# Cognitive Anthropology Research Group
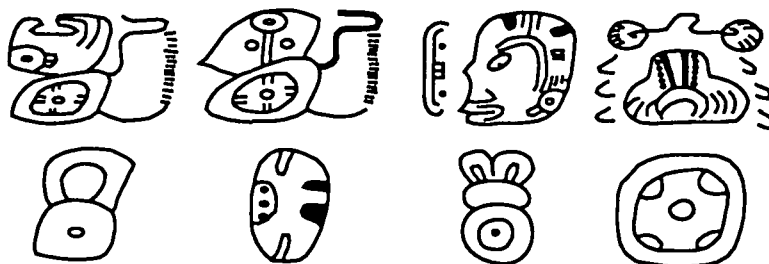
## at the Max Planck Institute for Psycholinguistics

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### LINGUISTIC AND NONLINGUISTIC CODING OF SPATIAL ARRAYS: EXPLORATIONS IN MAYAN COGNITION

### Penelope Brown & Stephen C. Levinson

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# Contents

## List of Figures

## List of Tables

## 1.0 The linguistic determination of conceptual categories[1]

Does a particular language constrain the way adult speakers of it *think*? The answer was taken to be self-evidently 'yes' by many thinkers from the eighteenth century through to the middle of this century: "language" opined W. von Humboldt (1836(1988:54) "is the formative organ of thought". And of course in the middle of this century Whorf controversially articulated a theory of *linguistic determinism* of conceptual organization, which enjoyed prominence for many years. But in our times the answer has been taken to be self-evidently 'no'. The reasons for this negative answer are embedded in the rationalist assumptions of current research throughout the linguistic and psychological sciences.[2] In addition, critiques of Whorf's work[3], and the discovery of significant universals in a few semantic domains,[4] have discouraged further examination. But there is scarcely any modern work that treats the question as one which might even allow an empirical answer.[5]

Here we try to show that the issues can be investigated empirically via the following stratagem: (a) first, pick a conceptual domain; (b) second, find two or more languages which contrast in the semantic treatment of that domain (i.e., where very different semantic parameters are employed); (c) third, develop non-linguistic tasks which will behaviourally reveal the conceptual parameters utilized to solve them; (d) compare the linguistic and non-linguistic representation systems as revealed by (b) and (c), and assess whether there is any correlation between linguistic and non-linguistic codings in the same domain.

In this paper we explore how spatial arrays which are viewed visually are coded for memory and subsequent inference. The general supposition in the cognitive sciences is that such coding will be determined by general properties of visual perception, together with universal conceptual primitives. This much is generally agreed, despite major differences between theorists about the nature of the coding, for example whether it is imagistic or propositional in nature.[6] However, in this paper we throw considerable doubt on this basic assumption; we show instead that the nature of the coding for spatial arrays

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[1] A great deal of collaborative effort has gone into the design and execution of the research paradigm of which this paper is but one instantiation (others are forthcoming, see e.g. Pederson 1994). We thank our colleagues in the Cognitive Anthropology Research Group and in the wider Max Planck Institute for Psycholinguistics for their part in this, together with John Lucy and Suzanne Gaskins of the University of Pennsylvania and Dan Slobin of the University of California at Berkeley, all visiting scholars at the relevant time. In addition, two scholars from the University of Braunschweig, Bernadette Schmitt (now of the Max Planck Institute for Psycholinguistics) and Lazslo Nagy (and indirectly through them, Dirk Vorberg) played an important role in, respectively, the initial design of the experiments and the statistical treatment of the data. We have tried to acknowledge specific debts below, but our debts extend well beyond these citations.

[2] See for example Hirst 1988, Gardner 1985.

[3] See e.g. Rosch 1977.

[4] Notably colour terminology (Berlin and Kay 1969) and ethnobotany (Berlin, Breedlove and Raven 1974).

[5] An exception is Lucy 1992.

[6] For a discussion of the so-called 'Imagery debate' see Tye 1991.

(that is, the relevant set of conceptual primitives) seems to depend on the language you speak. Some such codings are incongruent with perceptual information in fundamental ways. If this is so, we need to radically revise our ideas[7] about the nature of the interface between linguistic categories and non-linguistic conceptual structure.

The paper starts from an observed contrast between two linguistic systems, Dutch (or English or Germanic generally), and the Mayan language Tzeltal, in the domain of spatial description. It reports on a series of experiments designed to test whether this linguistic difference corresponds to conceptual differences, and in particular to test whether there are significant differences in performance in memory and reasoning tasks which may be attributed to the linguistic difference.

## 2.0 Absolute and relative in spatial description

Recently, with a number of colleagues we have begun to explore the conceptual organization of space in the semantic systems of over a dozen non-Indo-European languages.[8] All of these systems vary significantly from English or other familiar European languages in various ways. However, some of them offer a striking difference from familiar systems of spatial organization: in place of notions like 'in front', 'behind', 'to the left', etc., they utilize fixed angles or directions, similar to our cardinal directions 'north', 'south' etc. They do this not only for macro-locations on a geographic scale, but also for micro-locations. Thus instead of descriptions like 'John is in front of the post office', 'my glass is to the left of the bottle', 'there's a bug on your left leg', we find expressions that may be glossed as, say, 'John is north of the post office', 'my glass is west of the bottle', 'there's a bug on your eastern leg'.

Such systems of spatial description, utilizing fixed or 'absolute' directions, are fundamentally different in character from 'relative' systems, like English or Dutch, that use notions like 'in front', 'behind', etc. The difference can be seen by imagining oneself in one of those revolving restaurants characteristic of cities with grandiose pretensions. If I have before me an array in which the fork is to the left of the knife, and a glass of wine to the right of the knife, then all these locational specifications remain constant (if I do not move and the waiter doesn't come) as the restaurant revolves. But for a speaker of a language with cardinal direction specifications, all the locations are constantly changing (the glass is now north, now east, now south of the knife, etc.). On the other hand, if the restaurant now stops revolving and I approach the same table from the other side, the English specifications must now change (the fork is to the right of the knife), whereas the cardinal direction specifications remain the same (the fork is still, say, west of the knife).

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[7] For example, those articulated by Fodor 1983, or Jackendoff 1987.
[8] See Levinson 1992c, and the Max Planck Institute for Psycholinguistics' annual reports for 1991, 1992 and 1993.

2

Location specifications like the English ones depend on relative angles between objects (including the speaker): the angles are given either by coordinates projected from the observer, or by coordinates projected from an oriented object (as in 'My bike is in front of the truck'). When the observer or the reference object rotates, the description changes. But cardinal-direction specifications are invariant to the rotation of the speaker or the reference object: it doesn't matter which way the truck faces, the bike may still remain south of the truck. In short, cardinal directions are fixed angles, in this sense 'absolute'; while notions like 'in front', 'to the left' are angles fixed with respect to the orientation of a reference object (whether ego or object), and are thus in this sense 'relative' to that orientation.

Systems of linguistic description that utilize absolute directions (absolute systems, for short[9]) are not covered by current theories in linguistics, psychology or other branches of cognitive science. In fact, they have been confidently predicted by students of spatial language and cognition to be non-occurring in natural languages (see, e.g., Miller and Johnson-Laird 1976, Clark 1973), following the Kantian tradition that sees spatial cognition as grounded in the human frame (see Levinson and Brown, in press, for discussion). Yet in fact they are probably widespread, occurring in perhaps a third or more of the languages outside the major literate traditions of Europe and Asia. The fixed directions vary from case to case, sometimes being based on sunrise/sunset, sometimes on wind directions, sometimes on landscape inclination, sometimes on distant (effectively unreachable) landmarks. The variety of such systems is large, and the details variable, but the contrast with 'relative' systems is clear.

Systems of absolute spatial description self-evidently require different kinds of spatial computation from relative systems. For a start, it will be essential to keep constant track, night and day, inside or outside, of the cardinal or fixed directions. In addition it can be shown that such systems can only be used effectively if their users can 'dead-reckon' current location with respect to other locations they may want to refer to (Levinson 1992a). Thirdly, since any reference to spatial arrays observed in the past must specify fixed directions, all spatial arrays must be memorized in terms of the fixed angles obtaining within them, otherwise they will be undescribable. Empirical work also shows that gesture in such languages may reliably indicate actual directions of events, and thus that such a cognitive system drives gesture as well as speech (see Haviland 1993). An absolute system of spatial description appears to drive a distinct set of cognitive procedures or computations, together with a distinct set of representations, even when

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[9] Such systems are not 'absolute' in the same sense that Cartesian coordinates might be said to give an absolute fix, since they specify a location with a fixed angle from another location (to which they might be said to be relative). But they are absolute in the sense that the direction (or more accurately, the *range* of directions) is fixed once and for all, and is independent of the position or orientation of observer or reference location.

speaking is not directly involved. There are thus some far-reaching consequences for theories of speech production (Levinson 1992b).

One striking fact about the difference in conceptual style between relative and absolute coding of spatial arrays needs to be borne in mind when considering the experiments described below. A relative coding of spatial arrays, in terms of relations like 'in front of', 'to the left of', etc., is *congruent* with the kind of information provided by the visual, auditory and haptic senses: position is coded egocentrically. An absolute coding of spatial arrays must be decoupled from immediate sensory information, because the coding is invariant under different viewpoints or positions of ego.[10]

There is every reason to expect, therefore, that it should be possible to demonstrate directly that there are cognitive consequences of speaking a language which enforces location specification in terms of fixed or 'absolute' directions.

## 3.0 The Tenejapan system of spatial coordinates

One of the absolute systems currently under intensive investigation is the spatial system of the Mayan language Tzeltal, as spoken in the municipio of Tenejapa in Chiapas, Mexico. In this system, spatial locations between objects not in contact are primarily described in terms of fixed coordinates. In this case the coordinates are not directly related to cardinal points or directions, but are instead notions of 'uphill' and 'downhill' vs. 'traverse' (across the slope), where these directions are fixed by the general nature of the terrain in the territory of the speakers. Roughly, the land slopes down towards the north from the high southern end of the territory, losing over two thousand metres in thirty-odd kilometres. Although the terrain is deeply fissured by valleys, and in general very rugged, so that this overall fall of the terrain is locally masked by reverse or orthogonal inclinations, still the overall inclination is used as the conceptual anchor for the system. The system is linguistically encoded in a systematic three-way distinction in nominals and verbs of motion: if one goes (roughly) south, one goes 'to the up', or 'upwards of X', or one 'ascends'; if one goes either (roughly) east or west, one goes 'to the traverse' or one 'traverses' or 'goes across', etc. This system is then the primary means of describing locations of non-contiguous objects in the visual field: notions like 'at the left of', 'right of', 'in front of', 'behind' etc. are missing from the language, and instead one talks, for example, of the cup as being 'downhill' of the bottle on the table.[11]

Although there is an apparent correlation with our cardinal directions, it is only approximate, and the system is not based on solar or sidereal anchors. Neighbouring

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[10] That is not to deny of course that the computation of fixed bearings does not indirectly involve the ability to sense egocentric rotation and distance.
[11] For a full account of the system see Brown and Levinson 1993a; for the absence of 'left' and 'right', see Brown and Levinson 1992, and Levinson and Brown, in press.

4

Mayan peoples whose terrain slopes in different directions angle their systems in those directions.[12] Note too that the system has one 'strong' axis, namely the 'up'/'down' one, with different labels at its extremities; the other 'weak' orthogonal axis is labelled 'traverse (across the slope)' at both ends. The weak axis roughly corresponds to east and west, but although it is possible to designate east and west by phrases of the sort 'where the sun comes out/goes in', solar passage does not seem conceptually connected to the notion 'traverse'; Tenejapans are keenly aware of the large range of solar motion between the solstices, but have no notion of equinox or midpoint of that motion.[13] Research by colleagues indicates that spatial systems of this sort, based on 'uphill'/'downhill'/'across' may in fact be widely distributed: we have found one such system in a tribal Dravidian language in South India, one in Papua New Guinea, and one in a Tibeto-Burman language in Nepal.[14]

There is one other characteristic trait of Tenejapan language and behaviour that needs to be mentioned. The absence of 'left' and 'right' terms seems to be correlated with a high degree of 'mirror-image blindness'; that is to say, subjects tend to judge images reflected across the (apparent) vertical axis to be identical. In a pilot experiment where subjects were simultaneously shown a figure and either a matching part or a mirror image of a matching part, the subjects judged 75% of mirror-image parts to be identical matching parts, even after discrimination training. (Brown and Levinson 1993b) A further experiment, again with preliminary training, formed part of the series reported here: 27 subjects judged over 60% of mirror-image parts to be identical matching parts of the figures,[15] and only seven subjects consistently avoided this identification of real part with its mirror image.

This experiment is not reported in detail here, but the result has a bearing on the interpretation of the results from the other experiments: one may expect a certain error rate on memory for spatial arrays based on this 'mirror-image blindness' effect.

## 4.0 Testing for non-linguistic cognitive correlates: the paradigm of research

As a domain of research into the language/cognition interface, spatial thinking and language offer certain advantages. Spatial arrays can be presented to subjects for linguistic description, or for non-linguistic memory, judgement or reasoning tasks. The

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[12] See e.g. Gossen 1974
[13] At least as far as we have been able to enquire: such notions are certainly not general knowledge. Compare Vogt 1992 on the Zinacantan Tzotzil system.
[14] See Bickel 1994, and the Max Planck Institute for Psycholinguistics 1992 Annual Report.
[15] There are a number of reasons for the lower percentage in the second experiment: there were a smaller number of judgements after training, so that training effects persisted; the figures were more complex, so that some genuine parts and their mirror-images were not recognized as parts; and finally, and most relevantly, the second experiment was run on the 'strong' uphill/downhill axis which may have made it easier to code the differences between the reflections (this effect being amplified by a directional dot within each figure to ensure that rotation was not confused with reflection). See Brown and Levinson 1993b.

direct perceptual character of a spatial array lends itself to cross-linguistic and cross-cultural comparison.

The experiments described below are based on a single simple paradigm (Levinson 1992a), in which subjects are shown a spatial array, and are then rotated 180 degrees and asked to perform a task on a related array. The rotation is a simple and direct way of discriminating between absolute and relative strategies for encoding spatial relations. For example, suppose you are facing north, and on the table in front of you is an arrow pointing to your left (and thus to the west). You are now rotated 180 degrees and led over to another table which you now face looking south, and you now see two arrows: one points to your left, and the other to your right. You are asked to identify the first arrow seen on the first table with one of the two arrows on the second table. If you think in a relative way, in terms of egocentric coordinates, you will identify the left-pointing arrow with the first arrow; but if you think in terms of absolute coordinates, you will choose the right-pointing arrow, because, like the first arrow, it too points west. (See Figure 1 for illustration.) Notice that under rotation, a relative coding will lead you to select a stimulus that is congruent with the visual image of the arrow on the first table, whereas an absolute coding will lead you to choose a stimulus that is incongruent with - indeed the mirror image of - the initial arrow. Thus *it is possible to directly infer from non-linguistic behaviour the general nature of the conceptual representation* used to code spatial arrays in memory.

Surprisingly enough, there are peoples who reliably think in the second way - by hypothesis, peoples with linguistic systems of spatial description lacking notions of 'left' and 'right' in favour of cardinal directions. Results from an Australian Aboriginal group (Levinson 1992a) showed that such an association exists, and pilot work by us in Tenejapa in 1992 suggested that similar results could be obtained there. A subsequent investigation (Pederson 1993) showed that dialect differences within a South Indian community are also associated with such differences in non-linguistic judgement. Following this, a battery of tasks was developed by researchers of the Cognitive Anthropology Research Group (see Danziger 1993), and this paper reports on the results from these experiments as conducted in Tenejapa in August 1993.
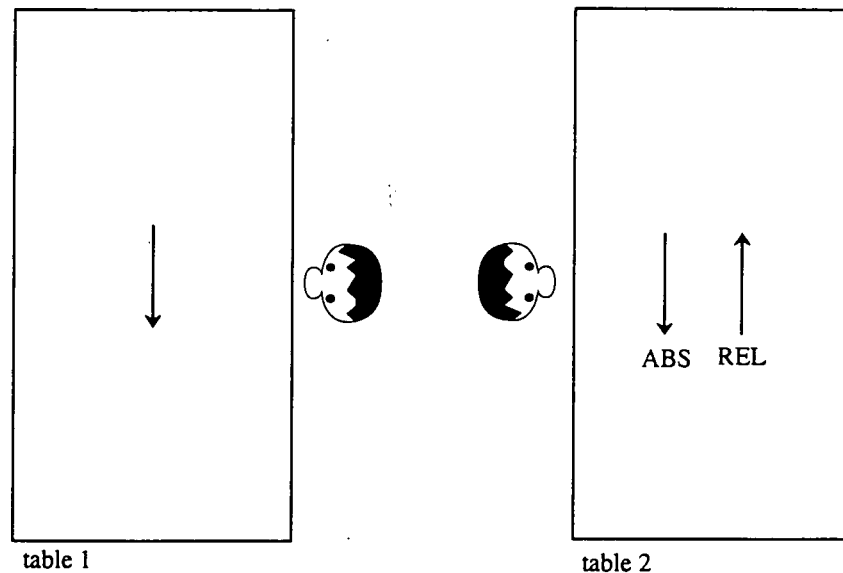
*Figure 1*: 'Absolute' vs. 'Relative' coding of a visual array

The tasks are devised to tap a range of non-verbal psychological properties: recognition memory, recall memory, inference of path from motion, and the inference of transitive relations. They thus have a cumulative impact: if one can show that the whole range of memory and inference tasks are solved using an 'absolute' coding of spatial arrays, there is convincing evidence that the linguistic coding has had a deep influence on non-verbal coding for memory and reasoning. Clearly, it is crucial that the tasks are perceived as non-verbal tasks, and that the verbal instructions do not induce a special task-induced verbal encoding of the arrays. Subjects therefore came fresh to these tasks as naive subjects, and considerable effort went into the design of the instructions: these were always brief, in the native language (Tzeltal in Tenejapa, Dutch in Holland), and they never used expressions encoding absolute directions. Instead, explanations used deictic expressions and accompanying gestures (always delivered with the same hand), on the assumption that such explanations could only bias towards relative thinking, not the absolute coding that was being tested for in the Tenejapan case. It was only at the end of the series of non-verbal tasks that linguistic descriptions were elicited from each participant.[16]

There were five cognitive tasks run consecutively, with short rest periods between them. The tasks were preceded by an interview collecting life-history information, and followed by a short linguistic descriptive task. The whole sequence took about two hours per subject for the Tenejapans, about 45 minutes for the Dutch, due mostly to longer training times. The first task was different in kind,' involving judgements of 'same' or 'different' between figures and mirror-images of them. It is not reported here, but served to attune

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[16] The Tenejapan experiments were run with the help of a native-speaker assistant, Antun Gusman Osil; we are grateful to him for making it possible for us to carry them out under these constraints.

subjects' attention to the details of spatial arrays. The four tasks reported here were run in the following order:

(1) Animals Recall Task: Recall of direction and order of animals in a row;

(2) Maze Recognition Task: Recall of motion and construction of path;

(3) Chips Recognition Task: Recognition of card by direction of coloured elements;

(4) Transitive Inference Task: Inference of transitive relation of relative direction of objects.

All these tasks share the following pattern:

(a) the subject sees a stimulus set on one table (table 1), then:

(b) the array is removed, and (except for task 4) the subject is made to wait facing the same direction without distractions for 30 seconds;

(c) the subject is now rotated 180 degrees and led over to a second table at a distance of about 6 metres;

(d) now facing table 2 in the opposite direction, the subject is asked to recognize a stimulus from a set or to reconstruct an array identical to that seen on table 1, or to use a new stimulus as a second premise in an inference.

The tasks shared certain other design characteristics, for example enough trials (between 5 and 12) were provided to yield a confident 'typing' of individuals as absolute or relative coders of spatial arrays.

For the Tenejapan subjects, the tasks were all run in the same physical setting, under the long veranda of a house. The house lies on the diagonal between the linguistically given 'up/down' axis and the 'traverse' axis, but the tables were so organized that they were approached directly facing east (table 1) and west (table 2) with a screen between[17]. (See Figure 2.) Thus left/right asymmetries in the spatial arrays could be coded using the strong 'up'/'down' reference directions. This might be important given the attested tendency to equate mirror-image arrays. To test whether the location of the tables on these axes had a specific effect, half of the Tenejapan subjects were later recalled, and experiments (2), (3) and (4) (the latter two with different shaped and coloured stimuli) were rerun with the axes reversed, i.e., with the tables facing north and south, so that left/right asymmetries now lay along the weak 'traverse' axis.

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[17] The function of the screen was to prevent the subject from looking backwards to the first table as an aid to mentally reconstructing the array.

'down'

N

W

E

S

'up'

table 2

table 1

house
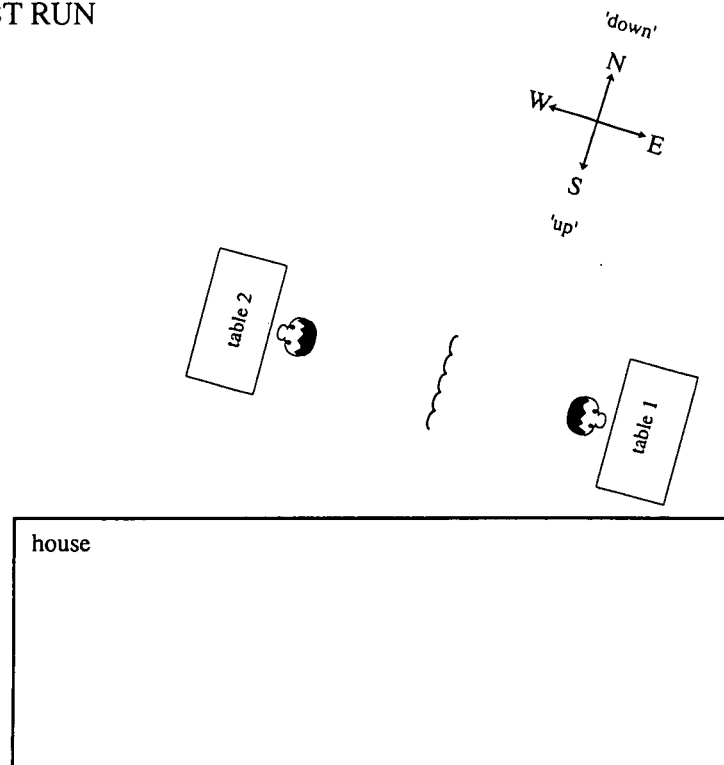
*Figure 2:* Physical layout for first run of experiments in Tenejapa

All the tasks involved a delay between seeing the original stimulus on table 1 and seeing the second array on table 2. The delay was ensured by the distance between the tables, but as mentioned a further 30 seconds was imposed before rotation, yielding an effective 45 seconds between stimulus and response.[18] The reason for the delay was to minimize the chances of specific short-term memory effects,[19] although to ensure this it would be necessary to 'mask' by imposing additional visual and auditory tasks between stimulus and response.

Before proceeding, a few reservations should be recorded. These experiments were conducted under field conditions in a remote hamlet of Tenejapa, a mountain community unreachable (at the time of the research) by road, where the majority of subjects are monolingual and illiterate. Most subjects had no experience with any kind of testing or Western classroom type of activity, all being subsistence peasants by occupation. The

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[18] Except in the case of task (4) where no further delay was enforced beyond the walking time between tables and the time required to set up the stimuli (about 15 seconds together).

[19] In addition to a very brief 'iconic' visual buffer (with duration for up to half a second), many theorists posit a short-term visual buffer, or 'visuo-spatial scratch pad' which is flushed by new visual information and has a natural decay period so that a complex visual stimulus would be less than half retained after 9 or 10 seconds, and a simple one after 20 seconds (Baddeley 1990:31). Since a visual image automatically encodes an egocentric viewpoint, a visual stimulus might be highly accessible to visual short-term memory inside 30 seconds, predisposing relative codings of arrays. Similarly, apart from the very brief echoic memory, auditory short-term memory is thought to have a natural decay period within 5-10 seconds with a maximum period of 20-30 seconds (Baddeley 1990:31, Potter 1990:24). This is the system involved, with or without overt vocalization, in for example remembering a telephone number when dialling. Thus its use might predispose towards a coding system in line with the language. But without constant rehearsal such a coding would not be available after the effective 45 second delay imposed in the tasks.

small paper or plastic stimuli used were unfamiliar objects. Laboratory conditions could not be approximated, as (in the absence of substantial buildings) experiments had to be conducted in the open, with inevitable distractions and interruptions by wind, rain and other persons. Women typically had accompanying infants in their care. Bystanders could not always be avoided.

A series of pilot experiments conducted with sixteen subjects in December 1992 had revealed a number of particular design problems (results from these pilot tasks will be mentioned below in passing). First, poor performance on tasks could be expected given the unfamiliar nature of the activity. To counter this, the experiments reported here were designed to be as 'concrete' as possible (e.g., with large spatial arrays rather than small diagrams where possible); they were designed with the maximum number of trials through which attention might be retained; and a larger sample of subjects was used (27 in most tasks: 15 men and 12 women).

Second, there is rapid change and acculturation in progress in this community, so that a portion of the population has now had some experience of the wider Mexican, Spanish-speaking culture. This portion is almost exclusively formed of younger males (up to the age of about 30). Even partial bilingualism raises significant difficulties of interpretation for the experiments. Thus an attempt was made to exclude younger males, and the youngest men in the sample were 25, two aged 33, one 35 and the rest above. In addition, all subjects were asked extensively about any education or experience they might have had outside Tenejapa, and after the cognitive tasks they were given a set of spatial arrays to describe linguistically. During this linguistic task, any knowledge of Spanish was probed for if it seemed remotely relevant. Thus individuals' performance on the non-linguistic tasks can be correlated with information about their experience of the wider Mexican national culture. Incidentally, subjects were drawn from a wide area around, and the great majority of them had had no prior acquaintance of any professional sort with the investigators.

Upon returning to The Netherlands we ran the same experiments following similar procedures on 40 Dutch subjects, of a similar age and sex profile to the Tenejapan sample[20] ; the results of these are presented below along with those for the Tenejapan subjects.

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[20] The Dutch experiments were run by Misja Schreuder Peters, with a slightly modified setting: the tables were only about 4 meters apart and there was no screen between them. The 40 Dutch subjects ranged in age from 21-77, and were of mixed age and occupation. Language usage was also checked after the non-verbal tasks, and as expected all but one of the subjects used a 'relative' linguistic coding using the notions 'front'/'back'/'left'/'right'. However, one subject reported difficulty distinguishing his left and right, and this subject was responsible for many 'absolute' codings in the non-verbal tasks; he was eliminated from the statistical tables below as an isolated outlier.

## 5.0 Part I: the first run of experiments with Tenejapan and Dutch subjects

## 5.1 Experiment 1: Animals Recall Task

*Recall and Reconstruction of an Array*

This experiment was designed to investigate the coding of a spatial array for memory, under conditions where the subject had to recall the array and rebuild it after a short interval. Before reconstructing the array, subjects were rotated 180 degrees, to see whether they would preserve the absolute directions in the array, or whether instead they would preserve the directions relative to the direction of viewing. A simple linear array was used of three distinct objects, drawn from a pool of four, presented in the transverse (left-right) plane.

Under these conditions there are just two main options:[21] to preserve relative left/right ordering, or the cardinal direction (or absolute bearings) of the array. We felt it important to distract attention from this. So the subject's attention, through the instructions and prior training, was focussed on remembering and reproducing the correct internal ordering of the three objects. In fact, the investigator is interested primarily not in the relative order, but in the direction of the line. To separate out these two kinds of information, direction and relative order, objects were used (models of familiar animals) that had intrinsic or inherent parts. Since all three animals were, in a single trial, facing in the same direction in the stimulus (and this was always preserved in the response), mistakes in order will still allow a scoring for direction.

*Hypothesis:*

Tzeltal, the language of our Tenejapan subjects, codes asymmetric spatial arrays in 'absolute' terms ('uphill', 'downhill', 'traverse'). The hypothesis is that this kind of linguistic coding will influence their non-linguistic coding for memory, so that in recall the direction of the line of animals will retain the absolute bearing (in this case, facing either 'uphill', roughly south, or 'downhill', approximately north), while the orientation of the line from an egocentric point of view, in terms of left/right, will not be preserved. If asked to recall a line of animals, head to tail, with the heads facing north and to the subjects' left, each subject, having been rotated 180 degrees, should reproduce a line of animals with heads to the north and thus to the subject's right.

The contrary prediction is made for Dutch subjects. Since Dutch, like English and other familiar European languages, encodes micro-scale spatial arrays in terms of the concepts

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[21] There is a third option, namely preservation of certain ordering properties of the assemblage (say, X in between Y and Z) without preservation of direction in terms of either left/right or absolute bearing. But only 1 subject of 27 Tenejapans showed any inclination to neglect direction. There is also the possibility for a 'monodirectional' solution (array placed always facing in the same direction regardless of the orientation of the original array) which appeared in the cross-linguistic application of these experiments; no Tenejapans performed in this manner.

'front', 'back', 'left', 'right',[22] subjects should under rotation preserve the left/right orientation of the animals, and disregard the absolute bearing (north or south).

The task allows the test of some subsidiary hypotheses. Since the objects have intrinsic directionality, the direction of the line (where the animals' heads are pointed) is independent of the order in which they are placed. A classification is therefore possible along the lines illustrated by the following example. A subject is presented with the line pig-sheep-cow heading to his left or downhill (north) on table 1. He is then rotated 180 degrees and facing table 2 may reconstruct the line in various ways; two of these, the consistent relative and consistent absolute solutions, are illustrated in Figure 3.

There are of course other possible outcomes, as illustrated in the following table (which depicts 6 of the possible 12), which should make it clear that responses can preserve e.g. 'absolute' order while pointing the animals in a 'relative' direction:

| RESPONSE-TYPE | | SCORING | RESULT TYPE |
|---|---|---|---|
| Direction: | (north, right) -> | Absolute | Consistent-Absolute |
| Order: | cow-sheep-pig | Absolute | |
| Direction: | <- (south, left) | Relative | Consistent-Relative |
| Order: | pig-sheep-cow | Relative | |
| Direction: | (north, right) -> | Absolute | Inconsistent |
| Order: | pig-sheep-cow | Relative | |
| Direction: | <- (south, left) | Relative | Inconsistent |
| Order: | cow-sheep-pig | Absolute | |
| Direction: | (north, right)-> | Absolute | Partial error |
| Order: | sheep-cow-pig | Error | |
| Direction: | <- (south, left) | Relative | Partial error |
| Order: | sheep-cow-pig | Error | |

We can now state the sub-hypotheses as follows: for both Dutch and Tenejapan subjects, both order and direction will tend to be congruent (i.e., both scored as Relative for Dutch, both scored as Absolute for Tenejapans). Inconsistent scorings (e.g., relative ordering with absolute direction) will be due to memory failure, and thus should not be above the

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[22] As ascertained through earlier experiments where Dutch subjects described the placements of a model man and tree, using these four deictic terms plus other deicticly anchored terms like 'coming', 'going', 'facing this/that way'.

level predicted by chance for each kind of error (e.g., apparent relative orders with absolute directions should occur less frequently than other kinds of order).
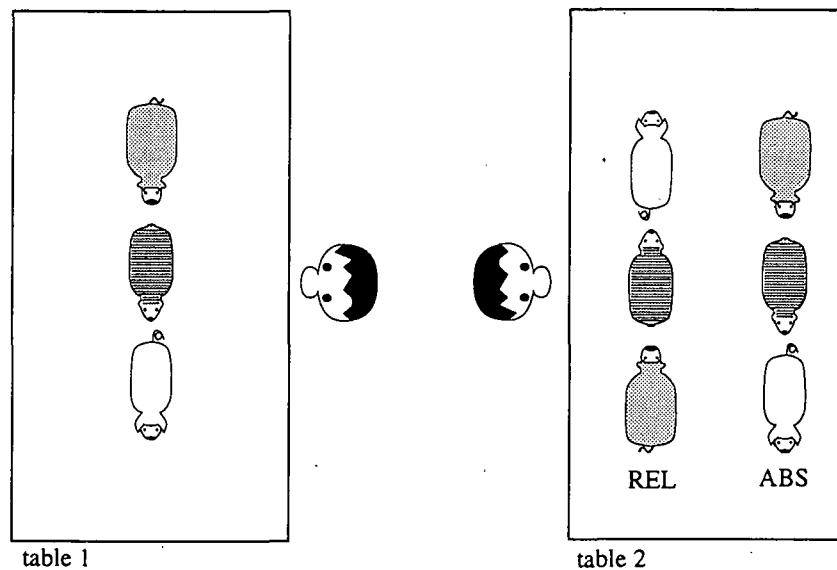


*Figure 3:* Animals Recall Task: 'Absolute' vs. 'Relative' solutions

*Method:*

*(a) stimuli*

Four model animals were used, distinct in colour, shape, size and species represented, and strictly symmetric along their longitudinal axis.[23] Four were placed on table 1 ready for use, and an identical four on table 2. The subject was trained on table 1 in the following way.

*(b) training procedure*

First, the model animals were each identified by the name of the species in the relevant language. Then a random sequence of three animals all heading in one or the other lateral (transverse, left/right) direction was presented, and the subject told 'Remember them just as they appear; remember where (e.g.) the cow is, where the sheep is, etc.' No motion verbs or description of motion or directional terms were used in the instructions. The animals were scooped up, and the subject asked to remake the line immediately. If the subject produced the wrong order, another training trial was given. No correction was necessary on lateral direction, since this was nearly always correctly maintained on table

[23]From the Duplo series for infants (each about 7 cm long; they were placed in a row at intervals of about the same amount). Although rather schematic, they did not have asymmetries such as heads leaning to one side, which would project a different visual shape on an absolute orientation. Other experiments on the Tenejapan population show that Tenejapans still recall arrays on an absolute basis even when the arrangement thus made is visually incongruent with the stimulus in striking ways (e.g., a model man in front of a tree viewed from the south may be recalled as a man behind a tree when the subject is rotated 180 degrees and asked to remake the assemblage now facing north).

1.[24] A second trial with a different selection of three out of four animals in the reverse lateral direction was then given, but this time a 30-second delay was introduced before recall. Again order was corrected if necessary to encourage precision. The subject was then told that next time the array would be reconstructed on a different table, and a third random order of animals was given, and after 30 seconds, the subject was led to table 2 (and thus rotated 180 degrees without explicit instruction) and given just the three relevant animals out of the four on table 2 (the fourth was placed out of the way). The instruction was 'Make it again, just the same'. This training trial was not corrected in any way. The main trials then began.

### (c) main trials: procedure

Five main trials were then administered. Each trial had a random sequence of animals, with random alternation of lateral direction, as precoded on score-sheets. Subjects were allowed to gaze at the stimulus as long as they liked, were asked whether they were ready, and when they said so, the array was scooped up. After a thirty second delay, they were led to table 2, and requested to 'Make it again, just the same'. They did not have to choose the relevant 3 out of the 4 animals: these were provided for them. If subjects claimed to have forgotten, they were given the next trial, with the forgotten trial repeated as the last trial in the sequence.

### Results:

### (a) Tenejapan subjects

Twenty-seven Tenejapan subjects completed the five trials. Despite training and instructions focussing on relative order of animals rather than direction, only one subject in training showed complete neglect of direction information (see fn. 20).

Subjects were classified as 'absolute coders' or 'relative coders' on the basis of performance. A strict typing required subjects to perform 4 out of 5 trials consistently preserving 'absolute' direction, or, alternatively, consistently 'relative' direction. A weaker typing, of 3 out of 5 trials consistently 'absolute' or 'relative', was also calculated.

The results are presented in Table 1. The classification of the 27 Tenejapan subjects as 'absolute coders' (20), 'relative coders' (2) or 'untypable' (5) is exactly the typing that would have been obtained on the basis of at least 4 out of the 5 trials consistently coded one way or the other (where 'untypable' would cover the residue, e.g. 3 'absolute' trials and two 'relative', etc.). But in fact we shall adopt a slightly more complex procedure to allow comparison across tasks, as follows.[25] First, each subject was assigned a score according to the following formula: the number of 'absolute' responses were divided by

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[24] One informant neglected directional information, and was corrected during training.
[25] Thanks are due to Laszlo Nagy of the University of Braunschweig for devising this system and applying it to our data. We are also deeply indebted to him for the statistical analyses throughout.

14

the number of trials and multiplied by 100. A fully consistent 'relative' coder thus receives a score of 0, and a fully consistent 'absolute' coder a score of 100 on what we may call a 'Relative-to-Absolute Gradient' or RA for short.[26] We can then type subjects as 'relative' coders if their scores fall in the interval 0-30, and 'absolute' coders if their scores fall in the interval 70-100, and as 'untypable' otherwise. This procedure allows us to represent less-than-consistent performance as a gradient and also allows us to compare performance across tasks.

Applying this classification, three quarters of Tenejapan subjects preserved the absolute *direction* of the array, in other words they were absolute coders on this task, recalling the direction of the array in absolute terms. Most of the remainder were 'untyped', i.e., their responses were mixed. Thus of classifiable subjects, over 90% were absolute coders. Only two subjects consistently coded the direction in terms of egocentric relative direction (i.e., preserving the leftwards or rightwards direction of the array).

The Dutch subjects' performance is also shown in Table 1, and shows exactly the opposite tendency: all but two of the 37 Dutch subjects performed consistently relatively on this task.[27] The difference between the two samples is statistically highly significant by the usual tests.

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**Table 1. Typing of Subjects by DIRECTION of animals**

*Tenejapan subjects: N = 27*

| ABSOLUTE | RELATIVE | UNTYPABLE |
|---|---|---|
| 20 (74%) | 2 (7%) | 5 (19%) |

*Dutch subjects: N = 37*

| ABSOLUTE | RELATIVE | UNTYPABLE |
|---|---|---|
| 0 | 35 (95%) | 2 (5%) |

*Difference between Tenejapa vs. Dutch samples:*
*p= 0.000 Mann-Whitney U test*

---

[26] Errors (choices of control responses), where the experiment provided for these, were factored in on the assumption that responses might have been 'relative' or 'absolute' with equal probability.
[27] Two Dutch subjects were eliminated, as they ignored direction and performed 'monodirectionally', always placing the animals facing the same way regardless of the stimulus orientation. This tendency was also seen among other groups of subjects in our cross-cultural samples, including one Yucatec Mayan one where 10 out of 16 performed 'monodirectionally' on this task, in contrast to the Tenejapans preference for 'absolute' responses (data from a parallel study by Christel Stolz).

The hypothesis that Tenejapans code for recall primarily in terms of absolute direction rather than egocentric relative direction is thus confirmed. The Dutch subjects, in contrast, were overwhelmingly relative coders in this recall task. It will be observed that Tenejapan subjects were less consistent than Dutch subjects, with almost a fifth producing behaviour too inconsistent to be classed 'relative' or 'absolute'. This greater inconsistency holds throughout the tasks, and is presumably a reflection of, amongst other things, the unfamiliarity of the stimuli, the procedure and the entire situation. Thus it is important to see the tendencies within these less consistent performances, and this can be brought out by a graph which plots percentages of Tenejapan vs. Dutch subjects who fall within successive bands of the RA gradient (see Figure 4).
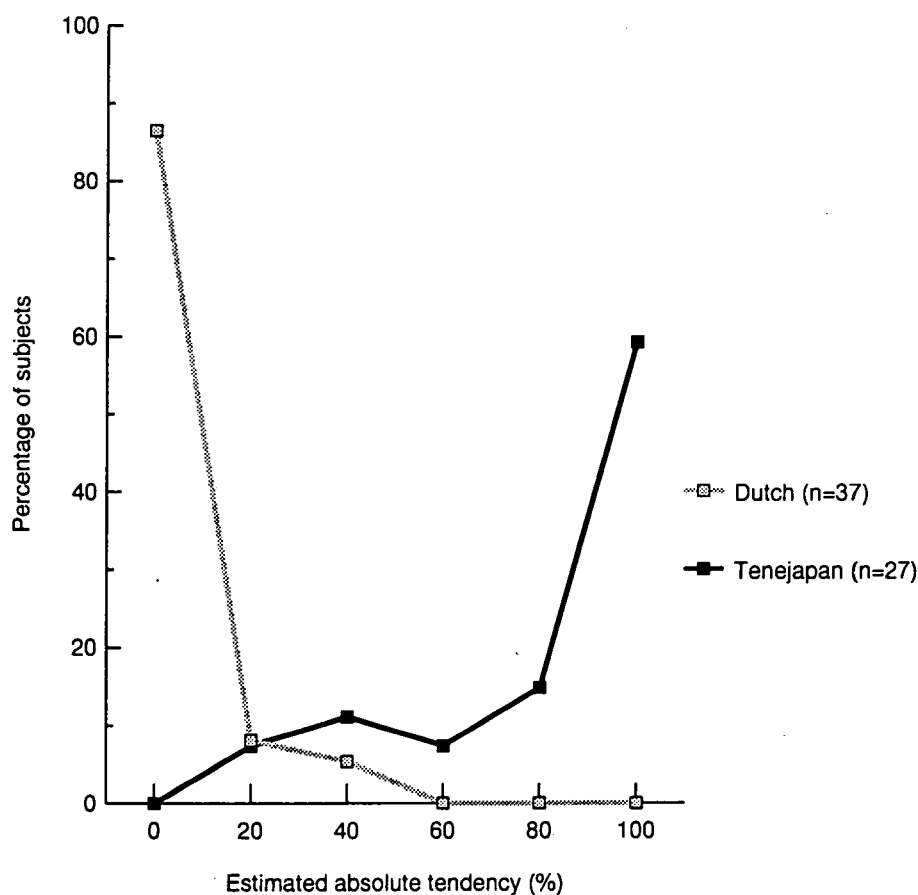


*Figure 4*: Animals Recall Task: Direction

Subsidiary hypotheses concern the preservation of *order* within the array. Despite a considerable number of errors in ordering, the Tenejapan subjects can be classified on the basis of the majority of orderings as absolute, relative or an unclassifiable mixture (of absolute, relative and errors), as given in Table 2:

| Table 2. Typing of Subjects by ORDER of animals | | | | |
|---|---|---|---|---|
| | ABSOLUTE | RELATIVE | UNTYPABLE | N |
| *Tenejapans:* | 18 | 4 | .5 | 27 |
| *Dutch:* | 0 | 34 | 3 | 37 |
| *Tenejapa vs. Dutch: p = 0.000 Mann-Whitney U-test* | | | | |

Figure 5 presents a graph of the percentage of subjects within each sample who fell within RA gradient bands. It will be seen that Tenejapan subjects show the same absolute tendency in the ordering of the animals as on direction but that performance is depressed: in fact mistakes on order occurred in 31% of trials, compared to only 3% of trials by Dutch subjects.
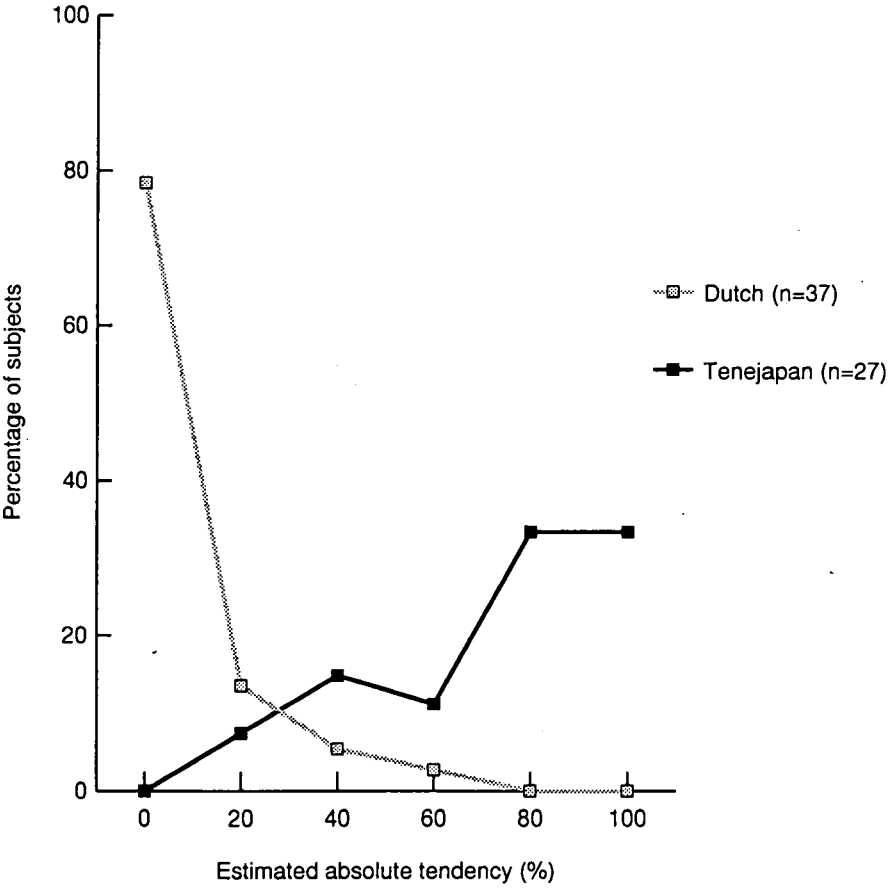


*Figure 5*: Animals Recall Task: Order

The greater number of errors by Tenejapan subjects may just be a reflection of their unfamiliarity with any such procedure, but there could be systematic reasons: retaining absolute order requires throwing away, as it were, the visual image. A relative coder will preserve the order X Y Z from left to right; an absolute coder will preserve the absolute order, and given a stimulus array X Y Z should reconstruct the array as Z Y X, i.e., in the

mirror-order viewed egocentrically. This may be one partial explanation of the confusion exhibited by Tenejapans between a spatial array and its left/right mirror-image (reflection across the apparent vertical axis) (see section 3.0 above). Of three elements, six orders are possible, of which one can be classed as relative (preserving viewpoint order of stimulus), one absolute (yielding mirror order of stimulus-order viewed egocentrically) and four can be classified as definite errors. Tenejapan subjects made such definite ordering errors on about one quarter of trials. They also made incongruent orders, i.e., absolute order with relative direction, or relative order with absolute direction, in about 7% of trials, which (assuming the direction is not random) is within the realm of chance. (There were over three times as many relative orders within absolute directions, as opposed to absolute orders within relative directions, presumably just because there were over five times as many absolutely aligned directions.) These facts are interesting because it was conceivable that relative left/right order, which preserves the visual image of the initial array, might show up more frequently than would be expected on a random basis.[28]

*Conclusion:*

The hypotheses were confirmed: subjects code for recall in a non-linguistic memory task along lines congruent with the coding of the language they speak. If the linguistic coding is absolute for a subject, the chances are that coding for memory will also be absolute; if it is relative, so is the coding for memory.


## 5.2 Experiment 2: Maze Recognition Task

*Inferring path from motion and recognizing path*

This task was devised and piloted in Tamilnadu by Eric Pederson, as a development of a route-finding task used by Levinson in Australia (Levinson 1992a). The current version is due to Pederson and Schmitt (see Danziger 1993). The task explores the coding of a motion path for recognition memory. Subjects see a motion event on table 1, are rotated 180 degrees, and must select the path traced from a set of alternate paths. Amongst the alternates are a path preserving the egocentric properties of the event (e.g., motion away from ego, then to the left) and a path preserving the absolute properties (e.g., motion to the east, then motion to the south), together with distractor or control paths. (See Figure 6.)

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[28] 24% of 135 trials by Tenejapan subjects were definite errors in order, with 7% incongruent collocations of orders and directions (7 trials relative order within absolute directions, 2 absolute order within relative direction).

table 1                                   table 2
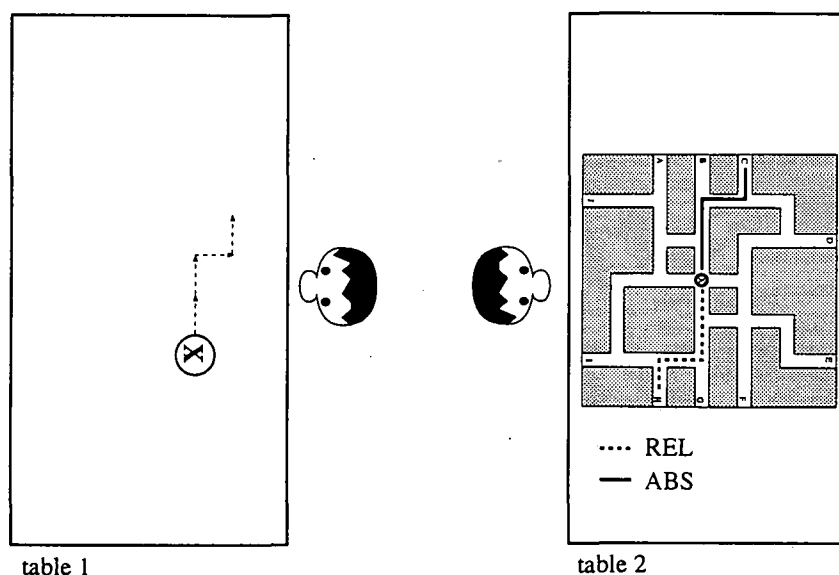
*Figure 6:* Maze Recognition Task: 'Absolute' vs. 'Relative' solutions

*Hypothesis*

Tenejapans will encode the motion for recognition purposes in terms of absolute directions, and choose the corresponding paths, in line with the most comprehensive linguistic coding of motion in the Tzeltal language.[29] Dutch subjects should encode the motion in egocentric relative terms, in line with the European languages, and choose the corresponding paths.

*Method*

*(a) Stimuli*

The motion event was enacted by the experimenter on table 1: for each trial he moved a toy man along a (predetermined unmarked) path, beginning from a white paper circle with a large X at the centre. Each path had either two or three segments. Each segment of each path was either in a transverse ('across', i.e. left-right) direction, or in a sagittal ('away' i.e. front-back) direction from an egocentric point of view, and successive segments were always orthogonal. Thus a typical path might run left, away, left again, with 90 degree turns. There was no back-tracking (e.g., no path ran away, left, towards ego again). Not all segments of the path were of equal length: each path had one long segment, and either one or two segments half as long as the long segment (the paper circle had a 4 cm radius, the length of this short segment, to help the experimenter accurately enact distances). To aid perception and memory of length, the experimenter made vocal 'footstep' noises to a regular rhythm.

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[29] The set of Tzeltal motion verbs in fact includes, in addition to verbs indicating absolute directions (motion 'uphill', 'downhill' and 'across'), deictic verbs of 'coming' and 'going'. Since the stimulus involves motion both on a transverse and sagittal axis, deictic coding of the 'come'/'go' sort will not be sufficient, and thus the absolute coding of direction will, by hypothesis, be invoked.

19

delay ensuring a 30-second interval between motion event and viewing of the maze, the subject was led over to the main maze on table 2, which he now viewed under 180-degrees rotation. He was asked to trace the motion that had been enacted on table 1 and to indicate where the man ended up. If there was incomprehension, the trial was repeated, until a response was achieved.

Some Tenejapan subjects had considerable difficulties with this training. Motion events and whole training trials were repeated as necessary. The precise rectangular nature of the paths was often not memorable to these subjects, who tended to 'flatten' out paths to straight lines or generalize them to meanderings. To clarify the restricted nature of the possible paths, subjects who were having trouble were encouraged to trace the enacted motion path with a finger. This motoric tracing may have inclined some subjects to an egocentric coding, but this could only endanger the hypothesis that Tenejapan subjects would perform absolutely.


*(c) Administration*

Five identical motion paths were administered to all 25 subjects, in randomized order as prearranged on a scoresheet. Two were simple two-segment paths, three were more complex three-segment paths. Each motion event was demonstrated twice on table 1, and further demonstrations were offered and occasionally requested. Where training had revealed difficulties with orthogonal turns, subjects were encouraged to trace the path with a finger. After viewing the motion, subjects were led across to table 2 so they viewed the maze under 180 degrees rotation after at least a 30-second delay. There the experimenter pointed out the centre, saying 'He started here, where did he go, where did he end up?'. Subjects pointed to the location, usually tracing the path with a finger.[31] They were told that if they forgot the motion event, they could see it again; but if they began to trace a path and then got confused and were unable to complete it, the next trial was run instead, and the forgotten trial repeated as last in sequence. The five trials were run without intermission.

*Results*

Subjects were classified as absolute coders or relative coders or untypable (through mixed or error responses) according to the same procedure (using a relative-to-absolute gradient measure) as before.[32] Since for each trial, there were many competing alternative paths, a

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[31] It was not feasible to collect this on-line tracing information, although it would have been interesting, since (a) on many occasions subjects 'edited' their performance, (b) the right answer may occasionally have been obtained via the wrong path.

[32] In this case the use of the RA gradient as a coding system, where errors are factored in on the assumption that they might with equal probability have been relative or absolute, makes a considerable difference to the way the patterns are analyzed. The raw facts are as follows: 27 Tenejapan subjects completed the task, 2 produced a majority of uncodable trials and were eliminated; on a classification in terms of at least 3 out of

subject's pattern of trials tending towards consistently relative or consistently absolute is not likely to be a random pattern. Table 3 shows the classification of subjects on the basis of the tendency towards a consistent selection of absolute or relative termination points (correct by either the relative or absolute criterion). The great majority of Tenejapan subjects emerge as absolute coders. In contrast, the Dutch subjects are almost exclusively relative coders.

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**Table 3: Classification of subjects by consistent selection of paths in maze according to absolute or relative criteria**

*Tenejapans: N = 25*

| | ABSOLUTE | RELATIVE | UNTYPABLE |
|---|---|---|---|
| | 18 | 4 | 3 |
| *Dutch: N = 39* | | | |
| | 0 | 38 | 1 |

*Tenejapa vs. Dutch p = 0.000 (Mann-Whitney U-test)*

---

The table obscures the fact that the Dutch subjects were much more consistent performers, all achieving at least 3 correct (in this case, relative) paths out of 5 trials, while only 72% of Tenejapans selected 3 correct paths (relative or absolute). The graph in Figure 7 makes this clearer.

The nature of the errors on this experiment can also be investigated in detail to explore whether there is any difference in the ease with which 'away' vs. 'across' (egocentric sagittal vs. transverse respectively) segments of paths can be recognized. Analysis shows that there were slightly more 'relative' treatments of the 'away' segments than of the 'across' segments for both Tenejapan and Dutch subjects. Furthermore, Tenejapan subjects who were consistent absolute coders made more relative selections (9 trials vs. 6) on the 'away' axis than on the 'across' (left/right) axis, a subject to which we will return in the final section of the paper.

*Conclusion*

This task had two components: (a) the conceptual conversion of a visually presented[33] motion event into a path, (b) recognition and selection of that path from a set of alternatives. The first component can be performed before rotation, but the second can only be performed after the rotation.[34] The coding in which the motion is conceptualized

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5 trials ending in one of two correct (absolute or relative) destinations (out of 10 possible ones), 14 subjects were absolute coders, 4 were relative coders and 7 achieved only less than 3 consistent trials. The RA gradient allows us to analyze the underlying tendencies among these under-achievers, assigning 4 to the category of absolute coders. Note that on both a 3/5 consistent trial basis, or on a RA gradient basis, roughly 80% of typable Tenejapan subjects are absolute coders.

[33] And sometimes manually traced by the subject, as mentioned above.

[34] Although the same maze is used for all five trials, it is sufficiently visually complex that there is little likelihood that a subject could retain an accurate mental picture of it.

will thus determine the recognition process. The results show that, once again, where Tenejapan subjects were able to consistently perform, over 80% of those who could be typed must be classified as absolute coders. Such absolute coders appear to make somewhat more mistakes on one axis than on the other, a puzzle to be explored more directly in the next experiment. The Dutch subjects must be classified overwhelmingly as relative coders.
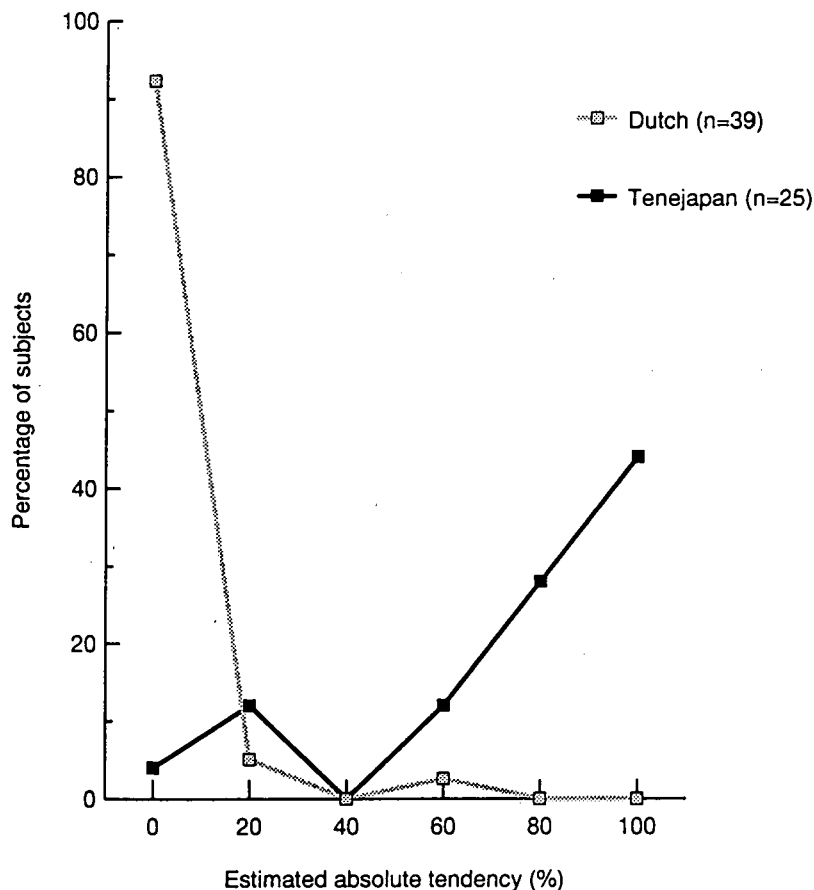


**Figure 7**: Maze Recognition Task

## 5.3 Experiment 3: Chips Recognition Task

*Recognition: Oppositions on two axes*

This experiment was designed to explore non-linguistic coding in a direct recognition task. It is a development by Pederson and Schmitt (see Danziger 1993) of an experiment devised and run in Australia by Levinson (see Levinson 1992a). A stimulus consisting of a simple pattern on a card was exposed on table 1, and then under 180 degree rotation and after a 30-second delay, the subject had to pick out the matching card from four cards arranged on table 2. (See Figure 8.) All five cards were in fact identical, as was pointed out to the subject, but their orientation was distinct on two axes. On the lateral or transverse axis, one card had, e.g., a yellow circle to the right and a green one to the left,

while another had green to the right and yellow to the left. On the sagittal (front/back) axis, one card had a distal yellow circle and a proximal green one, while the other card had a distal green circle and a proximal yellow one. Absolute coding of a stimulus on the transverse axis should result in one of the two cards on that axis being 'recognized', while relative coding should result in the other being selected; and similarly for the sagittal axis. While subjects were unlikely to confuse the stimulus on one axis with the two cards on the other, these acted as a control for understanding of the task. By alternating stimuli on both axes, any differential coding on the two axes ought to be revealed in differential patterns of recognition. It was thought that this task might therefore be of special interest in cultures where the linguistic coding (and thus by hypothesis the non-linguistic coding) of one axis is stronger or clearer than the coding of the other axis. This is the case in Tenejapan Tzeltal, where the 'uphill'/'downhill' (north-south) axis has distinctly labelled directions, but directions along the 'traverse' (east-west) axis are identically labelled unless periphrastic expressions are employed (see Figure 9b.) Note that a 'left/right/front/back' system, as available in Dutch, has four linguistic expressions, one for each half-axis - see Figure 9a, where we take the opportunity to make clear that we shall use the terms 'away' or sagittal axis to mean the egocentric front/back axis, and the terms 'across' or transverse axis (not to be confused with the Tzeltal absolute 'traverse' or east-west axis) to denote the egocentric left/right axis. In part II of this paper, we describe a rerun of the experiments in which we exploit the independence of the egocentric and absolute axis systems, by rotating the subject 90 degrees as depicted in Figure 9c.
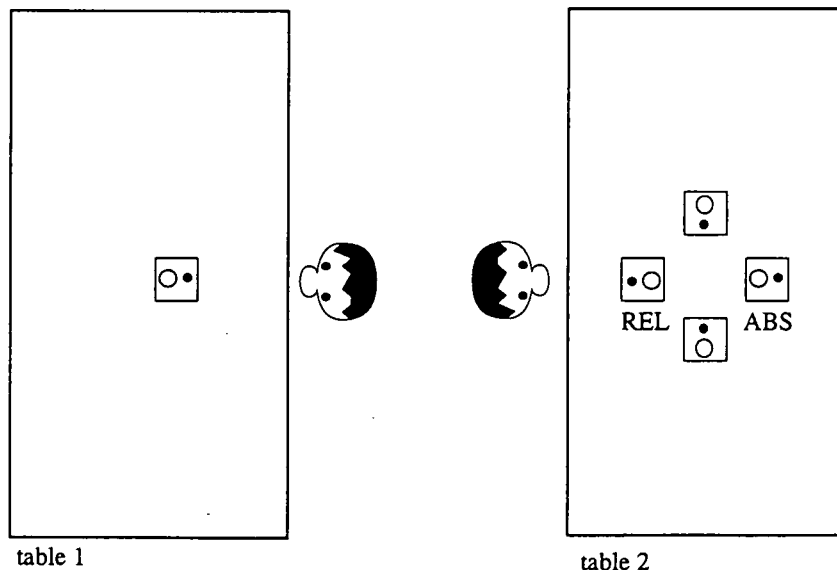


*Figure 8*: Chips Recognition Task: 'Absolute' vs. 'Relative' solutions

24
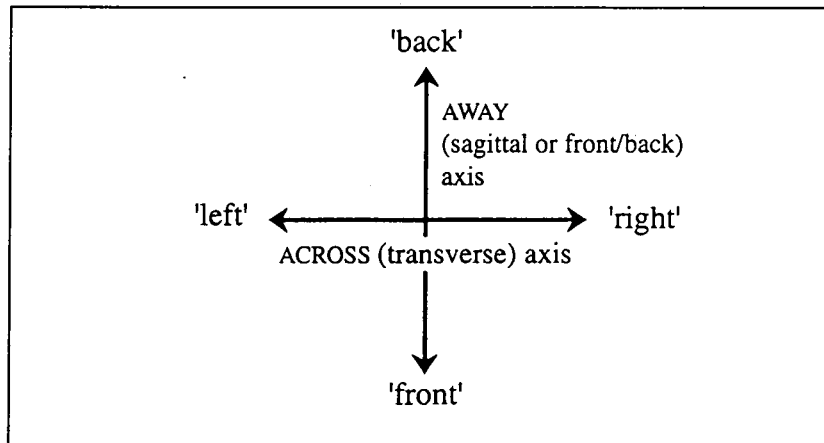
**Figure 9a:** Egocentric Axes
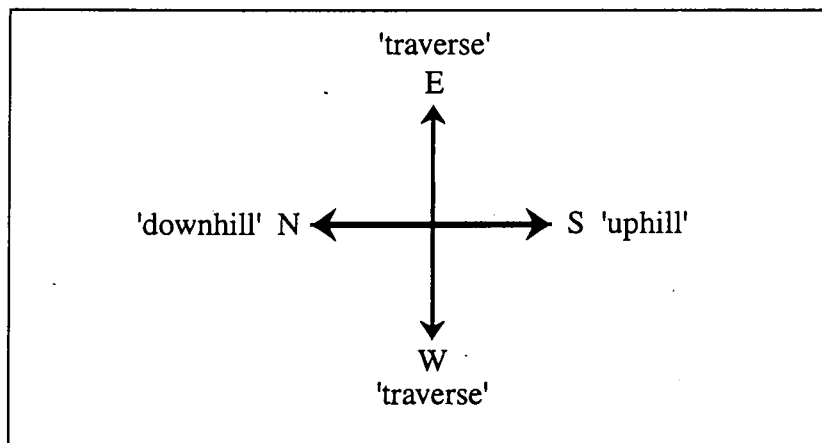


**Figure 9b:** Tenejapan absolute axes and their orientation on Experiments Run 1

*Hypothesis*

Tenejapan subjects were expected, as before, to code in absolute terms for recognition memory, and thus to match stimuli on the basis of an *absolute* coding of the positions of the two coloured chips on each card. In addition, if the non-linguistic coding is intimately bound up with the details of the linguistic coding, one might expect to find that cards distinguished on the strong 'uphill'/'downhill' axis might be more accurately recognized, while more errors might occur on the weak 'traverse' axis.

```
                    'traverse'
                        E
                        ↑
                        |
              N ←───────┼───────→ S
         'downhill'     |        'uphill'
                        ↓
                        W
                    'traverse'
```
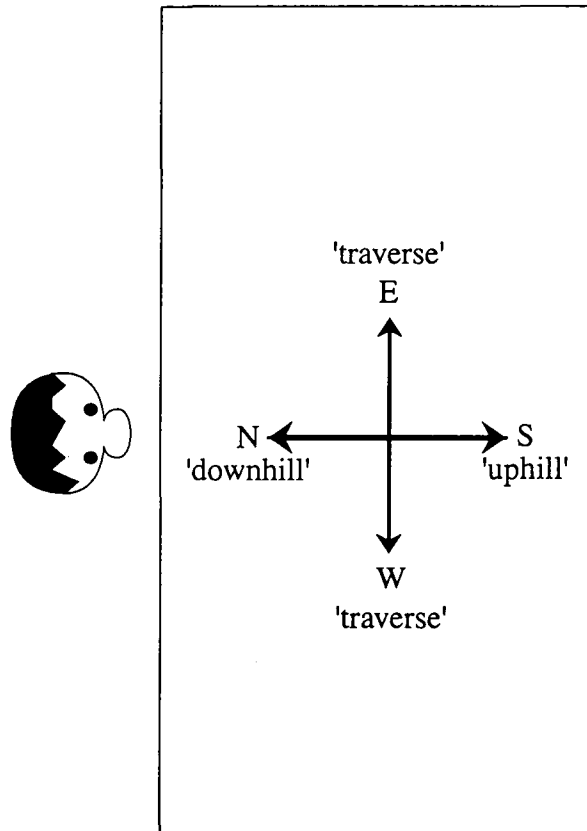
table 1

*Figure 9c:* Tenejapan orientation of Experiments Run 2

This secondary hypothesis requires a little more explanation. An alternative hypothesis might go as follows. The linguistic coding in terms of 'uphill', 'downhill' and 'traverse' forces constant computation of ego's bearings with respect to fixed angles regardless of the immediate terrain (recollect that these terms refer to fixed angles abstracted away from local inclinations). This computation, and the dead-reckoning of location that the linguistic system forces, will provide a fixed mental 'compass', which may be analog in nature. Memory of spatial arrays will then be coded in terms of this 'mental compass', and not directly in terms of the linguistic distinctions. One should then expect no difference in error rate on the two axes (or indeed on the diagonals).

On the first hypothesis, absolute coding for memory is closely based on the linguistic coding. On the second hypothesis, the linguistic coding forces mental computations of a more general sort that then provide the basis for memory coding. Both hypotheses seem reasonable, but they make different predictions about error rates on an experiment of this kind, which might be hoped to decide between them. However, there are a number of complicating factors. The first hypothesis needs supplementing with further linguistic facts: it is not the case that speakers *cannot* distinguish between the two directions of 'traverse' - they frequently do so by referring to the place 'where the sun emerges' or 'where the sun exits', or more often in terms of local landmarks (e.g., 'traverse towards

Red Cliffs over there'). On the other hand, asymmetries on the 'uphill'/'downhill' axis might be expected to be more memorable or more easily codable because of the rich set of opposed minimal lexical oppositions. Thus at most one can expect only a weak effect: a slight increase in errors on the linguistically less differentiated axis. In the first run of the experiment in Tenejapa the tables were so organized that the weaker absolute ('traverse') axis was the sagittal (front/back or away) axis for the subjects, while the strong 'uphill/downhill' axis coincided with the egocentric transverse or left/right axis (as illustrated in Figure 9b). Thus on the first version of the subsidiary hypothesis one expects slightly more errors on the sagittal axis, as it is the 'weaker' one.

There is a further complicating factor, however. We already know from other experiments that Tenejapans confuse left/right reflections even in a perceptual judgement task (reflections across the apparent vertical). This will predict a certain rate of errors on the transverse (left/right or across) axis (here equivalent to the uphill/downhill or north/south axis). These may equal or even exceed those generated by any weak coding for memory on the absolute traverse axis (here equivalent to the sagittal or front/back axis), as suggested by our subsidiary hypothesis. That this was not only a possible but an actual factor was clear during the training sessions for this experiment: subjects often identified the stimulus card with its left/right mirror-image, even when both were in front of them simultaneously.

One may conclude from all this that, although no pattern of errors is clearly predicted, one pattern would be significant if it occurred: a pattern in which, despite this countervailing tendency to make errors on the left/right axis, more errors occur on the sagittal axis than the transverse one.

*Method*

*(a) stimuli*

Five cards measuring 9 X 9 cm. were printed on a colour printer with two circles, one small green circle of diameter 1.8 cm. and another larger yellow circle of diameter 3 cm. The circles were identically spaced (4 cm between centres), shaped and coloured on a white background on each card. All cards were laminated to preserve them from stains or other distinguishing marks. Another set of five identical cards were prepared with red and blue squares of size 2.4 X 2.4 and 1.8 X 1.8 cm. respectively . Initially it was planned to alternate the two sets to provide variation, but the yellow-green set proved visually clearer on pilot tests,[35] and for the Tenejapan subjects the red-green cards were reserved for use in the repetition of the experiment with tables on a different axis.[36]

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[35] Yellow (*k'an*) and green (*yax*) are linguistically distinct in Tzeltal, as are red (*tzaj*) and blue (also *yax*), but a number of informants described the rather dark blue on the cards as *ijk'* (black, darkish), and the red may have been considered dark too, making that pair less distinct. Another possible factor is that the

## (b) training procedure

Experimenter and subject sat side by side at table 1. The subject was shown all five cards, placed in the same orientation (yellow circle proximal, green distal) in a row in front of him. The experimenter said in effect 'Here are five flat paper things: look, each is the same. But if I turn them thus, look, they are no longer the same'; four of the cards were then placed in a radiating pattern as illustrated in Figure 8 above, so that each of the four had a unique orientation. Explanation then proceeded as follows for (e.g.) the sagittally contrasting pair: 'They are no longer the same, because, look, this card has the yellow (thing) there (right-hand gesture away from subject), but the green here (right-hand gesture towards subject), but that card has the green there (gesture away), and the yellow here (gesture towards subject).'[37]

Comprehension of the idea that identical cards could be distinct by orientation alone was then immediately tested by showing the subject the fifth card in one of the orientations, and asking him to find the matching card in the radiating pattern of four. This was done at least twice, once on each axis, with different patterns of radiating cards, and was continued until the subject could reliably indicate the correct match. In some cases, subjects found cards that differed on the left/right axis hard to distinguish, as mentioned above, but the difference was explained to them again in the same terms as above. Then the subject was introduced to the need to memorize the single stimulus card: the other cards were scooped up and the stimulus card presented in one of the four orientations. It was then turned over on its longitudinal axis, and the four other cards organized in a radiating pattern so that each card had distinct orientation, and the subject was asked to identify the card matching the card turned over ('Which card is the same, which card is its true companion?').[38] The stimulus card was then turned over again to its original position, and the subject shown whether he was right or wrong. A repeated trial was then given on the other axis, and so on until two successive cards were correctly recognized. During these trials the idea of a delay was introduced, by putting the clock in front of the subject and waiting 30 seconds. Finally, the subject was told that henceforth although the single card to be memorized would be shown on table 1, the pattern of four radiating cards would be placed on table 2. A training trial was then given, and either a 'relative' or

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perceptual difference in brightness between the circles vs. the squares was accentuated by unequal difference in areas.

[36] This required a minor deviation from the original Pederson-Schmitt design where neighbouring trials might be logically identical but differ in colour of stimulus: in our Tenejapan experiments the order of trials were quasi-randomly generated, but orders in which two identical trials followed each other were discarded. The original design, with both sets of cards, was used with the Dutch subjects.

[37] Care was always taken throughout the experiments to gesture with only the one hand. It could be argued that the deictic nature of the instructions (opposing 'here' to 'there' etc.) biases the subject towards an egocentric frame of reference, but if so, it only biases against the hypothesis being entertained.

[38] We relate the instructions in detail because although there is a predicate 'same' (*pajal*) in Tzeltal, it might also gloss as 'similar, same in some respects' rather than 'identical'. The expression glossing 'true companion' (*batz'il sjoy*) is the clearest translation for 'identical in kind (but not one and the same material thing)'. Such translational difficulties have to be carefully considered in work of this kind.

28

'absolute' solution was accepted without comment; if the subject identified the stimulus with a 'control' card on the orthogonal axis, further trials were given. The subject then embarked on the main trials.

*(c) main trials*

There were eight main trials, four on each axis (sagittal and transverse, or equivalently in this context as illustrated in Figure 9b above, 'traverse' and 'uphill/downhill', respectively).[39] Since the stimulus card can be in four orthogonal orientations (rotated 0, 90, 180 and 270 degrees), there are really only four distinct kinds of trial, each occurring twice. The order of trials was varied quasi-randomly, as precoded on score-sheets, so that subjects might start on one axis or the other and successive trials might be on the same or different axis, but no two successive trials were identical. The eight trials were run consecutively without a break. Twenty-four Tenejapan subjects completed the task.

*Results*

Subjects can be classified once again as absolute or relative coders, according to their scores on the Relative-to-Absolute gradient. Less consistent subjects, with scores in the range 30-70, can be classified as 'untypable'. The basic results for both Tenejapan and Dutch subjects are shown in Table 4.

| **Table 4. Chips: Subjects classified as Absolute or Relative coders on the basis of consistent behaviour** | | |
|---|---|---|
| *Tenejapans: N = 24* | | |
| ABSOLUTE | RELATIVE | UNTYPABLE |
| 13 | 3 | 8 |
| *Dutch: N= 39* | | |
| 0 | 38 | 1 |
| *Tenejapa vs. Dutch p = 0.000 Mann-Whitney U Test* | | |

The first observation is that many Tenejapan subjects failed to reach a level of consistent behaviour that would allow them to be confidently classified as absolute or relative coders.[40] Nevertheless, of those who did attain a clear pattern of performance, over 80% utilized absolute coding on this recognition memory task. Just three subjects were consistently relative coders. The following diagram contrasts the performances of the Dutch and Tenejapan subjects.

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[39] In retrospect there were too few trials. Ten would have been preferable to give stronger indications of behaviour on each axis, so in the reruns of this experiment, described in part II below, the number of trials was increased to ten.

[40] A more direct measure of the degree of inconsistency is that a third of subjects (9 out of 24) failed to reach a threshhold of 6 out of 8 trials consistently relative or absolute.
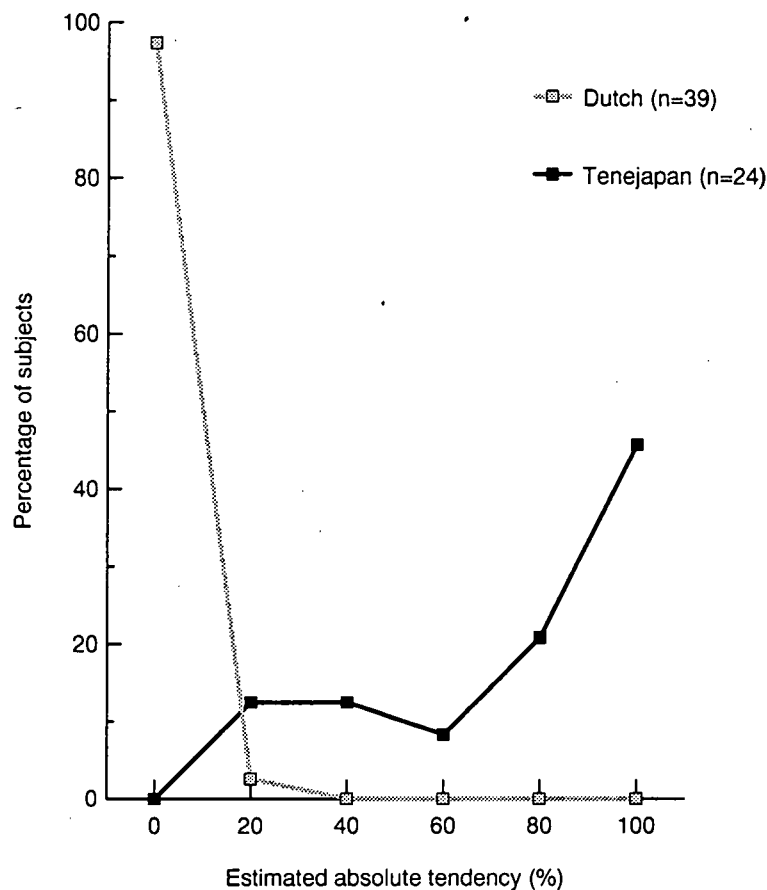
**Figure 10**: Chips Recognition Task

Allowing for poor performance in this rural community on an abstract task using small paper stimuli of an unfamiliar and 'fiddly' kind, the main hypothesis that Tenejapans would in general use a memory coding in line with their linguistic coding is substantiated. The Dutch, as predicted, coded relatively.

It remains to consider whether there was a patterned difference between the 'strong' and 'weak' absolute axes for the Tenejapans. The subsidiary hypothesis was that, if there were more errors on the weak absolute axis (for this experimental set-up, this was the egocentric front/back or sagittal axis), this might indicate a rather direct relation between the linguistic and non-linguistic codings. First, we may ask whether, if we consider each axis independently, more individuals are strongly classed as absolute coders on the strong absolute axis (here, the egocentric transverse or left/right axis). The answer is that there is a slight difference in the predicted direction, as illustrated in Table 5: there are three additional consistent absolute coders on the strong absolute axis compared to the weak absolute axis, where there are twice as many 'untypable' subjects. The explanation would be that absolute coders are making more errors on the weak absolute axis. The Dutch sample, by comparison, shows no such asymmetry on the two axes.

Table 5:  Chips: Subjects classified as Absolute or Relative coders, or Untypable,
on each axis independently

*Tenejapans: N=24*
(a) The transverse (ACROSS or left/right) or strong absolute axis

| ABSOLUTE | RELATIVE | UNTYPABLE |
|---|---|---|
| 16 | 5 | 3 |

(b) The sagittal (AWAY or front/back) or weak absolute axis

| ABSOLUTE | RELATIVE | UNTYPABLE |
|---|---|---|
| 13 | 5 | 6 |

*Dutch: N=39*
(a) The transverse (ACROSS or left/right) axis

| 0 | 39 | 0 |
|---|---|---|

(b) The sagittal (AWAY or front/back) axis

| 0 | 39 | 0 |
|---|---|---|

*AWAY axis: Dutch vs. Tenejapans p = 0.000 Mann-Whitney*
*ACROSS axis: Dutch vs. Tenejapans p = 0.000 Mann-Whitney*

The different response patterns of the Tenejapan subjects on the two axes can be clearly
seen in the graphs in Figures 11 and 12 below. Other ways of looking at the data support
the same slight asymmetry across the weak and strong absolute axes. If one looks at the
raw data, the pooled absolute responses decline 18% from the strong to the weak axis,
and the selection of the control cards (errors on the orthogonal axis) increase from 3 to 5,
while together relative choices and control choices increase 44% on the weak axis.[41]

These figures are compatible with the subsidiary hypothesis that there is indeed a very
close relation between the weak linguistic coding of the weak absolute (here equivalent to
sagittal) axis and a weakened ability to code for memory on this axis.

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[41] The data are as follows (one S eliminated because the experiment was run on a different fixed bearing):
*Tenejapans: (23 Subjects)*

|  | ABS | REL | ERRORS | Totals |
|---|---|---|---|---|
| weak axis | 53 | 34 | 5 | 92 |
| strong axis | 65 | 24 | 3 | 92 |
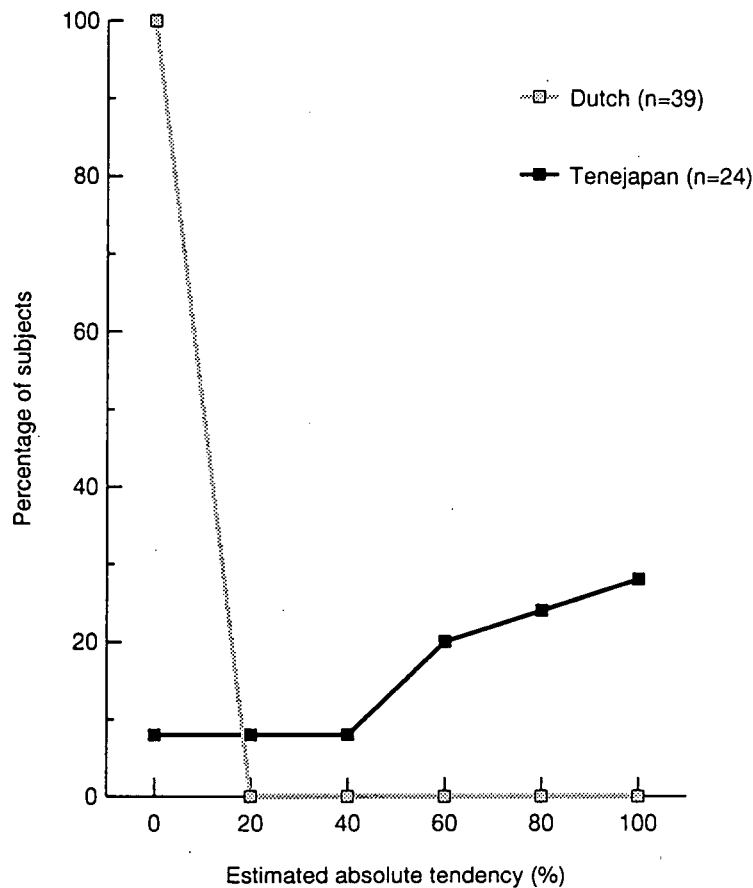
*Figure 11*: Chips Recognition Task: Away Axis

Another measure of differential performance on the two axes might be to ask whether those subjects classifiable as strong, reliable absolute coders made more errors on the one axis or the other. Table 6 shows the pattern of responses for those Tenejapan subjects who performed as absolute coders while the experiment was run on the same compass bearings. If we assume that these subjects are all attempting to perform consistently as absolute coders, then we can consider their 'relative' responses as well as choices of control cards as errors. The table provides data on two overlapping classes of subjects - those who performed consistently absolutely on at least 6 out of 8 trials, and those who did so on at least 5 out of 8 trials. The first group produced relatively few errors (i.e., relative or control responses): a total of 8 out of 88 (or 9%). Nevertheless, three quarters of these errors are on the weak absolute (the away) axis. The second class includes subjects who performed less consistently. Here the same pattern is repeated but with larger numbers: there are 20 combined errors on 120 trials (or 17% of responses). Again nearly three quarters of these errors (or 12% of responses) are on the weak absolute axis.

32
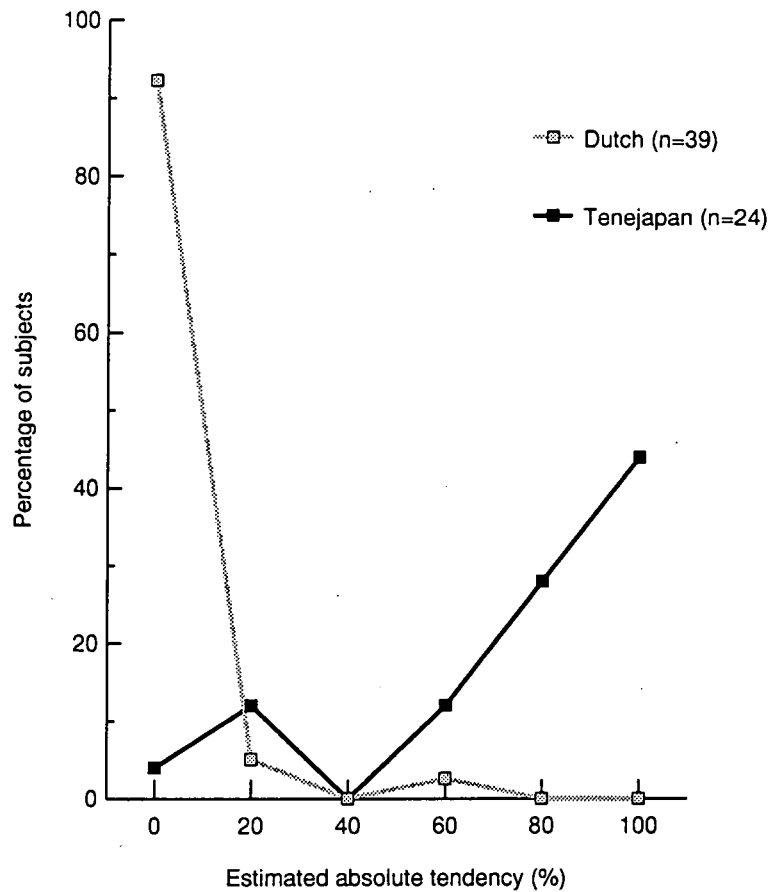
*Figure 12*: Chips Recognition Task: Across Axis

**Table 6: Responses by Tenejapan subjects typed as Absolute coders, Run 1**

(1) Responses of 11 Subjects typed as Absolute coders on 6/8 responses or better

|  | ABS | REL | ERRORS | Totals |
|---|---|---|---|---|
| weak axis (AWAY) | 38 | 6 | 0 | 44 |
| strong axis (ACROSS). | 42 | 1 | 1 | 44 |

(2) Responses of 15 Subjects typed as Absolute coders on 5/8 responses or better

|  | ABS | REL | ERRORS | Totals |
|---|---|---|---|---|
| weak axis (AWAY) | 46 | 12 | 2 | 60 |
| strong axis (ACROSS) | 54 | 5 | 1 | 60 |

33

*Conclusion:*

The results support the main hypothesis that non-verbal coding on this recognition task would match the subjects' linguistic coding. We may also conclude that there is some support for the subsidiary hypothesis that coding for memory is closely linked to the linguistic coding, which in Tzeltal offers more resources for coding the 'strong' absolute axis. But other explanations are not ruled out, and these will be considered in connection with the repetition of this experiment on different absolute bearings (see Part II below).

## 5.4 Experiment 4: Transitive Inference Task

The preceding experiments are essentially memory experiments: the first explored recall, the second conversion of motion to path for recognition, and the third straight recognition. This fourth experiment was designed to directly test for the kind of coding of a visual array that may be used for *inference*. It was designed by Pederson and Schmitt (see Danziger 1993), and piloted by Pederson in Tamilnadu, following discussions within the Cognitive Anthropology Research Group.

The experiment is based on the following observations. As pointed out by Levelt (1984), the relative linguistic coding known in Piagetian psychology (and subsequent linguistic theorizing) as projective or deictic left/right (as in 'The cat is to the left of the tree') is a *transitive, asymmetric relation*. This is not true of intrinsic left/right (as in 'The cat is at John's left (i.e., at John's left hand)'). Thus if the stool is to the left of tree, and the ball is to the left of the stool, the ball is to the left of the tree, providing we assume a constant viewpoint or static egocentre. This transitive left/right relation may be thought to be a basic predicate in perceptual coding (see Miller and Johnson-Laird 1976). Now, as pointed out in Levinson (1992a), absolute direction terms are also transitive: if the cat is north of the tree, and the ball is north of the cat, the ball is north of the tree. However, they differ in two respects: they are *always* transitive (and not ambiguously so), and secondly, and more importantly, they are *viewpoint independent*, so that transitivity is preserved regardless of the viewpoint or location of the egocentre (unless the egocentre is one of the reference objects).[42]

This similarity in inferential type, namely transitivity of the relation, together with the difference with regard to viewpoint independence, makes it possible to investigate non-linguistic cognition to see which of these two systems are employed in an inference task. This experiment makes uses of a transitive inference of the following kind: given A to, say, the left of B, and C to the left of A, what is the relation of C to B? This problem can

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[42] For a fuller discussion of varieties of left/right coding and their contrast with absolute systems see Max Planck Institute for Psycholinguistics' Annual Report 1992, pp. 92-106.

equally well be conceptualized as, say, (i) A is to the north of B; (ii) C is to the north of A, (iii) so where is C in relation to B? To distinguish the two conceptual codings, we need to introduce a rotation of 180 degrees. In the experiment below this is done as follows:

(i)    premise 1
       coded as   (R1)   "A is to the left of B"
       OR as      (A1)   "A is to the north of B"



(ii)   premise 2 (array seen under 180 degree rotation)
       coded as   (R2)    "C is to the far left of B"
                       =  "B is to the far right of C"


       OR as      (A2)    "B is to the far north of C"
                       =  "C is to the far south of B"



(iii)  inferred conclusion
                 (R3)   Therefore C is to the left of A
       OR        (A3)   Therefore A is to the far north of C

       R3: array constructed by *relative* coder
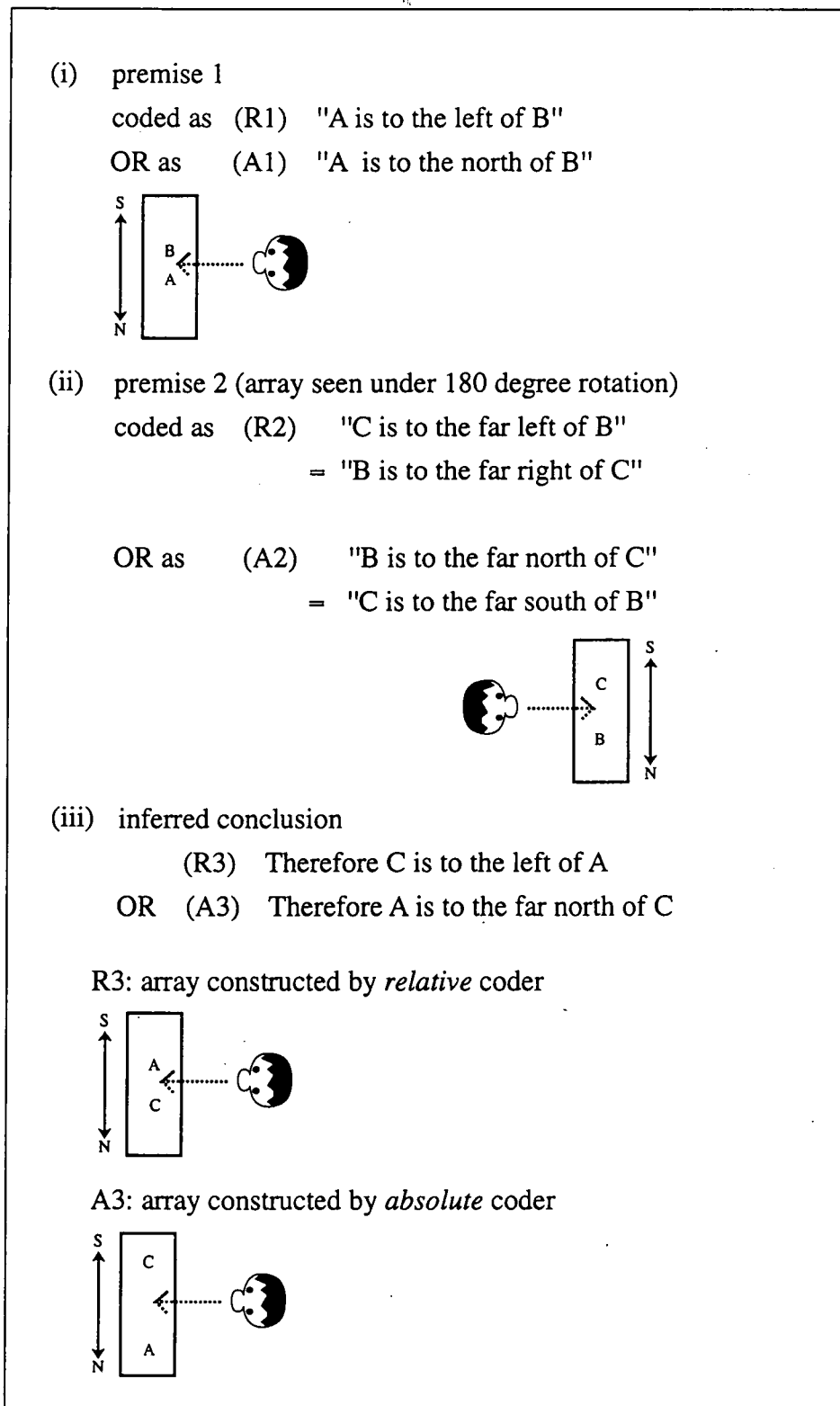


       A3: array constructed by *absolute* coder



*Figure 13*: Transitive Inference Task: 'Absolute' vs. 'Relative' solutions

(i)  the first array or premise (A in relation to B) is introduced on table 1 at 0 degrees rotation;

(ii)  the subject is rotated 180 degrees and sees the second array or premise 2 (C in relation to A) on table 2;

(iii)  the subject returns to table 1 (and thus is rotated 180 again back to 0), and is asked to construct the inferred array, the relation between C and B.

Because of the rotation at stage (ii), relative coders and absolute coders should make a different inference at stage (iii), as illustrated in Figure 13.

It needs to be stressed that this is not a linguistic task: the subject sees a first array, then a second array, and must *construct* a third array on the basis of the inferred relation between A and C.

The implementation of this task under rotation requires that something more than the simplest transitive inference may need to be made. Subjects will in fact need to code relative distance of objects from each other, and they may also find it natural to use the relevant converse relations - e.g., A is to the left/north of B, but C is to the right/south of B. Thus inferences of the following kinds may be involved:

(i)  A is to left of B

C is to the far left of B

Therefore C is to the left of A

(ii)  A is to the left of B

C is to the right of B

Therefore A is to the left of C.

The example of two codings, one relative, one absolute, should help to make it clear why these more complex inferences may be involved; see Figure 13 above (where the relative codings of the two premises and the conclusion are glossed under R1-R3, and the absolute ones under A1-A3).

The example should make it clear that, although without rotation both kinds of coding should produce congruent arrays, under rotation the codings will predict incongruent arrays and thus codings of different kinds of properties (close or far, for example). In the particular trial illustrated, the relation 'far left' is crucial to the relative coding conclusion that C is left of A, while the conclusion that A is north of C does not rely on coding distance at all. This was balanced so that in other trials the absolute solution requires distance coding and the relative one does not.

In an attempt to constrain the choice of converses, the pivot object (the 'landmark' object occurring in both premises, i.e., B in the example above) was made much larger than the other two objects (A and C above). (See Figure 14.) In that way, it should be natural to encode R2 (for example) as 'C is to the far left of B' rather than as the converse 'B is to the far right of C'. However, in this example, a large B object is predicted to induce a converse coding for A2, i.e., 'C is to the south of B' rather than 'B is to the north of C'.

The hypothesis then is only that the large B object may make it possible for the experimenter to know which form of the premise was most likely in use, although to investigate this would require response-time measurements or at least error analysis over a large sample. In any case, in pilot tests on western subjects, the task proved easier with such a large pivot object.
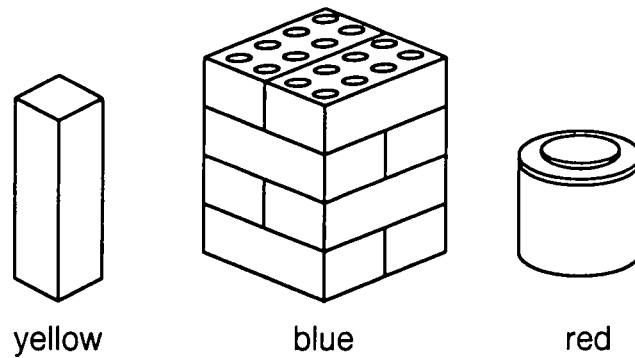


yellow              blue              red

*Figure 14:* Objects used in Transitive Inference Task, first run

*Hypothesis*

The prediction is that the Tenejapan subjects will code spatial arrays for inference using absolute directions, not egocentric coordinates, in line with the linguistic coding provided by their language. In contrast, Dutch subjects should use egocentric coordinates and concepts like front/back, left/right, to code the relative position of the objects, following the conceptual structure of the European languages. Subjects drawn from different language groups should thus make different inferences, and construct different arrays after seeing the two 'premise' arrays.

A subsidiary hypothesis may be taken over from experiment three: Tenejapan subjects may possibly show more errors on their weak linguistic axis (namely, on the current set-up, the away or sagittal, or east-west axis). See discussion above.

*Method*

*(a) stimuli*

Three coloured blocks (illustrated in Figure 14) were used for this experiment, each colour being uniquely codable in Tzeltal: red, yellow and blue. One block, used as the pivot (or B) object, was a blue rectangular solid about 7.5 x 6.5 x 6.5 cm built out of Duplo construction toy; another block used as the initial (or A) object was a yellow wooden rectangular 'pillar' about 7.5 x 2.5 x 2.5 cm., and the third (or C) object was a short red cylinder (of diameter c. 4.5 and height 5 cm.). These objects always played the same role in the inference. When this experiment was subsequently rerun with half the informants on a different axis, for novelty three objects of the same colours and shapes but about 2/3 the size were substituted (except that a red cone replaced the red cylinder).

As explained by example above, the presentation of the second premise array required that the B and C objects be placed at at least twice the distance as that of the A and B objects in the first array. In fact the distance between A and B objects was placed at about 3 to 4 cm, and the distance between B and C objects at about 15 cm.

*(b) training*

Subjects were introduced to the objects, which were described by their colours (circumventing the absence of any clear terminology in Tzeltal for such geometric solids). The experimenter sat with the subject at table 1, and speaking in Tzeltal gave an example of a transitive inference along the following lines:

'Here is a big blue (thing). Here is a yellow thing. The yellow thing is here (right-hand gesture to right) in relation to the blue thing . Do you see? It doesn't matter where on the table they are (moving both objects together around the table while maintaining the relation: yellow 4 cm to the right of blue). The yellow is always thus (gesture to right) in relation to the blue. Remember that please.'

The yellow and blue blocks were now removed, and after a pause the experimenter produced the red and blue blocks, with the red 15 cm to the left of the blue. 'Here is a red (thing). The red is there (gesture to left) with respect to the blue. It doesn't matter where they are on the table (demonstrating again). Remember that'. The red and blue blocks were put away. Now the yellow block was placed in a position on the table where it had not been before. 'If the yellow is here, where is the red?'. At this point the subject either placed the red block to the left of the yellow block, demonstrating understanding, or he placed the red block on one of the locations it had previously been, indicating lack of understanding, in which case the demonstration was repeated. When the subject correctly placed the red block, another trial was given on the 'away' (sagittal) axis, with the yellow in front of the blue, and the red behind the blue. Again, demonstrations were repeated until the subject produced two correct arrays, preserving the relative location of yellow to red without regard to position on the table. Normally at least four trials (two on each dimension) were required. By varying the position of the first and second arrays on the table, comprehension of the notion of *relative* position of objects could be checked. Finally, the subject was told that henceforth the relation between the blue and red blocks (B and C) would be shown on table 2, and the final training consisted of showing the relation of A to B on table 1, then of B to C on table 2, and then, given A in the middle of table 1, the subject was asked to place object C. If C was placed on the correct axis relative to A, the main trials began. If not, that is if the subject placed the C block on the wrong axis (e.g., front/back when testing for left/right) or on the diagonal, or wherever he had last seen the block on table 1, the trial was repeated till comprehension of relative position was achieved.

*(c) administration of main trials*

There were ten main trials, each involving a sequence of arrays on table 1, then table 2, and then table 1 again. Each 'premise' array was arranged by the experimenter, and both

subject and experimenter had to walk from table 1 to 2 and back again, ensuring at least 15 seconds between arrays, but otherwise no further delays were enforced. The subject looked for as long as desired at each 'premise' array, although the experimenter prompted, asking 'Have you got it?' after about 5 seconds; once the subject assented, the array was removed. After the two premise arrays the subject was led back to table 1, and the experimenter placed the yellow A object in the centre of the table, in a somewhat different location than it was displayed in the first premise array. The subject was then asked 'Where is the red (C object)?', while the experimenter held the red cylinder immediately above the yellow A column; sometimes the subject took the red object and placed it accordingly, sometimes he put his finger on the designated location.[43] Trials succeeded each other without a break.

Of the ten trials, five were on the front/back (away or sagittal or weak absolute axis), five were on the left/right (transverse or strong absolute axis). The order of trials was random across both axes, the experimenter following pre-coded scoresheets. Thus the subject might have two trials on the front/back axis, followed by an alternation of axes, and so on.

If subjects claimed to have forgotten an array, the entire trial was skipped, and repeated at the end of the experiment. Although both the experiment and the training of Tenejapan subjects took at least 30 (more often 40) minutes each, Tenejapan subjects did not appear to find the experiment conceptually difficult. Twenty-five subjects began, and all completed, the task.

*Results*

Using the same classification system as before, subjects were classed as absolute, relative or inconsistent ('untypable') coders according to their RA-gradient scores.[44] Table 7 summarizes the results for both Tenejapans and Dutch control subjects.

Once again, the Dutch subjects show higher consistency levels, being all but one clear relative coders. But although almost a quarter of the Tenejapan subjects fail to be reliably classified as absolute or relative coders, those that are so, are 90% absolute coders.

The corresponding graph of RA-scores against percentage of the sample is shown in Figure 15, where the opposing trends are clear. There is therefore strong support for the main hypothesis from these results: on this inference task, Tenejapans are coding absolutely, the Dutch relatively.

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[43] Pederson (Danziger 1993) recommends that the experimenter should indicate one of two positions that the C objects may be placed in, to avoid the subject worrying too much about relative distance of C from A. We felt however that it was better to give no indication, (a) because if the subject chose the wrong axis altogether, this acted as a kind of control on comprehension, (b) there was a danger that the order in which the positions were indicated might be used as a 'clue' by the subject.

[44] This typing of subjects is identical to that obtained by using a more direct classing of subjects according to a consistency requirement of 7 trials out of 10 being 'absolute' (17 Ss), 'relative'(2) or 'untypable' (6). On a stiffer requirement of 8 out of 10 trials, the figures are 14 absolute coders, 1 relative-coder and 10 untypables.

**Table 7: Transitivity Inference Task: Numbers of subjects typed as Absolute or Relative coders, or Untypable**

*Tenejapans: N = 25*

|  | ABSOLUTE | RELATIVE | UNTYPABLE |
|---|---|---|---|
|  | 17 | 2 | 6 |

*Dutch: N = 39*

|  | ABSOLUTE | RELATIVE | UNTYPABLE |
|---|---|---|---|
|  | 0 | 38 | 1 |

*Tenejapans vs. Dutch: Mann-Whitney U-test p = 0.000*
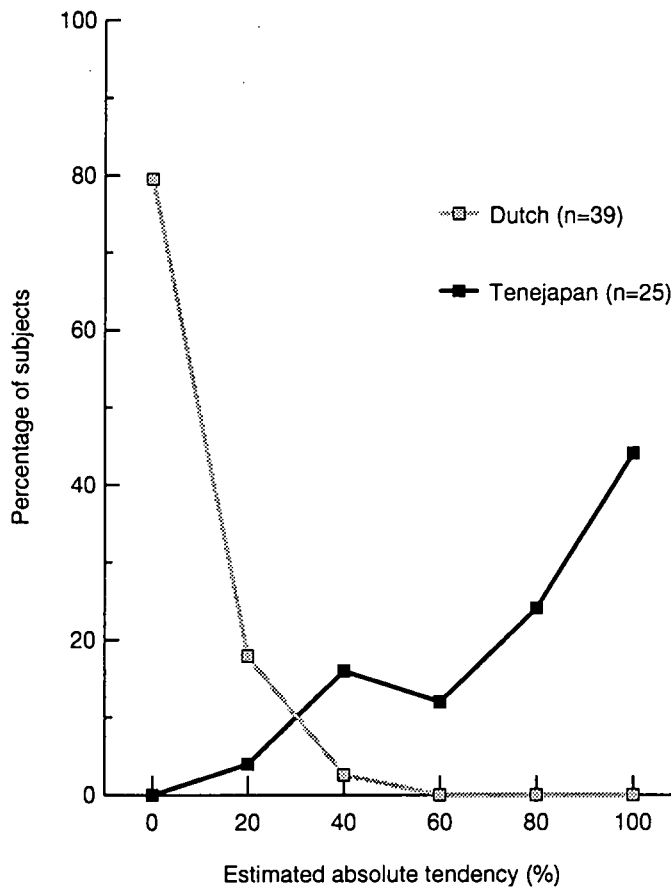


*Figure 15*: Transitive Inference Task

We may now turn to the subsidiary hypothesis: is there any evidence that Tenejapan subjects make more errors on the weaker absolute axis (east-west, here equivalent to the front/back axis)? First we consider whether more individuals can be classified as consistent absolute coders if we consider only the five trials on the strong absolute (north-south, here the left/right) axis. Table 8 provides the breakdown for the two axes. It shows a striking difference between the axes: on the strong absolute axis for Tenejapans, 20 out

of 25 subjects are typed as absolute coders; but on the weak axis, only 13 out of 25 subjects achieve this level of consistency.[45]

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**Table 8. Transitive Inference Task: Numbers of individuals typable as Absolute or Relative coders by performance on each axis separately**

*Tenejapans: n = 25*

*(a) Strong absolute axis (uphill/downhill, here ACROSS or left/right)*

| ABSOLUTE | RELATIVE | UNTYPABLE |
|---|---|---|
| 20 | 1 | 4 |

*(b) Weak absolute axis (traverse, here AWAY or front/back)*

| ABSOLUTE | RELATIVE | UNTYPABLE |
|---|---|---|
| 13 | 6 | 6 |

*Dutch: n = 39*

*(a) ACROSS axis (left/right)*

| ABSOLUTE | RELATIVE | UNTYPABLE |
|---|---|---|
| 0 | 37 | 2 |

*(b) AWAY axis (front/back)*

| ABSOLUTE | RELATIVE | UNTYPABLE |
|---|---|---|
| 0 | 38 | 1 |

---

Notice the large increase in the number of Tenejapan individuals who appear to be relative coders on the weak axis. The patterns of response across the two axes are represented in the two graphs in Figures 16 and 17 below. On the subsidiary hypothesis, at least some of these individuals might be in this category simply by virtue of repeated 'errors', i.e., failures to consistently identify absolute solutions. But on that hypothesis one would rather expect such individuals to fall into the 'untypable' category by virtue of a mixture of 'absolute' and effective errors ('relative' solutions).[46] One possibility is that, in

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[45] Just for the record, a more direct typing of subjects without use of the RA gradient, in terms of 4 out of 5 trials consistently performed one way or the other gives the following very similar figures:
*strong axis*: absolute coders: 20, relative: 4, untypables: 4; *weak axis*: absolute: 14, relative: 8, untypable: 3.
[46] Again, the same patterns are observable in the raw data viewed from various perspectives. For example, if we pool total trials for the 25 Tenejapans, then we obtain the following pattern:

| | Absolute | Relative responses | Totals |
|---|---|---|---|
| Weak Axis | 78 | 47 | 125 |
| Strong Axis | 106 | 19 | 125 |

If we take the pooled responses of just the 17 Ss who were consistent absolute coders on at least 7 out of 10 trials, we find the following:

| | Absolute | Relative responses | Totals |
|---|---|---|---|
| Weak Axis | 70 | 15 | 85 |
| Strong Axis | 81 | 4 | 85 |

the absence of a strong absolute conceptualization of the arrays, a relative system of 'front'/'back' coding kicks in *despite* the lack of linguistic support for it in Tzeltal. The puzzle remains and will be discussed below in Part II.
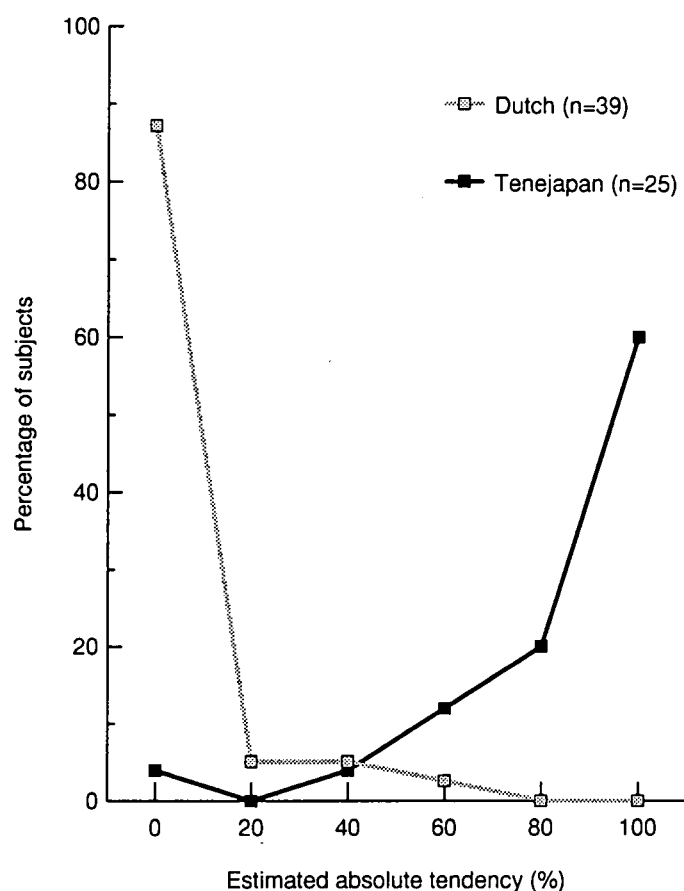


*Figure 16*: Transitive Inference: Across Axis

*Conclusion to Transitivity experiments:*

Performance on an inferential task shows the same pattern as performances on the memory tasks above: Tenejapan subjects solve this task by coding the two non-verbal 'premises' in terms of fixed bearings or absolute orientations, which is a kind of coding parallel to the linguistic coding most prominent in the language they speak. Dutch subjects code the arrays in egocentric coordinates, and thus come to different conclusions, again in line with the coordinate system prominent in the language. The subsidiary hypothesis that Tenejapan subjects might code spatial arrays more consistently on one absolute axis, namely the one maximally differentiated in the language, also seems to be supported by the data for this as for the previous experiment.

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Here perhaps it is legitimate to judge the relative responses to be errors rather than vacillation between two kinds of coding.

*Figure 17*: Transitive Inference Task: Away Axis

## 5.5 Conclusions to Part I

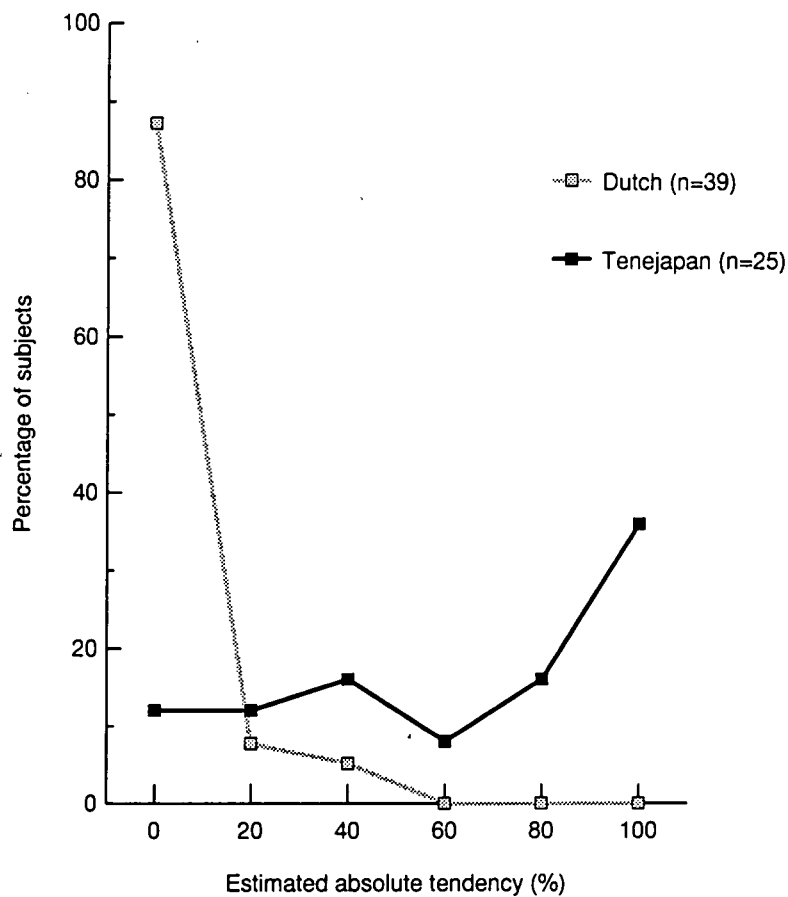The tasks above explore a range of cognitive faculties: recall, recognition memory, recoding of motion as path and recognition thereof, and finally inference using a transitive relation. The tasks that subjects had to perform were non-verbal in character: required responses were the selection between arrays or their parts by pointing, the rebuilding of arrays, and the physical placement of an object according to an inference about its location. Nevertheless, the tasks were designed to reveal some basic properties of the *representation system* employed in these non-verbal performances, and in particular to distinguish 'absolute' (using fixed coordinates like cardinal directions) from 'relative' (using egocentric coordinates) kinds of coding for memory and inference.

The hypothesis, it will be recalled, is that, in a particular culture group, there would be congruence between the linguistic representation of the arrays and the non-linguistic coding for memory and inference. The null hypothesis would be that there simply is no such congruence. But the more interesting counter-hypothesis would be that the strong underlying universals in human visual and spatial memory, which must indeed exist, and which must be essentially egocentric in character, would override any effects from differing linguistic representations: differing linguistic representations would all be.

'translated' into the same underlying spatial representation system, based on egocentric coordinates, which also guides our motor behaviour, visual imagery, etc.

To test this, two cultural groups were sampled, Dutch and Tenejapan, where it was known that there was a fundamental difference in linguistic representation of spatial arrays, Dutch offering 'relative' descriptions and Tenejapan Tzeltal 'absolute' descriptions for the relevant spatial arrays. The results of these non-linguistic tasks show that there is indeed a striking congruence between the linguistic representation system and the non-linguistic representation system: Dutch subjects mostly code spatial arrays for memory and inference using egocentric coordinates, while Tenejapan subjects mostly use a system of absolute coordinates. The differences between the behaviour of the two samples were statistically significant at a high level.

The strong contrast between the performances of Tenejapans and Dutch on this series of tasks strongly suggests that language does influence coding for memory and inference on non-linguistic tasks. But it is possible that language is not the causal factor: it could be, for example, that other cultural or ecological factors induce the character of both the linguistic and non-linguistic representations. To explore this issue, we need to consider just how closely the details of the linguistic representation are reflected in the non-linguistic performance, and this is done in Part II below.

It remains to remark on some of the variability within each sample. The Dutch performance was highly consistent: 39 out of 40 subjects coded consistently relatively on all tasks. (The one exception who sometimes coded absolutely for the left-right axis was a subject who claimed to have difficulty distinguishing his right and left, and used local landmarks in the experimental situation to solve the tasks.) The Tenejapans, by contrast, showed a strong tendency over all the tasks to code absolutely. There is, however, considerable variability in their responses (errors aside), with some subjects choosing 'relative' responses in some tasks, and evidence of a difference between the two ('strong' and 'weak') axes, which impels us to examine the Tenejapan behaviour more closely. The discussion in Part II, setting the Dutch aside as demonstrating a consistent relative or egocentric coding system (with one aberrant subject displaying some absolute coding), turns to consider the evidence as to whether the Tenejapans have one (absolute) or both (absolute and relative) systems in operation.

## 6.0 PART II: Two Tenejapan systems or one? Understanding mixed results

## 6.1 Introduction

In this section we consider two theoretically independent conjectures, which are interdependent in the particular data to hand - that is, they offer rival (but not incompatible) explanations of the variability in the Tenejapan response patterns. The first conjecture is that the details of the linguistic representation are faithfully reflected in the non-linguistic coding for spatial arrays, so that specific weaknesses (missing distinctions) in the linguistic coding are responsible for certain performance errors in the non-verbal tasks. In the Tenejapan case, the 'uphill'/'downhill' system of grammatical oppositions for spatial description clearly distinguishes points corresponding roughly to north and south, but conflates those corresponding to east and west under a single 'traverse' linguistic description - the opposition can of course be made periphrastically, but it is linguistically less salient.

If this conjecture could be substantiated it would be important: it would demonstrate that the Tenejapan linguistic coding and non-linguistic coding are at least partially isomorphic, and most probably that both coding systems are based on the same underlying conceptual parameters. That would support the presumption of a causal relation between the linguistic coding and the non-linguistic coding, rather than say a congruence caused by a third factor, perhaps some general cultural tendency or ecological inducement to view space non-egocentrically.[47]

The second conjecture is that the variation in response patterns shows competing systems at work. In particular, apart from the absolute system dominating in most tasks for most subjects, it seems very likely that a relative system of egocentric coordinates is also available for memory coding. For all the normal perceptual and motor systems must of course be egocentric in character. In addition the language Tzeltal makes available such a relative system for deictic expressions: there are the normal range of expressions glossing 'this' and 'that', 'here' and 'there', 'coming' and 'going' etc. (see Brown 1991). One should note, however, that although these encode relative distance from ego, or motion towards and away from ego, these notions can only distinguish between sagittal (front/back) oppositions: two objects equidistant from ego on the transverse plane (left vs. right) cannot be distinguished in the available deictic system. In sum, much of the variation in Tenejapan response might be due to subjects vacillating between the culturally dominant absolute coding system and a universally available egocentric system.

Both factors could in fact be at work. One must also consider of course the possibility that the variation in the Tenejapan response patterns are simply 'noise' generated by the unfamiliarity of the testing materials and situation, or by other failures to adequately adapt the design and administration to local conditions.

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[47] For example, suppose one could show that all desert hunter-gatherers use 'absolute' systems of coding - this might be attributable to ecological conditions, which make both a linguistic and non-linguistic absolute system of adaptive value. In fact, Tenejapans are peasants practicing slash and burn agriculture over a small territory, living in similar conditions to other Mesoamerican peasants who use relative or purely intrinsic systems of orientation. Some of these contrastive groups are also under study by colleagues at the Max Planck Cognitive Anthropology Research Group.

There is a way to test these two conjectures, namely to compare subject performance twice on the same experiment, with the entire experimental situation rotated 90 degrees. Then what is clumsy to code in Tzeltal becomes easy, and vice-versa; while front/back (or left/right) oppositions remain constant in the two conditions. We had to choose between using new subjects, or using the same ones again, but decided that since the tasks provide rich detail on individual performance, it would be easier to interpret performance by the same subject under the two conditions. Consequently, half the subjects were recalled and some of the experiments run again under a 90-degree rotation of the experimental set-up (see Figure 18 for an illustration of the contrast between the two experimental set-ups). This section reports on these results and assesses the evidence for each conjecture.
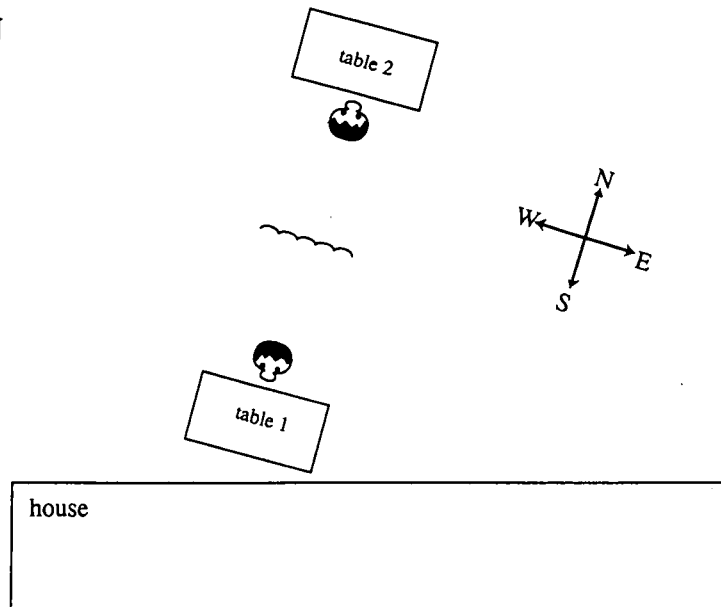
FIRST RUN
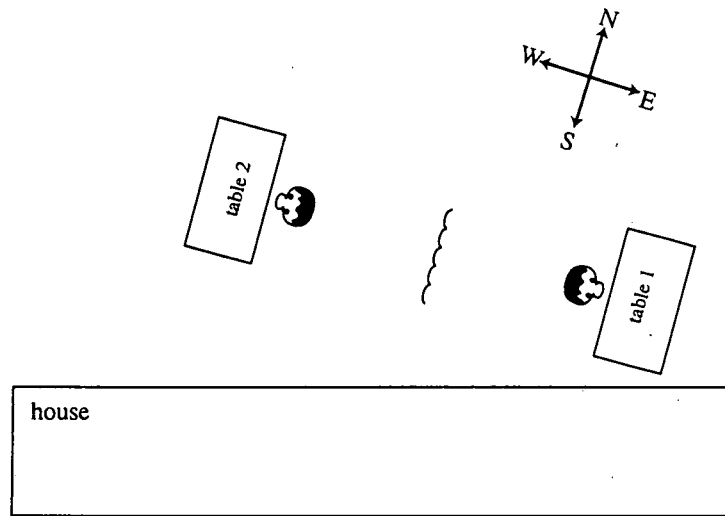
SECOND RUN

*Figure 18:* Physical layout for first and second runs of experiments in Tenejapa

## 6.2 Weak vs. Strong Axes on first run of experiments

Three of the experiments (numbers 2, 3 and 4) described above require responses which involve coding of direction on both the lateral and sagittal axes (i.e., the left/right and front/back axes, or respectively north/south and east/west axes, however conceived). We have analyzed the differential behaviour on these two axes in various ways in the discussions of the experiments above, but we may summarize the trend in the raw data by comparing percentages of responses (or response components) that were apparently coded absolutely or relatively on the two axes, as in Table 9. What is here called (following the Tenejapan linguistic facts) the 'strong (absolute) axis' corresponds in this first run of experiments to the egocentric 'across' or transverse (left/right) axis, while the 'weak (absolute) axis' corresponds here to the egocentric 'away' or sagittal (front/back) axis.[48]

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**Table 9: Percentages (numbers) of Tenejapan responses apparently coded absolutely or relatively on the weak vs. strong axes - first run.**

|  | ABS | REL | ERROR |
|---|---|---|---|
| **(a) Experiment 2** (Maze) | | | |
| weak axis | 67% (90) | 31% (42) | 2% (3) |
| strong axis | 73% (98) | 27% (37) | (0) |
| **(b) Experiment 3** (Chips) | | | |
| weak axis | 58% (53) | 37% (34) | 5% (5) |
| strong axis | 71% (65) | 26% (24) | 3% (3) |
| **(c) Experiment 4** (Transitivity) | | | |
| weak axis | 62% (78) | 38% (47) | – |
| strong axis | 85% (106) | 15% (19) | – |

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The point to note here is that in all three experiments there was a differential effect. Averaging across the three experiments, Tenejapan subjects produced 62% of absolute responses on the weak axis, but 76% of absolute responses on the strong axis. The magnitude of the effect varied across the experiments - absolute codings were reduced by

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[48] Note that much literature shows that the 'strong' egocentric axis is the 'away' (front/back) one, while the 'weak' egocentric axis is the 'across (left/right) one. Thus in the experimental set-up of the first run of the Tenejapan experiments described above, Tenejapan subjects found their strong absolute axis aligned with the weak egocentric axis, and the weak absolute axis aligned with the strong egocentric axis. This is the opposite classification (into 'strong' vs. 'weak' axis) than that for the Dutch subjects, where the front/back axis might be considered more strongly relative than the left/right; this was born out by the one Dutch subject who used some 'absolute' strategies - precisely on his 'weak' left/right axis.

6%, 13% and 23% on the weak axis across the three experiments (2, 3 and 4 respectively).

The difference is worth investigating further for two reasons. One reason, given above, is the subsidiary hypothesis that detailed properties of the absolute linguistic coding might be directly reflected in non-linguistic performance. In these experiments, the stimuli were presented in such a way that the sagittal axis (the 'weak axis' in the table above) corresponded to the more weakly coded absolute axis in the linguistic system.

Another reason to follow through the investigation is that, on *a priori* grounds one might suppose that Tenejapan subjects must have mentally available two systems for coding arrays. That they have an absolute system for coding spatial arrays for memory and inference is demonstrated by the experiments reported above. But they must also have a relative or egocentric system of coordinates (in terms corresponding to e.g. front/back, left/right) involved in immediately post-perceptual coding of spatial arrays for, for example, motor coordination, despite the absence of straightforward linguistic coding of these systems. Such egocentric systems, unlike absolute systems, are congruent with visual and haptic perceptual information, for example, 'in front of' matches visual occlusion, in a way that 'to the north of' does not.

It seems reasonable to assume that there are corresponding conceptual categories universally available; indeed some universal linguistic subsystems (notably deixis) rely upon these. If this egocentric system of conceptual categories is also available for coding for long-term memory and inference, Tenejapans would thus have two competing conceptual coding systems that can both be utilized in tasks of the sort presented. One or the other might be more salient or natural to employ on one or the other axis. We have already suggested that the absolute Tzeltal linguistic system provides more salient coding solutions for the uphill/downhill (north-south) axis than for the traverse (across the slope, here, east-west) axis. It is also well known that for egocentric coding systems (at least for those of the well-studied Indo-European languages), the left/right or transverse axis is weaker than the front/back or sagittal axis. There is both linguistic evidence for this (e.g., western children acquire the deictic left/right system years after acquiring the deictic front/back system) and non-linguistic evidence (e.g., children confuse left/right reflections across the perceptual vertical much more often than they confuse front/back reflections across the perceptual horizontal). Primates and other animals show the same differential coding abilities on egocentric axes.[49]

Now the experiments reported above were run in such a way that the weak absolute axis (traverse, east-west) corresponded to the strong egocentric axis (sagittal, front/back).

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[49] See Corballis and Beale (1976) for review. See also Levinson and Brown (in press) for a review of some of this literature with special reference to Tenejapa.

48

Thus just where the absolute system was weak or less salient, the relative system was strong or more salient. There are then three distinct hypotheses that might be invoked to explain the differential response patterns:

(i) *Absolute system hypothesis*: The weak absolute coding of the east-west axis in the linguistic system is matched by a weak non-linguistic coding on that axis. Except for a few manifestly relative coders, there was no serious interference effect from an egocentric system: there were simply many more 'errors' (scored as 'relative' responses) on the weak axis.

(ii) *Relative system hypothesis*: The egocentric perceptual system of coding has a strong front/back axis, and a weak left/right one: the weak axis had negligible effects on absolute coders, but the strong (front/back) egocentric axis was a salient coding system that imposed itself on some performances. Thus 'relative' responses are not errors, but interference effects from the strong axis of a rival system.

(iii) *Combined hypothesis*: For Tenejapans, there are two competing systems of conceptual coding available, but for most subjects the absolute system is dominant. But the area in which the absolute system is weak allows a conceptual 'gap' for the relative egocentric system to assert itself, and this happens to be the axis in the first run of experiments where the egocentric system is in any case salient.

There is so far no knock-down evidence to decide between these three hypotheses, although the facts reported for experiment 4 (where 5 extra subjects performed consistently as relative coders just on the weak absolute axis (=strong egocentric axis) is suggestive that either (ii) or (iii) may be involved.

## 6.3 The second run of experiments

It was decided to test these hypotheses directly by recalling one half of the Tenejapan subjects, and re-running the experiment with the experimental situation (the axis linking the two tables) rotated at 90 degrees. (See Figure 18 above.)

On the new arrangement, the weak left/right egocentric axis will coincide with the weak absolute axis, and the strong front/back egocentric axis will coincide with the strong absolute axis. Since an absolute coding should produce the opposite response from a relative coding on each axis, it should now be possible to differentiate the hypotheses.

**Predictions**

What we now expect is this:

(i) *absolute hypothesis:*

Relative responses, which are actually errors, should now cluster on the left/right axis, which now on this second run coincides with the east-west weak absolute axis. They

49

should not be high on the front/back axis, as this is now coincident with the strong absolute axis. Rates of errors, including relative responses, should remain similar to the first run of the experiment.

(ii) *relative hypothesis*:

Relative responses, which are produced by an alternate egocentric coding system, should occur more often on the strong egocentric (front/back) axis, which is now the north/south axis. Rates of relative responses should remain similar to the first run of the experiment.

(iii) *combined hypothesis:*

Both an egocentric system and an absolute system are potentially in play. But when the 'gap' in the absolute system, the weak east-west coding, coincides with the strength in the egocentric system, the strong front/back coding, one may expect the otherwise dominant absolute system to be at its weakest. Thus one might expect more relative responses in the first run of the experiments.

These different expectations must be further modified to take into account possible learning effects, for one may expect performance, other things being equal, to improve on the second run of the same experiment. It will be useful to introduce a four-celled matrix for the representation of the expectations under each of four conditions, as follows:

For each experiment:

|  | ACROSS | AWAY |
|---|---|---|
| RUN 1 | (cell 1) | (cell 2) |
|  | strong absolute | weak absolute |
|  | weak egocentric | strong egocentric |
| RUN 2 | (cell 3) | (cell 4) |
|  | weak absolute | strong absolute |
|  | weak egocentric | strong egocentric |

Here cells 1 and 2 will contain the results on the two axes of the first run of the experiment, 3 and 4 the results of the second run. The axes are grouped relatively: that is, the column labelled AWAY is the sagittal, front/back axis, that labelled ACROSS is the transverse left/right axis. Cells 1 and 4 on the diagonal collect responses on the strong absolute axis (north-south), while cells 2 and 3 collect the responses on the weak absolute axis (east-west). Following the same practice as the RA gradient, we can think primarily in terms of the number of absolute responses we might expect in each cell or condition. We can then represent the hypotheses in the following way.

*Hypothesis 1: Absolute system effects:*

The absolute axes are distributed as 'strong' and 'weak' across the cells as follows:

(1) | | ACROSS | AWAY
---|---|---|---
| RUN 1 | strong | weak
| RUN 2 | weak | strong

Thus we expect high and low numbers of *absolute* responses to pattern on the diagonal as follows:

(2) | | *absolute scores* | 
---|---|---|---
| | ACROSS | AWAY
| RUN 1 | high | low
| RUN 2 | low | high

The prediction to be tested statistically is then that each subject will show a higher percentage of absolute responses on the strong absolute axis, regardless of the egocentric relation to the array: absolute scores in cells 1 and 4 should exceed those in 2 and 3.

*Hypothesis 2: Relative system effects:*

The strong (front/back) vs. weak (left/right) egocentric axes pattern as follows:

(3) | | ACROSS | AWAY
---|---|---|---
| RUN 1 | weak | strong
| RUN 2 | weak | strong

Therefore we expect high and low numbers of *relative* responses to pattern in columns as follows:

(4) | | *relative scores* | 
---|---|---|---
| | ACROSS | AWAY
| RUN 1 | low | high
| RUN 2 | low | high

Since high numbers of relative responses will lower absolute responses, we expect numbers of absolute responses to pattern as follows, on this hypothesis:

(5) | | *absolute scores* | 
---|---|---|---
| | ACROSS | AWAY
| RUN 1 | high | low
| RUN 2 | high | low

Thus for each subject we should test statistically whether his absolute scores in cells 1 and 3 exceed those in cells 2 and 4.

*Hypothesis 3: Relative effects occur just where absolute system is weak*

The idea here is that the two systems of coding are co-present, but the absolute predominates; the relative system will only 'kick in' where it is strong and the absolute system is weak. This predicts a special pattern for cell 2 of the matrix, for here the absolute system is weak (east-west) and the relative system is strong (front-back):

(6)          *absolute scores*

|        | ACROSS | AWAY   |
|--------|--------|--------|
| RUN 1  | high   | **lowest** |
| RUN 2  | low    | high   |

We can test this hypothesis statistically by asking of each subject's performance whether we can find an ascending series of absolute scores: lowest should be cell 2, next lowest should be cell 3, with cells 1 and 4 with highest scores.

Finally, we should note that these expectations could be obscured somewhat by a learning effect over the two runs. If performance of absolute coders improves and gets more consistent, clearly absolute responses should increase on the second run. Thus in the abstract, one expects numbers as follows:

(7)          *learning effects on scores*

|        | ACROSS | AWAY   |
|--------|--------|--------|
| RUN 1  | low    | low    |
| RUN 2  | high   | high   |

The pattern in matrix (7) therefore could threaten to obscure the patterns predicted by the specific hypotheses above, especially if performance rises to approximate zero errors. Scores that are predicted to be low on the first run and high on the second run by the hypotheses may in fact be so due only to learning. In fact, as shown below, learning effects were minimal, and can effectively be ignored.

**The second run of experiments**

*Method*

Those experiments, namely 2, 3 and 4, which use both axes, were repeated. Thirteen of the original Tenejapan subjects repeated experiments 2 and 4 and twelve repeated experiment 3. Which subjects repeated the experiments was effectively determined by subject availability. The time lapse between experiencing the original experiment and its

rerun was mostly between three and seven days, but two subjects were run with an interval of about three hours between first and second runs of the same experiment.

Training on the experiments was repeated in full (subjects showed little evidence of recollection of the procedures). The visual stimuli in experiments 3 and 4 were varied to retain some element of novelty, as described in the relevant sections above. The main trials were also conducted in the same manner as on the first run of the experiments.[50]

*Results*

Subjects performed the tasks without overall marked improvement in consistency, although some individuals reached higher numbers of trials with the same coding, while others achieved less (see Table 10).

| Table 10: Changes in individual performance from Run 1 to Run 2 | | | | |
|---|---|---|---|---|
| Subjects who: | improved | deteriorated | no change | total |
| Experiment (2) | 5 | 6 | 2 | 13 |
| Experiment (3) | 4 | 4 | 4 | 12 |
| Experiment (4) | 6 | 3 | 4 | 13 |

On Experiments 2 and 3, only one individual had a majority of relative coded trials, but this individual along with all the rest had a majority of trials coded absolute on experiment 4. Apart from this one individual, the sample can be viewed as a set of absolute coders (see Table 11).

| Table 11: General profile of subjects on rerun experiments | | | |
|---|---|---|---|
| | ABS-coders | REL-coders | inconsistent |
| Exp. 2 3/5 trials | 8 | 1 | 4 |
| Exp. 3 6/8 trials | 9 | 1 | 2 |
| Exp. 4 7/10 trials | 11 | 0 | 2 |

*Experiment 2: Maze Recognition Task*

This task was not ideally adapted to this kind of analysis, since a single response combined elements of direction on both axes. However, it is possible to analyze each

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[50] Table 2 now projected from out of the shade of the veranda of the house where the experiments were run, and during rain table 1 had to be placed within the house so that table 2 could be brought into shelter while retaining the distance between them. As before, a screen was hung between the tables.

response, including erroneous ones, as a combination of two directional elements: each element could either be coded relatively (egocentric 'away' or 'across') or absolutely (cardinal 'up/down (north/south)' or 'traverse'), as illustrated for the second run of the experiments in Figure 19. When this reanalysis of paths is done, each trial can be scored for response on both axes.
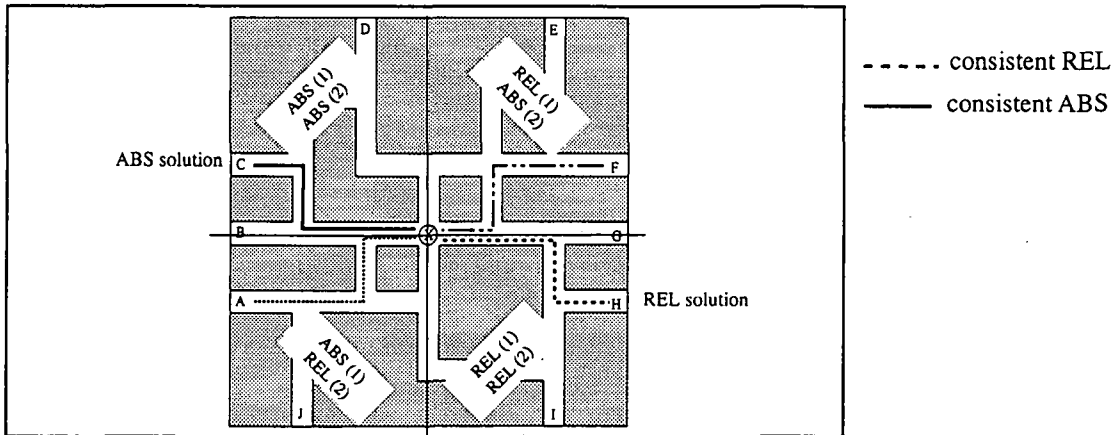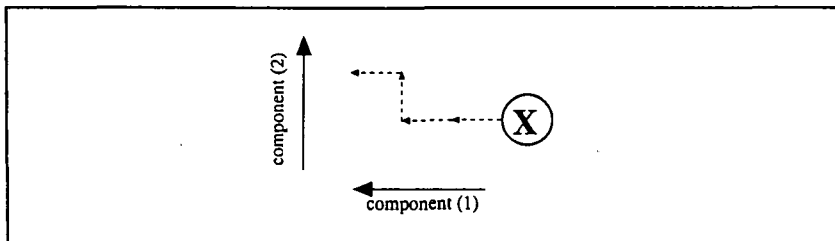


*Figure 19:* Maze Recall Task: 'Absolute' vs. 'Relative' components of each possible response

We can now test within the sample for each subject whether the pattern of responses across the four cells of the matrix is in line with any of the three hypotheses above. A multivariate repeated measures analysis within subjects was performed, but the results were non-significant for each of the three hypotheses. A test better adapted to the data (Wilcoxon signed ranks test on the basis of Arc-Sin transformations of RA scores) also failed to find significant values. None of the hypotheses was thus confirmed.[51]

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[51] Indeed, the raw data do not suggest any pattern across the axes. For example pooled responses across the subjects pattern as follows:

|        | ACROSS    | AWAY     |
|--------|-----------|----------|
|        | A:R:0     | A:R:0    |
| RUN 1  | 53:12:00  | 51:13:1  |
| RUN 2  | 50:15:00  | 50:13:2  |

*Experiment 3: Chips Recognition Task*

The recognition experiment with trials systematically organized on both axes is a more promising instrument with which to study these questions. The same procedures were applied: each subject's performance being examined under the four conditions, and the three hypotheses being tested as predicted patterns across these conditions. But once again, neither the multivariate test nor the Wilcoxon test found significant values for the predicted patterns.[52]

*Experiment 4: Transitive Inference Task*

Like the previous experiment, this task had independent randomized trials on both axes, but it had the benefit of a larger number of trials on each axis. The same techniques were used to test the three hypotheses on the basis of repeated measures within subjects. Analysis of variance of each subject's scores yielded values that support two of the hypotheses.

Hypothesis (1) that Tenejapan subjects are more consistent absolute coders on the 'strong' ('uphill/downhill') absolute axis than on the 'weak' absolute axis, regardless of their egocentric orientation, was confirmed at a high level of significance (p = 0.001, Multivariate repeated measures analysis on the basis of Arc-Sin transformations of RA gradient scores; p = 0.005 using the Wilcoxon signed ranks test). The diagram below shows graphically how performance shifts towards greater absolute consistency on the strong cardinal axis: the vertical axis represents the cumulative percentage of the sample, and the horizontal the RA gradient, so that each point represents 2 (or at most 3) subjects that share a band on this gradient. Inspection will show that there is a rightwards shift between the two curves, corresponding to the increasingly absolute performance from the weak to the strong cardinal axis.[53]

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RA scores for only 7 out of the 13 subjects were more absolute on the weak egocentric than the strong egocentric axis.

[52] Again the raw data were not promising, e.g. the pooled responses for all subjects across the four cells were as follows:

|  | ACROSS | AWAY |
|---|---|---|
|  | A:R:0 | A:R:0 |
| RUN 1 | 36:11:1 | 35:13:0 |
| RUN 2 | 33:12:3 | 36:9:3 |

[53] The curves converge because 100% absolute scores can of course not be bettered on either axis.
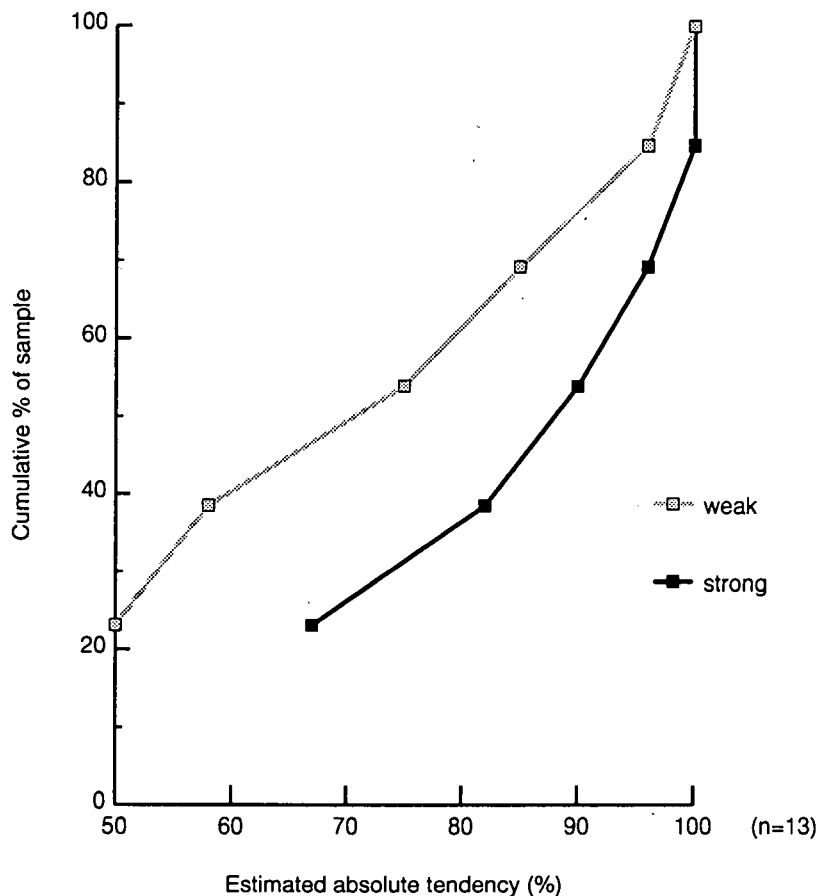
**Figure 20**: Transitive Inference Task: Cardinal Axis (Tenejapan sample, reruns)

Hypothesis (2) makes the prediction that regardless of absolute orientation, subjects will make more relative responses on the strong egocentric ('away' or front/back) axis than on the weak egocentric ('across' or left/right) axis. This hypothesis is also confirmed (p = 0.035, Multivariate repeated measures analysis; p = 0.037 Wilcoxon).

The third hypothesis, that there might be a principled interaction between these two effects such that the strong egocentric axis was operative especially on the weak absolute axis, was not confirmed (p = 0.74 Analysis of Variance; p = 0.232 Friedman analysis of variance).

*Discussion*

The second run of the experiments was designed to test whether the observed asymmetry between performance on the two axes (whether conceived of as egocentric or absolute) in the first run, could be attributed to either an effect of the linguistic asymmetry between a weak and a strong absolute axis, or to an effect of the well-known asymmetry of the egocentric axes, or to some specific interaction between them.

We failed to confirm any such effects on the first two experiments, perhaps because the maze task was not well adapted to this kind of analysis, while both the maze task and the chips task had relatively few trials on each axis. In addition, neither of these tasks elicited

very reliable performance from Tenejapan subjects, compared to the first (recall, animals) and the last (transitivity).

The third task, the inference experiment, showed strong evidence that there is both an effect of the cardinal axis asymmetry and of the asymmetry of the egocentric axes, but no evidence of a systematic interaction between them. We can thus take them to be independent tendencies.

For the reasons sketched, we are not surprised to find that there are demonstrable effects of the strong/weak axes of the egocentric system discernable in at least one of the experiments. But the other finding is more surprising: the fact that coding for a non-verbal task seems to share with the linguistic system a differential codability on the two absolute axes north/south vs. east/west. It seems that Tenejapans are coding spatial arrays (at least in these tasks) using a coding with conceptual structure isomorphic with the semantic structure of the language. If so, Humboldt's opinion that "language is the formative organ of thought", and thus that conceptual systems vary with linguistic systems, may after all be at least partially correct.

## 7.0 General conclusions

The experiments reported above show robust correlations between language-specific verbal-coding systems and the conceptual representations involved in solving non-verbal tasks. That correlation can be demonstrated across a range of psychological processes, from recall, recognition to inference. It can thus be replicated across tasks, and as demonstrated, across repetitions of tasks. Both similar and identical experiments have been conducted in other cultures with a predominantly absolute linguistic coding of spatial arrays, with similar results (see, e.g., Levinson 1992a for an Australian case, Pederson 1993 for an Indian case, and the Max Planck Institute for Psycholinguistics' annual report for many other cases). We are thus confident that the phenomenon is generally replicable.

A question that naturally arises then is whether all we have shown is that such tasks are, for whatever reason, naturally solved by using linguistic coding. For example, perhaps when searching for a mnemonic system, subjects consciously, as it were, talk to themselves. The delay between stimulus and response may make subvocal use of auditory short-term memory impractical, but linguistic coding in long-term memory is not ruled out. If subjects are using a linguistic mnemonic system specially for these tasks, in a way distinct from their normal processing, then no general conclusions about the relation of linguistic and conceptual systems can be made.[54]

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[54] We are grateful to John Lucy, Sotaro Kita, Eric Pederson, David Wilkins, and other colleagues for raising these questions and suggesting responses.

Various responses are possible. First, if across all these tasks, subjects of different speech communities tend to find just one kind of coding the most natural (namely one congruent with their linguistic coding), then whether or not it relies on a linguistic mnemonic, it is unlikely to be entirely distinct from normal conceptual processing.[55] Other kinds of mnemonic are available, e.g. pinching one's left thumb, which would induce relative coding, or observing alignments with landmarks in the experimental setting, which would induce absolute codings (see Pederson 1994 for discussion), yet subjects align with the dominant coding system in their speech community. But perhaps the most telling response is that one can find evidence in absolute-coding speech communities for the natural, unconscious and continuous coding of spatial distinctions in absolute terms: Tenejapans, for example, can be shown to preserve the fixed bearings of directions in their gestures. Thus if a subject sees a motion stimulus and is rotated and asked to describe it, the gestures retain the bearings of the stimulus, not the relation of the motion to the egocentric viewpoint.[56]

That an absolute linguistic system should engender a general tendency to the conceptual coding of spatial arrays absolutely is not surprising on first principles. First, specialized constant on-line processing of fixed bearings is required. Second, there can be no general algorithm for translating absolute codings of arrays (as required for the language) into egocentric codings: from 'x is north of y' we cannot derive 'x is in front of y' or vice versa. Thus to describe linguistically from memory, one must remember an array with its fixed bearings. Thirdly, absolute codings of arrays are efficient: all the conceptual primitives are good transitive, asymmetric relations.[57]

But one real puzzle about absolute coding systems is precisely their untranslatability, or mutual un-derivability, from egocentric systems. Since perceptual codings must be egocentric, absolute coders must utilize both relative and absolute coding systems. But as the design of our tasks illustrates, the two coding systems are fundamentally incongruent. How do absolute coders handle these two kinds of information? Our evidence, from these and other tasks, is that Tenejapans in effect give priority to the absolute coding: for example, to solve our tasks absolutely, they must in effect suppress the visual information - the viewpoint-centred coding of the spatial arrays. But recall tasks, in which the reconstruction of an array is undertaken under rotation (as, in a simple version, in the Animals Task above), seem to show that visual arrays can be mentally rotated to maintain fixed bearings (i.e., subjects can envisage what an array looks like from the other side, and thus reconstruct it when they are rotated 180 degrees). Thus absolute coding may

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[55] The cross-cultural replicability has some bearing here: Tenejapans for example do not have schooling in learning-by-rote or experience the need to remember strings of arbitrary digits such as telephone numbers.
[56] This correlation between gesture and linguistic coding system was first made by Haviland (1993) for an Australian Aboriginal speech community; he has also shown its operation in a Mayan (Tzotzil speaking) community, and pilot experiments and video recordings by us show its replicability in Tenejapa.
[57] These issues are explored in Levinson, 1992b.

engender very special uses of egocentrically coded information. These are interesting further questions that arise from this whole, unexpected phenomenon.

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