms of reference. We might also ask whether different communication networks have developed different stable forms of reference. To explore whether in fact such forms occur and to determine their generality across networks of interlocutors in Oksapmin, we asked people to identify names for coins and notes in Tok Ples. We conducted individual interviews with about 80 people, including elders, unschooled adults, schooled adults, and children. In the analysis of our data, we found that people used two principal types of expressions to refer to the 1-kina coin in Tok Ples, each of which appears to have roots in pragmatic efforts to communicate: *kat-hai* (shoulder [10]) and *temsi* (hole). The descriptive and orienting properties of these expressions should be clear. The reference to *kat-hai* (10) derives from the fact that a count of 10 *silings* is equivalent to 1 kina. The reference to *temsi* (hole) is associated with the hole at the center of the 1-kina coin (see Figure 26).

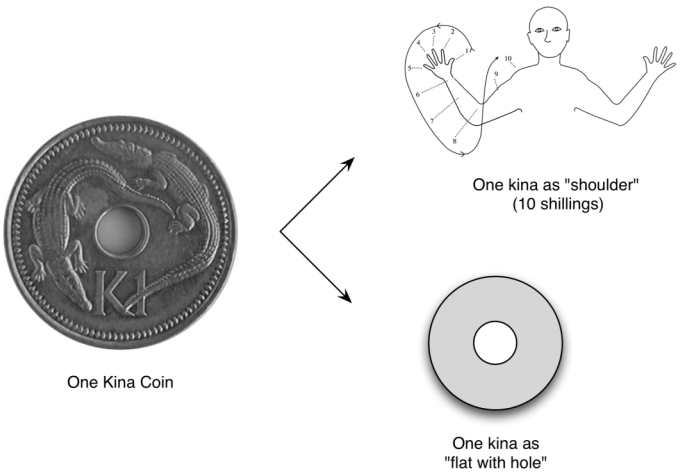

FIGURE 26 Two conventions differentially used to refer to the 1-kina coin.

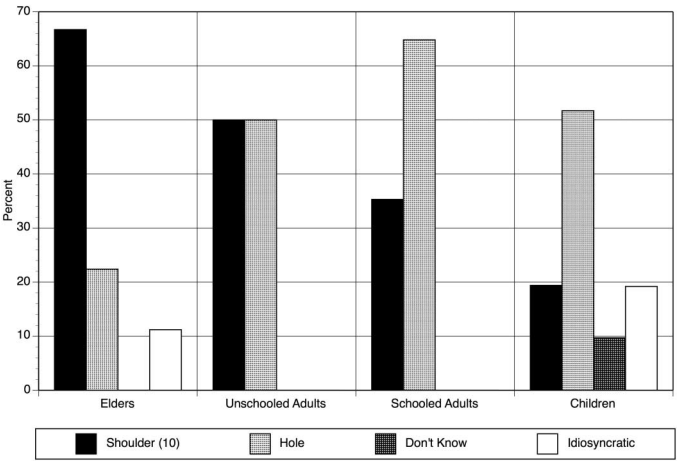

FIGURE 27 Percentage distribution of use of *shoulder* (10) or *hole* to refer to the 1-kina coin as a function of cohort.

Figure 27 shows the percentage distribution by cohort of the use of shoulder (10) and hole (*temsi*) (or flat with hole [*temsi tana*]) expressions. The patterns of use of these forms differ across cohorts. Elders used shoulder (10) three times more frequently than hole, whereas children and schooled adults showed the reverse profile. The unschooled adults used these expressions with equal frequency. A small minority of children and elders produced idiosyncratic terms, and some children indicated that they didn't know the Tok Ples word for the coin.[21] To understand these different profiles, we consider the different patterns of participation involving quantifications associated with each cohort.

Why did elders use *kat-hai* (shoulder) more frequently than hole? Why did children use hole more frequently than shoulder? We suspect that the answer lies partly in the history of semi-isolated communicative networks in which these informants participated in everyday collective practices in which quantification issues emerged (see Agha, 2003; Croft, 2000; Milroy, 1987). Consider some of the networks of collective practices involving quantification that may have had little overlap. This may provide some insight into why some forms may differ in frequency of use across cohorts.

At school, children communicated about quantity in English and Tok Pisin. This was the predominant system of quantification at this site and was itself a locus of communicative networks as children moved through various activities, interacting with one another and teachers in varied ways that involved quantification. For example, during whole-class presentations, teachers posed arithmetical, measurement, and other kinds of quantitative problems in English or Tok Pisin and children were expected to answer in kind. They interacted with one another at times in groups in which school-related math problems became topics of discussion. In contrast, elders participated

[21] A few people produced more than one expression to refer to the 1-kina coin. In the bar chart, we counted only the first representation offered by an individual.

in trade stores and perhaps to a more limited extent in vegetable markets (both export and local). Many did not know Tok Pisin and had a long history with the body methods of quantification, which, unlike in the school setting, were acceptable for use at these sites. To a limited extent, we find overlap in the communicative networks in school and at trade stores. Though elders had no participation (and have no history of participation) at school sites, children did frequent trade stores like the elders.

How might such differences support the differential use of *kat-hai* by elders and *temsi* by children to refer to the 1-kina coin? Elders, in their history of communications with others involving quantification, used the indigenous body system to communicate quantitatively. Many never learned Tok Pisin, and it may not have been supported in everyday talk. In their participation in collective practices in 2001, many made use of the body to quantify. Expressing 1 kina as a count of *silings* up to the shoulder was thus a natural extension of this approach to quantitative expression, setting the kina as a value that was related to other values. In contrast, schoolchildren regularly communicated about quantity with others in classroom life using Tok Pisin and English, and the body was not used much at all. Therefore it is not surprising that the common word choice is a descriptive term in Tok Ples, one that does not require knowledge of the internal coherence of body parts as a numerical system.

Other explanations are certainly plausible, however, and do not contradict the one that we offer. For example, it may be that use of a particular expression would identify an individual with one group as opposed to another. Thus the use of *kata* by schooled adults and children may have identified them with an unschooled population, perhaps carrying a negative value. Such sociolinguistic approaches to explanation appear appropriate in some contexts (Agha, 2003) and may be appropriate in this case as well.

In sum, problems of idiosyncrasy and the communicative press to avoid repeated negotiations of reference become an inherent part of communicative activity. In this process of local negotiation in which speakers make efforts to communicate meaning, some forms are taken up, becoming valued over others, competing with others in subsequent interactions over place and time. In the process, we find much room for contradiction and ambiguity, as a form used during a particular period may have two or more distinct genetic lineages.

How might our remarks about diachronic change bear on the sociogenesis of *fu*? We suspect that the processes of innovation, propagation, and conventionalization of forms that orient joint attention to objects of reference may be an important key in our observations of shifting relations between form and function over the social history of *fu*. To illustrate this idea, we consider two examples. In both, *fu* is recruited in an idiosyncratic way to serve a new function in a communicative interaction.

First, consider the use of *fu* and reference to 29 stones in our interviews. Recall that when presented with a group of 29 stones, one elder counted them and offered the oral representation of "one complete round and then forearm": *tit fu gon hama it bes-hai*. Noteworthy is the fact that she did not simply point to the terminating body part or state "*tan-bes-hai*" (forearm on the other side). Though such a response is generated by numerical operations of one-to-one correspondence, the resulting representation would not be interpretable from the listener's perspective.

In taking a listener's perspective in mind, a speaker makes an effort to represent the trajectory in language. One way of accomplishing this is through a particular use of *fu*. In other words, the public expression of the representation is geared toward revealing the speaker's microgenetic construction in a way that is coherent to a listener. The representation is a public production, and

fu is used to support or perhaps anticipate an issue of communicative coherence. To the extent that such adjustments are appropriated by others, they propagate through networks of individuals. In fact, many others used alternative means to produce such communications. This then is a kind of idiosyncratic construction that has not spread.

A second illustration is one that we did not observe directly. It illustrates one route whereby *fu* may have been an adaptation to solve a communicative problem that led to its use as a signifier for a 2-kina note. The scenario begins with an elder who wants to purchase a tin of fish. He puts out money on the counter to pay for the fish that the owner states costs K2.70. The owner counts the customer's display of money. Knowing that the customer is suspicious of being shortchanged, a common statement by clerks, the owner makes an effort to make his count clear, and in doing so, creates a new use of *fu*. He counts the coins with the body system to the value of 20 *silings* (that is, twenty 10-toea coins), calling the 20th a *fu*, making use of a term familiar to the elder, one that captures a complete group of plenty. He emphasizes a currency unit that is well known to the elder: that the 20 shillings are a complete group (a *fu*) that is also called *faun*. The owner then proceeds to count the additional 7 using the body system, starting from the thumb (1), resulting in a representation of *tit fu* (2-kina note), *bes-hai* (the seventh body part or seven 10-toea coins).

We take this scenario as emblematic of how recruiting joint attention through concern for a hearer's knowledge may be the key to the use of prior forms to serve new functions. The use of *fu* in such transactions orients joint attention to an object of reference—the 2-kina note—with specific regard for a mathematical abstraction, constituted as a unit of 20. To do so, the owner engages the elder with a prior meaning of *fu*, now stretching that meaning in a new direction, one that shows both continuity and discontinuity with previous uses. The new function is continuous with the prior function, in that it retains its reference to completeness, though it is discontinuous in that now completeness is defined in reference to a count that ends at the elbow.

Such serendipitous recruitment of forms to serve new communicative functions may be a useful device whereby one trade store owner communicates with his elderly customers. As we have argued, some such ad hoc recruitment may catch on and may propagate across interactions. This can happen without speakers being aware that they are participating in shifting the structure of a representational system, shifts that are better geared for current life circumstances (recall the traffic jam).

We end our remarks on sociogenesis with the note that the microgenetic constructions that pervade activities of interlocutors in collective practices can never be communicated directly—we can never know other minds. One person produces a construction in an effort to communicate intent, which then becomes subject to another's interpretive construction. Recruitment of joint attention through reference to a physical property of an object is one way to coordinate another's activities with one's own. In this process, interlocutors make efforts to create representations that not only are coherent mathematically (microgenesis) but that also orient joint attention to the same object of reference. Though joint attention to a common object does not ensure the construction of identical meanings, it does support microgenetic processes in which the same object may coordinate activities of different interlocutors.

Neither our remarks about microgenesis nor about sociogenesis capture change over the life course of individuals, a topic that has been at the center of treatments of cognitive development. We now turn to this strand of shifting relations between cultural forms and the functions they serve.

Ontogenesis. Ontogenesis is a strand of development that is often a target of research by developmental psychologists or at least by those concerned with issues that have come to be identified with developmental psychology (e.g., Piaget, 1970; Vygotsky, 1978; Werner, 1948). The strand is concerned with the development of the individual—progressive shifts in the organization of cognition over an individual's life span, though often defined as the period from infancy through adolescence. An important idea in developmental research is that higher cognitive functions, such as number, are not learned directly from the environment and are not prewired, simply unfolding in maturational sequences; rather, they are themselves constructed over development. In Piagetian accounts, these functions are the equivalent of cognitive structures, like addition–subtraction or multiplication–division.

As an illustration of processes of ontogenesis and their bearing on our treatment of *fu*, we draw on a study conducted in 1978, when many children knew the body-part count system or at least the sequence of body parts used in it. The study, though not directly focused on shifts in the function of *fu* in children's development, is closely related and provides a good illustration of this genetic strand and the development of numerical functions in children's activities.

In the study, I individually interviewed children using two kinds of stories. Each story was designed to reveal the functions of body parts in comparisons of numerical values of sweet potatoes. Specifically, the study examined whether children's judgments about a body part's value of groups of sweet potatoes was based on its ordinal position in an enumeration or some other way of treating body parts in an enumeration.[22]

In one story, children were shown the place to which one person counted sweet potatoes (a sweeping gesture was made from children's right thumbs to a specified body part on the right side of their bodies). Children were then told that on another day the person counted sweet potatoes and counted to a different place (another sweeping gesture was made from children's right thumbs to a specified body part on the left side of their bodies). Children were then asked if the person counted to the same amount of sweet potatoes (pointing to the two body parts) or different amounts. If children responded with different amounts, they were asked which was the bigger amount. The interviews revealed that the younger children tended incorrectly to identify symmetrical body parts as equivalent in value (e.g., left ear–right ear), and when they correctly identified asymmetrical body parts as not equivalent, they did not regularly identify which of the two represented the greater value. Older children produced accurate body-part comparisons, regardless of the physical similarity of the body parts.

The findings with the second interview corroborated the first. For the second interview, children were told that people in their own hamlet count from the right to the left sides of their bodies (this was indicated with a sweeping gesture on the child's body); in a village over the mountains, however, people count from the left to the right side of their bodies (again, illustrated with a gesture). The children were told that two people from these hamlets counted to the same body part, one beginning at the right thumb and the other beginning at the left thumb. The children were then asked whether the two men counted to the same number of sweet potatoes or whether they counted to a different number. Again, children's approaches to these comparisons were revealing, pointing to a shift in function of the body parts in children's understanding of them in enumerative activities over ontogenetic time. Younger children tended to consider the same body part reached

[22]Note that this study that is used to make claims about ontogenesis makes use of a cross-sectional method, sampling children of two age groups, a common technique used to make claims about ontogenetic development.

from two points of origin (left and right thumbs) to represent the same value. In contrast, children in the older age group considered the value of a body part to be based on its ordinal position in an enumeration.

Though *fu* was not the target of inquiry in this 1978 study, inferences about *fu* would seem straightforward with regard to ontogenesis. If *fu* were understood by these children to refer to a particular body part or body-part position (e.g., the pinky, the elbow), the function of *fu* would shift just like the functions of the other body parts. Younger children may well treat *fu* with respect to the physical characteristics of the body part—the elbow or the pinky—not as an ordinal number in a numerical series. In contrast, older children would tend to define a numerical body part with reference to numerical order, its value defined in relation to an ordinal position in an enumeration.

In our account of ontogenesis, children shift in the forms that they use and the functions that these forms serve in activities. Thus, ontogenetic trajectories constrain and enable micro- and sociogenetic developments in fundamental ways. Indeed, moments of time in ontogenetic trajectories manifest in activities that have implications for the ways in which forms are taken up and the functions that they are used to serve in micro- and sociogenetic processes.

SUMMING UP, LINGERING ISSUES, AND NEXT STEPS

Earlier in our article, we sketched three sets of related challenges that are common conundrums for genetic analyses, evolutionary biology, historical linguistics, or comparative psychology. The challenges were to identify through evidence and argumentation (a) progenitors of an extant form, (b) shifts whereby progenitor form–function relations became transformed into successor ones, and (c) the ecocultural niches that support (and are supported by) the dynamics of the form–function shifts. In our treatment, we took up these challenges in relation to the social history of mathematics in Oksapmin communities. We leveraged our efforts by focusing on *fu,* a cultural form used in mathematical activity from precontact times through the present. We organized our inquiry in a way to further our understanding of the interplay between historical and developmental processes in cultural life. In the course of our efforts, we pursued two related tacks with the threefold challenge in mind.

The first tack was empirical, though guided by a cultural-developmental framework that we explicated in the later part of our article. We selected economic exchange as a target for study and structured methods and gathered varied kinds of convergent data about *fu* as it was used in activities involving exchanges. We drew on informal observations made in 1978, 1980, and 2001 to raise questions about meanings of *fu* and its social history of use. Systematic study of varied aspects of people's mathematical activities allowed for the analysis of the spontaneous uses of *fu* in quantifications in varied contexts. We also probed people about their knowledge of *fu*. For example, interview studies about the meaning of *fu* across cohorts allowed for systematic explorations of its conceptualization by individuals both in contexts of quantification and in its meaning in ordinary language contexts. Across such studies, we used a stratified sampling approach in which we analyzed interviews as a function of cohort to gain insight into (a) the heterogeneity of form–function relations within the community at a particular moment in time as well as (b) a historical perspective on shifting form–function relations linked to a shifting organization of collective practices. Finally, archives of original reports by patrol officers during the period of early contact in Telefomin and Oksapmin as well as accounts of Oksapmin people themselves about

early practices were important resources for us in efforts to document changing practices of economic exchange from precontact times through today.

The second tack was conceptual. We noted that serious efforts to incorporate social history into empirical analyses of cognition are largely absent from cognitive developmental treatments. Those few projects that have made headway lack ways of well incorporating the interplay between collective and individual activity in emerging trajectories of historical change. In this regard, we sought to refocus historical analyses on form–function relations in collective practices, with a concerted treatment of the dynamics of micro-, socio-, and ontogenetic processes in the dynamics of historical stability and change.

The cultural-developmental framework that we have outlined here shows promise in that it has supported an analysis that reveals some of the important dynamics of the shifting structure of mathematics in Oksapmin communities. Of course, *fu* is only one and perhaps a unique case. In our prospective work, we are exploring new ground. We are widening our scope of inquiry into shifting properties of Oksapmin mathematics related to economic exchange and also focusing on schooling as an additional site for study and diachronic analysis.

ACKNOWLEDGMENTS

This article was made possible by the help and support of numerous individuals and funding from the Spencer Foundation (#200100026). The data presented, the statements made, and the views expressed are solely the responsibility of the authors.

We have drawn on exchanges with Thomas Moylan, Virginia Guilford, and Marshall Lawrence for insights into some of the empirical issues that we discuss in this article. Wilfred Kaleva and Rex Matang of the Glen Lean Ethnomathematics Centre provided key support for enabling the 2001 trip to Oksapmin. Many Oksapmin people were important in enabling our 2001 research effort; these included the staff at both Bak and Divanap community schools, in addition to many other members of the Oksapmin community.

We greatly appreciate comments on a prior draft of this article from Sam Gosling, Thomas Moylan, Michael Cole, William Croft, Thomas Welskopp, and Walter Johnson. We owe Michael Wesch a special note of appreciation for his help in Tabubil. The Center for Advanced Study in the Behavioral Sciences provided an extraordinary work environment for Geoffrey Saxe to complete the manuscript.

Appreciation is also extended to National Archives & Public Records Services of Papua New Guinea for providing access to original patrol reports from the Telefomin and Oksapmin Patrol Posts.

REFERENCES

Agha, A. (2003). The social life of cultural value. *Language & Communication, 23*, 231–273.

Barth, F. (1987). *Cosmologies in the making*. Cambridge, England: Cambridge University Press.

Berry, J. W. (2003). Ecocultural perspective on human psychological development. In T. S. Saraswathi (Ed.), *Cross-cultural perspectives in human development: Theory, research, and applications* (pp. 51–69). New Delhi, India: Sage.

Bourke, R. M., Allen, B. J., Hide, R. L., Fritsch, D., Grau, R., Lowes, et al. (2002). *West Sepik Province: Text summaries, maps, code lists and village identification*. Canberra, Australia: The Australian National University, Research School of Pacific and Asian Studies.

Brongersma, L. D., & Venema, G. F. (1962). *To the mountain of the stars* (A. G. Readett, Trans.). London: Hodder and Stoughton.

Brumbaugh, R. (1990). Afek sang: The 'old woman' myth of the Mountain-Ok. In B. Craig & D. Hyndman (Eds.), *Oceania monographs: Vol. 40. Children of Afek: Tradition and change among the Mountain-Ok of Central New Guinea* (pp. 54–87). Sydney, Australia: University of Sydney.

Brutti, L. (2000). Afek's last son: Integrating change in a Papua New Guinea cosmology. *Ethnohistory, 47*(1), 101–111.

Butler, L. M. (2000). *A study of the interplay between traditional agricultural practices, horticultural concepts, and cultural change in rural South Africa.* Unpublished doctoral dissertation, University of California, Los Angeles.

Clark, H. H. (1996). *Using language*. Cambridge, England: Cambridge University Press.

Cole, M. (1996). *Cultural psychology: A once and future discipline?* Cambridge, MA: Harvard University Press.

Cole, M. (2002). *Cross-cultural and historical perspectives on the consequences of education.* Paper presented at the Herbert Spencer Lecture, Oxford University, England.

Craig, B., & Hyndman, D. (1990a). Introduction. In B. Craig & D. Hyndman (Eds.), *Oceania monographs: Vol. 40. Children of Afek: Tradition and change among the Mountain-Ok of Central New Guinea* (pp. 1–8). Sydney, Australia: University of Sydney.

Craig, B., & Hyndman, D. (Eds.). (1990b). *Oceania monographs: Vol. 40. Children of Afek: Tradition and change among the Mountain-Ok of Central New Guinea.* Sydney, Australia: University of Sydney.

Cranstone, B. (1990). The Tifalmin and their environment: Material culture of a Mountain-Ok people. In B. Craig & D. Hyndman (Eds.), *Oceania monographs: Vol. 40. Children of Afek: Tradition and change among the Mountain-Ok of Central New Guinea* (pp. 35–53). Sydney, Australia: University of Sydney.

Croft, W. (2000). *Explaining language change: An evolutionary approach*. New York: Longman.

Croft, W. (in press). The relevance of an evolutionary model to historical linguistics. In O. N. Thomsen (Ed.), *Different models of linguistic change*. Amsterdam, The Netherlands: John Benjamins.

Crump, T. (1990). *The anthropology of numbers*. Cambridge, England: Cambridge University Press.

Damerow, P. (1996). *Abstraction and representation: Essays on the cultural evolution of thinking.* Dordrecht, The Netherlands: Kluwer Academic.

Dasen, P. R. (1972). Cross-cultural Piagetian research: A summary. *Journal of Cross-Cultural Psychology, 3*(1), 23–40.

Dasen, P. R. (2003). Theoretical frameworks in cross-cultural developmental psychology: An attempt at integration. In T. S. Saraswathi (Ed.), *Cross-cultural perspectives in human development: Theory, research, and applications* (pp. 128–165). New Delhi, India: Sage.

Gammage, B. (1998). *The sky travellers: Journeys in New Guinea 1938–1939.* Victoria, Australia: Melbourne University Press.

Gould, S. J. (1996). Creating the creators. *Discover, 17*(10), 42–54.

Greenfield, P. M. (1993). *Historical change and cognitive change: A two-decade follow-up study in Zinacantan, a Mayan community of southern Mexico.* Paper presented at the Biennial Meeting of the Society for Research in Child Development, New Orleans, LA.

Greenfield, P. M. (1999). Cultural change and human development. In E. Turiel (Ed.), *Culture and development: New directions in child psychology* (pp. 37–59). San Francisco: Jossey-Bass.

Greenfield, P. M., Maynard, A., & Childs, C. (1997). *History, culture, learning, and development.* Paper presented at the 62nd Biennial Meeting of the Society for Research in Child Development, Washington, DC.

Grice, H. P. (1989). *Studies in the way of words*. Cambridge, MA: Harvard University Press.

Guilford, V. (1994). *Oksapmin trade stores*. Unpublished manuscript.

Hallpike, C. R. (1979). *The foundations of primitive thought*. Oxford, England: Oxford University Press.

Healey, P. M. (1965). *Telefol Noun Phrases* (Vol. 4). Canberra, Australia: The Australian National University.

Hicks, J. S. (1962a). *Patrol report #2 of 1962/1963—Oksapmin.* Boroko, Papua New Guinea: National Archives & Public Records Services of Papua New Guinea.

Hicks, J. S. (1962b). *Patrol report #3 of 1962/1963—Oksapmin.* Boroko, Papua New Guinea: National Archives & Public Records Services of Papua New Guinea.

Hull, D. L. (1988). *Science as a process: An evolutionary account of the social and conceptual development of science*. Chicago: University of Chicago Press.

Hutchins, E. (1995). *Cognition in the wild*. Cambridge, MA: MIT Press.

Hyndman, D. (1990). The Ok Tedi mining project: Problems with the pot of gold. In B. Craig & D. Hyndman (Eds.), *Oceania monographs: Vol. 40. Children of Afek: Tradition and change among the Mountain-Ok of Central New Guinea* (pp. 161–168). Sydney, Australia: University of Sydney.

Hyndman, D., & Morren, G. (1990). The human ecology of the Mountain-Ok of Central New Guinea: A regional and inter-regional approach. In B. Craig & D. Hyndman (Eds.), *Oceania monographs: Vol. 40. Children of Afek: Tradition and change among the Mountain-Ok of Central New Guinea* (pp. 9–26). Sydney, Australia: University of Sydney.

Keller, R. (1994). *On language change : The invisible hand in language*. New York: Routledge.

Lawrence, M., & Snyder, D. M. (1993). *Oksapmin dictionary*. Ukarumapa, Papua New Guinea: Summer Institute of Linguistics.

Leont'ev, A. N. (1981). The problem of activity in psychology. In J. V. Wertsch (Ed.), *The concept of activity in Soviet psychology* (pp. 37–71). New York: Sharpe.

Lewis, D. K. (1969). *Convention: A philosophical study*. Cambridge, MA: Harvard University Press.

Luria, A. R. (1976). *Cognitive development: Its cultural and social foundations*. Cambridge, MA: Harvard University Press.

Menninger, K. (1969). *Number words and number symbols: A cultural history of numbers*. Cambridge, MA: MIT Press.

Miller, P. H., & Coyle, T. R. (1999). Developmental change: Lessons from microgenesis. In E. K. Scholnick & K. Nelson (Eds.), *Conceptual development: Piaget's legacy* (pp. 209–239). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Milroy, L. (1987). *Language and social networks* (2nd ed.). Oxford, England: Blackwell.

Moylan, T. (1982). *The Oksapmin counting system.* Paper presented at the 1982 Meeting of the Northeastern Anthropological Association.

Nunes, T., Schliemann, A. D., & Carraher, D. W. (1993). *Street mathematics and school mathematics*. Cambridge, England: Cambridge University Press.

Piaget, J. (1970). Piaget's theory. In P. H. Mussen (Ed.), *Carmichael's manual of child psychology* (pp. 703–731). New York: Wiley.

Piaget, J. (1977). *The development of thought: The equilibration of cognitive structures*. New York: Viking.

Robbins, J. (1999). This is our money: Modernism, regionalism, and dual currencies in Urapmin. In D. Akin & J. Robbins (Eds.), *Money and modernity: State and local currencies in Melanesia* (pp. 82–102). Pittsburgh, PA: University of Pittsburgh Press.

Rogers, J. R. (1949). *Patrol Report #2—Telefomin*. Telefomin, West Sepik: National Archives & Public Records Services, Papua New Guinea.

Saxe, G. B. (1981). Body parts as numerals: A developmental analysis of numeration among the Oksapmin in Papua New Guinea. *Child Development, 52*(1), 306–316.

Saxe, G. B. (1982a). Culture and the development of numerical cognition: Studies among the Oksapmin of Papua New Guinea. In C. J. Brainerd (Ed.), *Children's logical and mathematical cognition* (pp. 157–176). New York: Springer-Verlag.

Saxe, G. B. (1982b). Developing forms of arithmetic operations among the Oksapmin of Papua New Guinea. *Developmental Psychology, 18*(4), 583–594.

Saxe, G. B. (1988). Candy selling and math learning. *Educational Researcher, 17*(6), 14–21.

Saxe, G. B. (1991). *Culture and cognitive development: Studies in mathematical understanding*. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Saxe, G. B. (1999). Cognition, development, and cultural practices. *New Directions for Child and Adolescent Development, 83*, 19–35.

Saxe, G. B. (2005). Practices of quantification from a sociocultural perspective. In A. Demetriou & A. Raftopoulos (Eds.), *Cognitive developmental change: Theories, models, and measurement* (pp. 241–263). New York: Cambridge University Press.

Saxe, G. B., Dawson, V., Fall, R., & Howard, S. (1996). Culture and children's mathematical thinking. In R. Sternberg & T. Ben-Zeev (Eds.), *The nature of mathematical thinking* (pp. 119–144). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Saxe, G. B., & Esmonde, I. (2004). Making change in Oksapmin trade stores: Studies in shifting practices of quantification under conditions of rapid social change. *South Pacific Journal of Psychology, 15*(1), 11–28.

Scribner, S. (1984). Studying working intelligence. In B. Rogoff & J. Lave (Eds.), *Everyday cognition: Its development in social context* (pp. 9–40). Cambridge, MA: Harvard University Press.

Scribner, S. (1985). Vygotsky's uses of history. In J. V. Wertsch (Ed.), *Culture, communication, and cognition: Vygotskian perspectives.* New York: Cambridge University Press.

Scribner, S., & Cole, M. (1981). *The psychology of literacy*. Cambridge, MA: Harvard University Press.
Siegler, R. S., & Crowley, K. (1991). The microgenetic method: A direct means for studying cognitive development. *American Psychologist, 46*, 606–620.
Spencer-Oatey, H., & Jiang, W. (2003). Explaining cross-cultural pragmatic findings: Moving from politeness maxims to sociopragmatic interactional principles. *Journal of Pragmatics, 35*(10–11). 1633–1650.
Sperber, D. (1996). *Explaining culture: A naturalistic approach*. Oxford, England: Blackwell.
Swadling, P., Mawe, T., & Tomo, W. (1990). Archaeology of Telefolip. In B. Craig & D. Hyndman (Eds.), *Oceania monographs: Vol. 40. Children of Afek: Tradition and change among the Mountain-Ok of Central New Guinea* (pp. 109–114). Sydney, Australia: University of Sydney.
Vygotsky, L. S. (1978). *Mind in society*. Cambridge, MA: Harvard University Press.
Vygotsky, L. S. (1987). *Thinking and speech*. New York: Plenum.
Weeks, S. G. (1981a). Introduction. In S. Weeks (Ed.), *Oksapmin: Development and change* (pp. 13–33). Port Moresby, Papua New Guinea: Educational Research Unit, University of Papua New Guinea.
Weeks, S. G. (1981b). Oksapmin Chronology. In S. Weeks (Ed.), *Oksapmin: Development and change* (pp. 218–225). Port Moresby, Papua New Guinea: Educational Research Unit, University of Papua New Guinea.
Werner, H. (1948). *Comparative psychology of mental development*. New York: International Universities Press.
Werner, H., & Kaplan, B. (1963). *Symbol formation: An organismic-developmental approach to language and the expression of thought*. New York: Wiley.
Wertsch, J. V. (1991). *Voices of the mind: A sociocultural approach to mediated action*. Cambridge, MA: Harvard University Press.
Wertsch, J. V. (2002). *Voices of collective remembering*. Cambridge, England: Cambridge University Press.
Wertsch, J. V., del Rio, P., & Alvarez, A. (1995). Sociocultural studies: History, action, and mediation. In P. del Rio, J. V. Wertsch, & A. Alvarez (Eds.), *Sociocultural studies of mind* (pp. 1–34). Cambridge, England: Cambridge University Press.
Wesch, M. (2005). Nekalimin.net: A developing ethnography of a Papua New Guinea people in the midst of "development." Unpublished manuscript, University of Virginia, Charlottesville. Retrieved April 18, 2005, from University of Virginia graduate student M. L. Wesch's Web site: http://www.people.virginia.edu/~mlw5k/
Wurm, S. (1983). Linguistic prehistory in the New Guinea area. *Journal of Human Evolution, 12*, 25–35.