



Distinguishing three-dimensional forms from their mirror-images: Whorfian results from users of intrinsic frames of linguistic reference

Eve Danziger *

Department of Anthropology, University of Virginia, 100 Brooks Hall, Charlottesville, VA 22901, United States

ARTICLE INFO

Article history:

Received 1 March 2011

Accepted 22 June 2011

Available online 7 September 2011

Keywords:

Linguistic relativity

Maya

Mental rotation

Mirror image

Psycholinguistics

Spatial cognition

ABSTRACT

Mopan (Mayan) speakers, who rely heavily on intrinsic frames of reference in spatial language, also classify two-dimensional forms intrinsically on a non-linguistic task (Danziger, 1999). This is compatible with the predictions of the Whorf hypothesis, but could also be an artifact of using 2D materials in a population with low literacy levels. This paper reports that Mopan speakers categorize even 3D objects as predicted by intrinsic encoding, thus increasing support for the Whorfian interpretation of their performance. A group of US English speakers shows the opposite tendency, confirming that task performance is under cultural, and therefore perhaps linguistic, influence.

© 2011 Elsevier Ltd. All rights reserved.

1. Introduction¹

The question whether linguistic reference to spatial relations correlates with preferred spatial problem-solving strategies has in recent decades become a major focus of language-and-thought inquiry. Space has become an area where Whorfian claims have been strongly made, empirically supported, and in turn fiercely contested. At stake is some of the clearest evidence for the revival of the Whorfian claim that contingent facts of language structure actually have an effect on cognitive processes like memory, reasoning, and “worldview” (Whorf, 1956 [1940]). Much of the evidence from space supports the claim, since in experimental settings of several types and in many languages, spatial problem-solving strategies have been shown to match differential predictions derived from documentation of language-particular descriptive strategies (Pederson et al., 1998).

One obvious question remains to be settled – are these correlations evidence of causality, and if so, in which direction? But opponents of the Whorfian claim have also attacked the empirical evidence for the correlation itself.² The history of one counter-claim and the response to it (Li and Gleitman, 2002; Levinson et al., 2002) has shown that it is imperative for the

* Tel.: +1 434 924 3002.

E-mail address: ed8c@eservices.virginia.edu

¹ Mopan orthography in this paper follows that of the ALMG (England and Elliott, 1990). Glossing abbreviations follow where possible the Leipzig glossing rules as found at http://www.eva.mpg.de/lingua/pdf/LGR09_02_23.pdf and are as follows: 1 – First Person; 2 – Second Person; 3 – Third person; A – Actor/Possessor Pronoun; B – Undergoer Pronoun; COMP – Complementizer; CONJ – Conjunction; DEM – Demonstrative; DET – Determiner; DUR – Durative; DX – Deictic; IPFV – Imperfective; IRR – Irrealis; LOC – Locative; NEG – Negator; OST – Ostensive; PASS – Passive; PL – Plural; PREP – Preposition; Q – Interrogative; REL – Relativizer; SCOPE – Scope; TR – Transitive; TRR – Transitivity.

² Li and Gleitman claim for example (2002), that under certain task circumstances, US English speakers readily use ‘absolute’ cognitive solutions despite their non-use of absolute linguistic encoding. However, their claim rests on the mis-assignment of any allocentric FoR to the absolute sub-category (see Levinson et al. (2002) for refutation).

debaters to share an understanding of the particular frame of reference (FoR) classification which is at stake, if they are to avoid arguing at cross purposes (see also Danziger, 2010).

Clarification of terminology and concepts in the FoR literature is especially important when the discussion turns to languages – like those of Mesoamerica – which make heavy use of intrinsic strategies to accomplish spatial reference, and some of which may make little if any use of other strategies in the crucial comparative context (Danziger, 1996, 1999, 2001, papers by other authors in this issue). Many existing experimental tasks are ineffective in offering Whorfian predictions for cognitive strategies under these circumstances (Pederson et al., 1998; Danziger, 2001, Bohmeyer, this issue), since intrinsic usage in language usually predicts more than one correct solution at the cognitive level on these tasks. In what follows I report recent results from a cognitive task which has been specially designed to offer a Whorfian prediction for heavy intrinsic FoR users that will distinguish them from other populations. The task has only one correct solution, thus also eliminating any possible confounding of consultants' problem-solving strategies by their attempts to guess at the experimenter's desired solution (cf. Pinker, 2007; Li et al., 2011). Comparison of performance on this task between speakers of Mopan (Maya) and a group of US English speakers yields a significant difference in the direction predicted by linguistic relativity. Cross-cultural variation in conceptual frames of reference therefore here runs parallel to – and may derive from – variation in the frames of reference used in speech.

2. A cognitively-oriented classification of frames of reference in language use

I make use of a set of distinctions developed in Levinson (1996), modified in Danziger (2010), and lightly adapted to the terminology of O'Meara and Pérez Báez (this issue). This classification of linguistic frames of reference contrasts egocentric with allocentric frames on the one hand, and binary (or 'intrinsic') with ternary (or 'extrinsic') frames on the other (Levinson, 1996; Danziger, 2010).³

Unlike earlier versions (Levinson, 1996), this matrix identifies two types of binary ("intrinsic") FoRs just as there are two types of ternary ("extrinsic") frames (Danziger, 2010). The term "intrinsic" is therefore used here in the same sense as in Levinson (1996) to refer to any FoR usage in which the anchor is identical to the ground. The term "extrinsic" is used to contrast with it at the same level, i.e. to refer to any FoR usage in which anchor is distinct from ground. New terms ("object-centered", "direct") have been added to unpack the intrinsic frames of reference according to their egocentric/allocentric properties, just as the extrinsic frames have traditionally been distinguished ("relative" and "absolute"). Any use of any one of these terms in this paper should be taken to be in the sense defined by Table 1.

The classification separates FoR types according to their sensitivity to rotation possibilities of participant, ground, and figure-ground array (Levinson, 1996, modified in Danziger, 2010). In identifying four rather than three separate frames of reference, the classification follows the logic of rotation sensitivities to these three criteria to its fullest conclusion (Danziger, 2010).

Such a criterion for assignment of a particular piece of language usage to a FoR category is eminently practical. Since cognitive tasks designed to investigate effects of spatial language use on non-linguistic spatial problem solving have from the beginning been built around rotation manipulations, this classification ensures that each FoR type possesses a unique signature in terms of rotation sensitivity, which can in turn be used for cognitive investigations. Other typologies and classifications, developed on other principles and for other purposes, are of course also legitimate – but less well suited to matching language type with predictions for non-linguistic problem-solving strategies under rotation.⁴ Reliance on rotation sensitivities as the final classificatory diagnostic not only keeps classificatory types at the level of language tightly connected to empirically testable cognitive correlations, it also inhibits unfettered proliferation of linguistic FoR "types" each time a slightly new configuration is encountered. Entries in column B of Table 2 (rotation of speech participant) distinguish the two allocentric frames (absolute, object-centered) from the two egocentric frames of reference (relative, direct). Columns C and D on the other hand, distinguish the two extrinsic frames (absolute, relative) from the two intrinsic ones (object-centered, direct).

3. Mesoamerica

In Mesoamerica, the abundant use of 'body-part' terms as spatial relators has long been recognized as an areal feature (Campbell et al., 1986). As the papers of this special issue make clear, such constructions are widely used in this region for the linguistic description of the location of spatial figures with respect to their grounds. The following examples are from Mopan Maya, a language of the Yucatecan (Mayan) subfamily spoken in Southern Belize and Western Guatemala. These

³ I use Talmy's (1983) terminology, in which 'figure' refers to the entity that is to be located in a spatial expression, and 'ground' to the entity with respect to which the figure is located. In addition, I use Levinson's (1996) notion of 'anchor' – the point from which a matrix of vectors is projected, one of which identifies the direction to be followed from the ground to find the figure. Finally, a notion of 'participant' will be useful: the 'participant' is the locus of psychological perspective for a spatial representation. In most cases the 'participant' is the speaker of a linguistic expression or the solver of a spatial-cognition task, but in some cases the participant may be the linguistic addressee, and in others the participant may even be a third person, as long as this entity has the subjectivity features normally characteristic of speech participants (Benveniste, 1966 [1958]), as in some cases of the generic observer (e.g. English *one*).

⁴ Note for example that because of the reliance on rotation sensitivity as the typing criterion in the classification presented here, characterizations of particular cases of language usage as "geocentric" or "landmark" based, as distinct from "absolute" are redundant. These kinds of cases are considered in this classification to be subsumed under the absolute type, since the rotation sensitivities in all of these cases are identical.

Table 1

Two cross-cutting dimensions for classifying frames of reference.

	Allocentric	Egocentric
	Anchor is not a speech situation participant	Anchor is a speech situation participant
Extrinsic	<i>Absolute</i>	<i>Relative</i>
Anchor is not ground	The milk is to the east of the kettle	The milk is to the right ^a of the kettle
Intrinsic	<i>Object-centered</i>	<i>Direct</i>
Anchor is ground	The milk is at the spout of the kettle	The milk is in front ^b of me

^a From speaker's perspective.^b With reference to speaker's own front.**Table 2**

Frames of reference distinguished by rotation sensitivities.

A. Example locative description	B. Description still true under rotation of participant?	C. Description still true under rotation of ground?	D. Description still true under rotation of figure-ground array?	Frame of reference assignment
1. Milk east of kettle	Yes	Yes	No	Absolute (extrinsic; allocentric)
2. Milk to right ^a of kettle	No	Yes	No	Relative (extrinsic; egocentric)
3. Milk at spout of kettle	Yes	No	Yes	Object-Centered (intrinsic; allocentric)
4. Milk in front ^b of me	No	No	Yes	Direct (intrinsic; egocentric)

^a From speaker's perspective.^b Reference to speaker's own front (i.e., 'at my front').

utterances were produced by Mopan speakers who were playing Game 2 of the “Men and Tree” (MT) conversational elicitation game (Danziger, 1992) in which contrasts of spatial location on the lateral horizontal must be verbally distinguished by players, in order to correctly instruct a partner to select one of six similar pictures on the basis of the description alone.

- (1) *ka'* *a-käx-t-e'* *a* *nene'* *tz'ub'* *ada'*,
 CONJ 2A-SEEK-TRR-TR.IRR DET little child DX.DEM.1
a *t-u-pach* *ke'en-Ø* *a* *t'opo*.
 REL PREP-3A-back be.located-3B DET flower
 ‘You should find this little child, who has the flower **at his back**’.

See Fig. 1 for the photograph to which example (1) refers. Such usage can readily be classified according to the classification of Table 1 as intrinsic – the anchor from which the vector of figure to ground is calculated is actually found in the ground object. The example instantiates object-centered intrinsic usage, in which the anchor/ground is found outside the speech situation.

While specification of spatial relations using “body-parts” is in principle compatible with the relative (extrinsic) frame of reference in language (Levelt, 1984), such usage in Mopan (Danziger, 1996, 1999, 2001) and in certain other Mesoamerican languages (see papers by other authors in this issue) is predominantly intrinsic (direct or object-centered) rather than extrinsic (relative). In Mopan, in fact, locutions specifying spatial location in manipulable space have been found in controlled observations to be largely confined to the intrinsic type, especially when the locations to be specified are found across the speaker's own line of vision, and when the speaker is female (Danziger, 1996, 1999, 2001).⁵ Although both direct and object-centered frames of reference are found in Mopan speech under these conditions, relative and absolute language use is in general absent. To put this more generally, intrinsic FoRs are massively favored over extrinsic ones in these Mopan language contexts.

4. Intrinsic FoR usage and cognitive tasks

A standard task used by neo-Whorfians to investigate the possible correlation of non-linguistic spatial problem-solving strategies with habits of spatial FoR usage in language has exploited the rotation sensitivity articulated in column B of Table 2 (Pederson et al., 1998; Levinson, 2003). In this kind of task, a consultant is asked to contemplate an array of small objects which is oriented across his or her line of vision. The consultant is then asked to turn his or her back on the original array (180° rotation), and is requested to re-build “the same” array in the new visual space which appears as a result of the rotation (Danziger, 1993). Under the Whorf hypothesis, relative and absolute FoR encodings in habitual speech predict different re-creations of spatial arrays under these circumstances. A consultant who uses absolute FoR encoding to solve the cognitive problem of re-assembling the array under 180° rotation, should maintain north–south relationships of the array to the rest of the world, even at the price of sacrificing the right–left relations of the array to the consultant's original (pre-rotation) body position and line of vision. Conversely, a consultant who uses a relative cognitive encoding will re-assemble the array under

⁵ When locations are found at different distances in front of the speaker – along his or her sagittal axis, specifications in the relative frame may be found in Mopan (Danziger, 1996).

rotation so that right–left relations are preserved, even though that will mean sacrificing the original orientation of the array to north–south coordinates. In the simplest version of this kind of task, the original array consists of a set of three toy animals arranged nose to tail as if they were marching across the consultant's line of vision (the “Animals” task).

Pederson et al. (1998) reported that across a wide variety of languages, the solution chosen to solve the non-linguistic problem of re-assembling such an array under 180° rotation corresponded to a significant degree with the particular linguistic habits in use by the populations of speakers in question. Consultants from communities which had been documented to use relative but not absolute FoRs in language solved the Animals rotation task by preserving right–left and not north–south relations under rotation. Consultants from communities which had been documented to use absolute but not relative FoRs in language solved the Animals task by preserving north–south but not right–left relations under rotation. These and subsequent results (see Majid et al., 2004 for one overview) have been seminal in their suggestion that there may indeed be an effect of language upon reasoning and other forms of cognition.

It is clear that the Animals and similar tasks exploit the differential rotation sensitivities summarized in column B (“rotation of participant”) of Table 2. These sensitivities serve admirably to distinguish extrinsic allocentric from extrinsic egocentric reference frames, but do not distinguish extrinsic from intrinsic frames (cf. Levinson et al., 2002; Li and Gleitman, 2002).⁶ The Animals task is therefore uninformative when applied to consultants who come from communities like that of the Mopan, in which linguistic usage is exclusively or dominantly characterized by intrinsic rather than by any extrinsic frame of reference.⁷ In the intrinsic FoR, linguistic descriptions are impervious to rotation of the figure-ground array (column D in Table 2). This means that the Whorfian prediction for cognitive performance on the Animals task is for *any* form of re-assembly which respects the identity and order of the animals in the line-up, regardless of the orientation of the animals to any external landmark or feature, including the speaker (Danziger, 2001). As long as the pig is still “at the tail of” the horse, the array will be correctly re-assembled in intrinsic encoding, whether the horse and pig now face north or south, right or left. Put simply, this is because a spatial description phrased exclusively within one of the intrinsic frames of reference (object-centered or direct) is identical whether applied to a particular array or object, or to that array or object's mirror-image reflection (see Van Cleve and Frederick, 1991; Levinson and Brown, 1994; Danziger, 1999).⁸

But if the Animals and related tasks based on rotation of the speaker cannot be expected to yield useful Whorfian predictions for languages like Mopan and others in Mesoamerica, in which intrinsic frames of reference are dominant and extrinsic frames rarely used, where should we turn for empirical evidence on the question whether language usage affects thought in these languages? What is needed is a cognitive task that probes for special cognitive prominence of intrinsic over extrinsic frames of reference, but which will not get confounded on the egocentric/allocentric dimension (since intrinsic FoRs as well as extrinsic ones can be either egocentric or allocentric). It will be fruitful to turn once again to the properties articulated in Column D of Table 2 (intrinsic encodings are impervious to rotation of the figure-ground array; extrinsic encodings are sensitive to such rotation).

5. Mirror-Image task and results to date

An experimental task designed to yield specific predictions from intrinsic-dominant language users, which distinguish them from users of extrinsic FoRs, has been implemented in various languages, including Mopan, precisely for this purpose (Levinson and Brown, 1994; Danziger, 1999). In this “Palmer's” task (Palmer, 1977; Verhaeghe and Kolinsky, 1991; Danziger, 1993), participants contemplate printed shapes on plasticized cards, and make judgments as to whether they should be considered equivalent to or different from their right–left mirror-image counterparts. The task exploits the fact that it is only in extrinsic but not in intrinsic linguistic encoding that an original form is distinguished from its mirror-image. The Whorfian prediction for speakers of languages such as Mopan, in which intrinsic frames of reference are dominant in speech, is that mirror-image objects and arrays in allocentric space should be treated as similar or identical to one another (cf. Levinson and Brown, 1994). And indeed, despite prior training that the mirror-images should be classified separately from the originals, Mopan participants persist to a significant degree in classifying as equivalent forms which are left–right mirror-images of one another (Danziger, 1999, see also Levinson and Brown, 1994). This suggests an interaction between spatial conceptualization and habitual language use which is compatible with the Sapir–Whorf hypothesis—that the nature of habitual language use actually influences thought.

The persuasiveness of the mirror-image task as evidence in the Whorfian debate is, however, bedeviled by the fact that various cultural practices other than language use are suspected of making a difference to performance on the

⁶ Nor does it distinguish intrinsic frames from one another: If a participant is using a direct FoR, then the Animals task actually also involves rotation of the figure-ground array, since the participant is by definition in that case him or herself the ground, and some element of the Animals array is the figure. But rotation sensitivities of the direct frame under rotation of the figure-ground array (line 4, column D) are identical to those of the object-centred frame under rotation of the participant (line 3, column B). Responses of a direct frame user to the standard version of the Animals task are therefore expected to be indistinguishable from those of an object-centered FoR user.

⁷ The task is also uninformative when applied to communities in which both absolute and relative FoRs are used in language (cf. Pederson et al., 1998, Bohemeyer, *this issue*). Under the Whorf hypothesis, both the absolute and the relative cognitive solutions are predicted for such consultants, so the empirical occurrence of either solution yields no information of interest for the hypothesis.

⁸ This follows from the fact that in an intrinsic encoding, by definition the anchor of the spatial relation specified is internal to the figure-ground array. No spatial point external to the array is recruited to give information on the vector between figure and ground, and consequently, arrays in which all the internal parts are similarly arranged will be described similarly, regardless of the fact that they may have different orientations to spaces outside the array itself.



Fig. 1. Picture 4 of game 2, men and tree.

task.⁹ In particular, although in many cases an appreciable additional effect is observed (Levinson and Brown, 1994; Danziger, 1999), the task is known to be heavily influenced by literacy of participants (Verhaeghe and Kolinsky, 1991; Kolinsky et al., 1994; Danziger and Pederson, 1998; Pederson, 2003). Since the task involves contemplation of printed two-dimensional shapes on plasticized paper cards, it is perhaps not surprising that this is the case. Roman alphabet literacy certainly teaches that two-dimensional mirror-image forms should be treated as distinct from one another (consider the graphemes “b” and “d”). Concomitantly, it also teaches that printed forms should be treated as fully two-dimensional—that mentally ‘flipping’ such forms through the third dimension to make them look identical (consider “b” and “d” once more) is not an allowable maneuver.¹⁰ It is impossible to be sure that the different results documented from different populations around the world are not attributable simply to the fact that people of different cultural backgrounds (especially where levels of habitual literacy were greatly variable) had different degrees of difficulty in thoroughly learning this arbitrary rule.

To the extent that population differences in preferred solutions to the mirror-image task are the result of literacy rather than language use, such differences should be attenuated or even disappear if the task is modified so that all stimuli are fully three-dimensional objects. A three-dimensional object and its mirror-image cannot be flipped or rotated to render them identical in extrinsically encoded space. Mental rotation in fact, is, famously, the operation that many people employ in order to verify that two objects are mirror-images and not identical copies of one another (Shepard and Metzler, 1971). On the other hand, if population differences in mirror-image classification are traceable to intrinsic-dominant language usage, they should persist into the classification of three-dimensional objects.¹¹

Before proceeding, let us dispose of one intuitive objection to the possibility that three-dimensional objects might be classified by some populations as identical to their mirror-image counterparts: namely that such a classification would pose such insurmountable problems for actual navigation among real-world objects as to render it completely impractical as a cognitive reality for any human group. This objection in fact dissolves once we remind ourselves that intrinsic frames of reference exist in both egocentric (direct) and allocentric (object-centered) varieties (see Table 1). In the direct frame of reference (an intrinsic but egocentric frame), the participant (viewer, speaker, navigator) is himself or herself the ground of the array. And while intrinsic encodings are insensitive to rotation of the participant (column B of Table 2), they are sensitive to rotation of the ground entity (column C). In just that case in which the participant is also the ground entity (direct frame) therefore, rotation of the participant will result in a new description/cognitive encoding of the spatial situation. Navigators will never classify as similar any two mirror-image arrays in which they themselves participate. An informative demonstration is afforded by recent experimental work (Li et al., 2005) which shows that Tzeltal consultants handle right–left relations extremely well when they themselves are the ground of the relation (direct frame) but are indifferent to such relations when another object is ground (object-centered frame—Abarbanell and Li, 2009).¹²

⁹ Verhaeghe and Kolinsky (1991) report that among the non-literate Portuguese speakers whom they consulted, those few who distinguished the mirror-images were also those who engaged in the activities of lacemaking and sea navigation.

¹⁰ This rule of the Palmer’s mirror-image task was explicitly demonstrated with transparent overlays to all participants during training for the task.

¹¹ Using this logically pristine formulation to predict the cognitive performance of people who use both intrinsic and extrinsic FoRs turns out to be problematic. Levinson and Brown (1994) for instance, find that speakers of Tzeltal Maya, heavy users of both intrinsic (Levinson, 1994) and extrinsic (Brown and Levinson, 1993) frames of reference, do not find the differences between two-dimensional mirror-image forms to be cognitively significant. Levinson and Brown (1994) suggest that there are differences in Tzeltal language and thought between encoding the parts of a single object (intrinsic; mirror-images not distinguished), and encoding relations between two distinct entities related as spatial figure and ground (extrinsic; mirror-image arrays should be distinguished). There is an obvious empirical problem here in deciding for any given cognitive task which of these two approaches one expects to encounter, and therefore what the Whorfian cognitive prediction should be. For this reason, cases like that of the Mopan, in which extrinsic usage is absent altogether in various specifiable contexts, become all the more important (Danziger, 2001).

¹² Since use of the direct frame in language is probably culturally universal (Bühler, 1990 [1934]; Danziger, 2010; cf. Tanz, 1980), the cognitive observations in these Tzeltal report are compatible with Whorfian predictions for intrinsic-dominant speakers (contra Pinker, 2007). But see Li et al., 2011; Bohemeyer et al. ms. or additional results and more discussion.

In what follows, I report Mopan results from a version of the mirror-image task in which the forms to be compared are three-dimensional objects and not two-dimensional outlines. Mopan speakers again tend to categorize these objects together with their mirror-image counterparts – exactly as would be the case if making a linguistic description of them within an intrinsic frame of reference. Results on the same task are also reported from US English speakers, who overwhelmingly distinguish the three-dimensional objects of the task from their mirror-images, as is predicted by use of the relative FoR – an extrinsic frame – in US English. These results strengthen the hypothesis that the Mopan cognitive pattern is an outcome of habitual language use, and make clear that the tendency of these intrinsic-dominant speakers to classify mirror-image counterparts together is not a literacy-related artifact of the two-dimensional task.

6. Materials and methods

Materials were constructed of plastic blocks of Lego DUPLO®, a snap-together building toy for toddlers. DUPLO® blocks come in different colors and lengths. Lengths of DUPLO® pieces can be measured in terms of the number of protuberances each provides for snapping onto another piece (see Fig. 2). Protuberances are regularly spaced about one half-inch apart, so that a DUPLO® piece with a length of two protuberances is exactly 3 cm or about 1 inch long:

Implementation of the current task required two pieces of red DUPLO® of 6-protuberance length, three pieces of yellow DUPLO® of 4-protuberance length, and 12 pieces of blue DUPLO® of 2-protuberance length. All pieces had a width of two protuberances. In the task, these pieces are differently combined to make a uniquely matched pair of three-dimensionally extended objects for each of the 6–9 training and practice trials, and 14 actual trials. Appendix A gives detailed descriptions of the exact DUPLO® configurations used in each trial.

Participants in the task were a group of 22 female and one male Mopan Maya speaking volunteers, and a group of 12 female and 12 male US English speaking volunteers. Mopan volunteers were subsistence agriculturalists, most with education only at or below elementary school level. The majority reported themselves as literate (see analysis below). The US English speaking volunteers were almost all college students. Mopan volunteers were interviewed by the author – a second-language speaker of their language – at the author's house in their home village, using Mopan instructions which were developed in consultation with a Mopan-speaking assistant. US English speaking volunteers were interviewed by a US English speaking research assistant in a private room on the University of Virginia campus. All participants were paid for their time.

The fact that virtually all of the Mopan volunteers were female is a result of the fact that recruitment proceeded by word of mouth in the Mopan village, and that social networks and appropriate social visiting in this village are heavily segregated along gender lines. Since exclusive use of intrinsic frames of reference in speech to the virtual exclusion of all others, is found most strongly in the Mopan data among female speakers (Danziger, 1999),¹³ this distribution of participants is fortuitous. It allows for the strongest possible prediction for a language effect in Mopan cognitive treatment of the task materials. On the other hand, no difference has so far been reported in habitual linguistic frame of reference usage between male and female speakers of US English, and there is therefore no prediction that gender will make a difference in US English speakers' treatment of the mirror-image materials. In fact, gender was not found to influence the direction of US English speakers' responses.

In the task, each participant is given a pair of three-dimensional DUPLO® objects, and encouraged to handle them in order to ascertain whether they are « different » (*jun paay*) or « not different » (*ma' jun paay*) from one another.¹⁴ In six of the actual trials (identical trials), the two objects of the pair are identical to one another. In three of the trials (bad-match trials), the two objects are completely different from one another and cannot be understood as copies or as mirror-images of one another. In five of the trials (mirror trials), one object is the mirror-image of the other. The shape of mirror-image objects was inspired by the mental rotation studies of Shepard and Metzler (1971), cf. Fig. 3.

A prior training established that bad-match trials were to be classified as « different », identical trials were to be classified as « not different », and, crucially, that mirror trials were to be classified as « different ».

7. Implementation and instructions

As the experimental interaction begins, the experimenter explains to the participant that this is a game about things that are different and other things that are not different from one another. The experimenter explains that s/he will show pairs of objects to the consultant and that the consultant's job is to tell the experimenter whether they are different or not different from each other. In an initial training trial, two DUPLO® objects are presented to the consultant which are very different from one another, and which are not construable as mirror-image reflections (see Appendix A for details of the objects involved). The experimenter explains that the two objects are 'different', pointing out the places where the parts of the two objects are

¹³ In the controlled « men and tree » speech elicitation context, male Mopan speakers occasionally used nonce landmarks, or attempted to use a relative FoR using lexemes borrowed from English. In the 2D mirror-image task, there was a gender effect in the expected direction, but Mopan men as well as women accepted mirror-images as the equivalents of true copies even when they had been trained not to. It would be of interest in the future to recruit larger numbers of Mopan men for the 3D mirror task, in order to further investigate gender differences at the level of non-linguistic problem-solving.

¹⁴ A phrasing of 'different' rather than 'the same' was preferred because the Mopan expression meaning 'the same' (*ket*) can in some usages also be translated as 'even, aligned' and might therefore be accurately applied to the relation between a (smooth) DUPLO® object and its mirror-image reflection. No such difficulties attend the use of *jun paay* 'different, distinct' in Mopan.

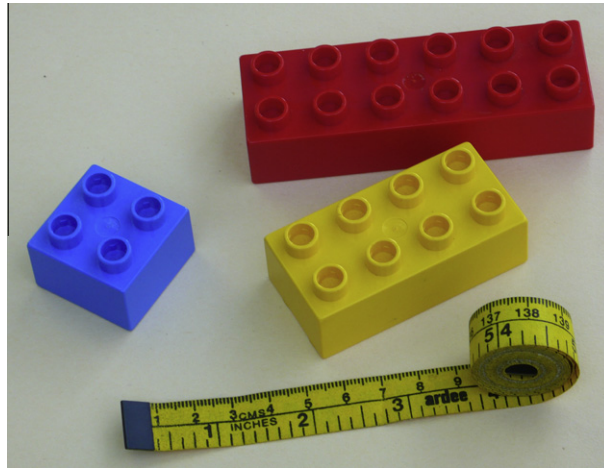


Fig. 2. DUPLO® pieces.

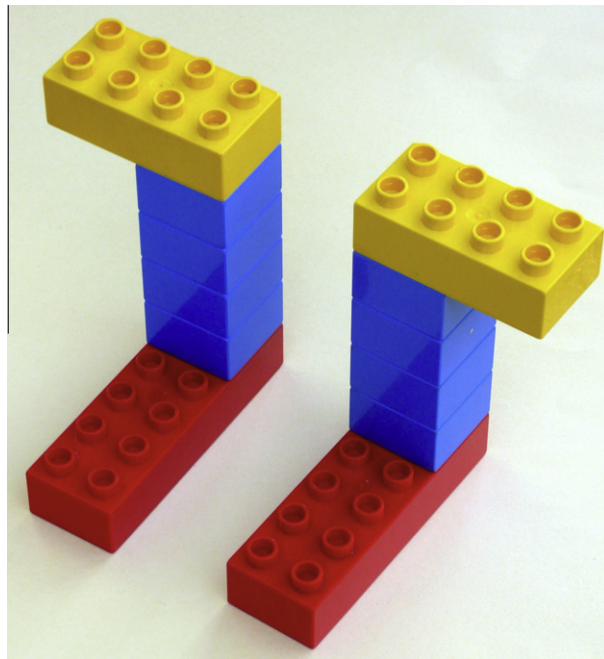


Fig. 3. Example of three-dimensional object with mirror-image.

differently oriented, and saying “This piece goes this way and that piece goes that way”. Example (2) shows the Mopan instructions for the training component of trial 1.

- (2) *jun.paay-oo'*
different-3.PL
waye' *tun* *b'el* *a* *jeda,*
DX.LOC.1 DUR.3A GO.IPFV REL DX.OST.1
etel *tido'* *tun* *b'el* *a* *kana'*
CONJ DX.LOC.3 DUR.3A GO.IPFV REL DX.DEM.2

‘They’re different. This [part] goes off in this direction, and that [part] goes off in that direction.

Once the consultant has agreed with this statement (all consultants readily agreed), the experimenter then re-builds the second object in such a way as to make it an identical copy of the original. The experimenter explains that these two objects are

“not different”, and points to the relevant parts of the two objects, saying “This piece goes this way, and that piece goes that way” (same utterance as in example 2 above). Example (3) presents the Mopan instructions for the training component of trial 2.

- (3) *ma'* *jun_paay-oo'*
 NEG different-3.PL
waye' *tun* *b'el* *a* *jeda,*
 DX.LOC.1 DUR.3A GO.IPFV REL DX.OST.1
etel *tido'* *tun* *b'el* *a* *kana'*
 CONJ DX.LOC.3 DUR.3A GO.IPFV REL DX.DEM.2
 ‘They’re not different. This [part] goes off in this direction, and that [part] goes off in that direction.’

Once consultants have agreed to this statement, the experimenter once again re-builds the second object, this time constructing a mirror-image copy of the first object. The experimenter explains that the two objects are now « different », and seeks agreement to this from the consultant. Consultants may not agree on the first presentation. If consultants protest that the objects are « the same » or « alike » (*ket*), the experimenter responds by pointing to the parts of the two objects and saying “they look alike/the same, but see, this piece goes this way and that piece goes that way. They’re different.” Example (4) provides the Mopan instructions for the training component of trial 3.

- (4) *ket-oo'* *u* *chaan-b-äl* *pero* *k'u-i,*
 same-3.PL 3A look-PASS-IPFV but what-scope
waye' *tun* *b'el* *a* *jeda,*
 DX.LOC.1 DUR.3A GO.IPFV REL DX.OST.1
etel *tido'* *tun* *b'el* *a* *kana'*
 CONJ DX.LOC.3 DUR.3A GO.IPFV REL DX.DEM.2
Jun_paay-oo'
 different-3.PL
 ‘They look alike, but you see, this [part] goes off in this direction and that [part] goes off in that direction. They’re different.’

At this point the experimenter begins to refer explicitly to the fact that the models can be handled and rotated, saying “Whichever way you turn them, the parts go different ways.” Example (5) provides these Mopan instructions.

- (5) *kaax b'ikij* *ka'* *a* *sut-u'*
 however COMP 2A turn-TR.IRR
jun_paay-oo' *a* *tan-oo'* *u* *b'el*
 different-3.PL REL DUR-3.PL 3A GO.IPFV
 ‘However you turn them, they go differently.’

The experimenter now explains that s/he will be giving the consultant two objects together, and that the consultant's job each time is to say whether the two are “different” or “not different” from each other. From this point on, the experimenter encourages the consultant at every trial to handle and rotate the objects before deciding. The experimenter says “You should give them a good turn-around, to see whether they are different or not”. Example (6) provides the Mopan instructions for this part of the 3D Mirror-Image Task.

- (6) *ka'* *a* *sut-u'* *ti* *ki'*
 COMP 2A turn-TR.IRR PREP good
ka' *a* *il-a'* *waj* *jun_paay-oo'* *waj* *ma'*
 COMP 2A see-TR.IRR Q different-3.PL Q NEG
 ‘You should turn them well, so that you see whether they are different or not.’

Training trials are now complete. The experimenter proceeds to the practice trial(s), presenting a new object with a bad-match partner, as described in Appendix A. The experimenter asks, “Are they different or are they not different?” (or “are they different or not?”). Example (7) illustrates the Mopan instructions for the practice trial.

- (7) *jun_paay-oo'* *waj*
 different-3.PL Q
waj *ma'* *jun_paay-oo'*
 Q NEG different-3.PL
 ‘Are they different or aren't they?’

If the answer is “different”, the experimenter provides feedback that this is correct. If the answer is “not different”, the experimenter returns to the pointing and phrasing from the training trials to continue to instruct the consultant that for this game bad match pairs are to be considered “different”.

The second object is now rebuilt, so that an identical match to the original object is provided. The same question (“are they different or not different?”) is asked, and once again, positive feedback is provided for the correct answer that the two objects are “not different”. Return to the demonstrative phraseology of the training trial is once again adopted to explain why the objects are not different from one another, should a consultant have answered that they were.

Finally, the second object is rebuilt so as to offer the mirror-image match to the original object, and the same question is asked. Once again, positive feedback is offered for the desired answer (“different”), and re-training using the phrasing of the training trials is offered if the answer is “not different”.

If the bad and identical match cases have not both been correctly dealt with on these practice trials, the experimenter proceeds to another series of three practice trials, once again providing positive feedback for desired answers and re-training with demonstrative phrasing if desired answers are not provided. If the bad match and identical match cases have been correctly dealt with after one series of three practice trials, the experimenter may proceed directly to the actual trials. If the bad match and identical match cases have not been correctly dealt with after two sets of practice trials (six practice trials in all), then the experimenter thanks the consultant and moves on to another consultant without proceeding to actual trials.

Actual trials were like the practice trials described above, except that the same original object was never presented twice in a row during actual trials (although sometimes the same original object was paired on different trials with both identical and with mirror image matches). The order of bad match, mirror match, and identical match trials was randomized. Order of presentation of the response options (different or not different?/not different or different?) was also varied across trials in both English and Mopan. At each trial, the objects were always actually handed to the consultant and s/he was invited to handle and turn them as part of making the decision. Objects were never simply placed in front of the consultant for visual inspection alone. Rebuilding of objects between all trials, including practice and training trials, was always done in sight of the consultant.

8. Results

Four Mopan consultants were removed from the analysis because during the actual trials they judged more than one of the three bad matches to be “not different” from the original, or they judged more than one of the six identical matches to be “different” from the original. No US English-speaking participant was eliminated for these reasons. This difference is attributed to the differences in schooling between the two populations. Elimination of the four Mopan participants left the total of Mopan consultants at 18 women and one man, of whom five women reported themselves as non-literate. [Appendix B](#) gives the number of mirror matches classified as « different » by each Mopan consultant and each US English-speaking consultant.

Crucial to the hypothesis of language effect on cognitive classification is the treatment of the mirror-image trials by the two populations. The Whorfian prediction from language usage is that the Mopan consultants, who are drawn from a speech community in which extrinsic FoR use in language is rare, would be inclined to classify the mirror matches as « not different » from the original objects, even when the task allows amply for rotation of the objects through the third dimension. The US English-speaking college students on the other hand, drawn from a population in which use of an extrinsic FoR (the relative frame) is common in speech, are expected to classify the mirror matches as « different » from one another.

Data conforming to this prediction had in the past been collected from a group of Mopan consultants similar to the present one ([Danziger, 1999](#)). A primary purpose of the current experiment was to ascertain whether the tendency to classify forms and their mirror-images together would persist if the relatively artificial conditions of the two-dimensional test were lifted and the test were conducted with three-dimensional objects. The principal comparison to be carried out therefore is between the present set of results and the earlier-reported ([Danziger, 1999](#)) results from the two-dimensional task.

In earlier versions of this task ([Verhaeghe and Kolinsky 1991](#); [Danziger, 1999](#)), literacy was reported to have an effect on task performance, such that non-literates also tended to classify forms together with their mirror-images. In the present population of task volunteers, the majority of the Mopan consultants (14 of 19) are literate.¹⁵ The distribution of literate to non-literate participants is therefore not such as to allow for a statistical comparison of the effects of literacy (although future studies might well discover such an effect: 4 of the 5 non-literates are high accepters of three-dimensional mirror-image objects as « not different » from one another). For Whorfian purposes however, we are most interested in the performance of literate individuals on these tasks, since any intrinsic-compatible result from non-literates might be explained as a result of their non-literacy rather than as a language effect.

The results from the 14 self-declared literates in the current Mopan sample are therefore compared with those of the 19 self-declared literates from the prior Mopan group who participated in the two-dimensional version of the task. The number of trials (out of five), on which each participant classified an object as « not different » from its mirror-image (the predicted preference of intrinsic-dominant language users) was collapsed into two categories to allow for statistical testing. A total score of 0, 1, or 2 mirror-image matches classified as ‘different’ out of 5 for any participant resulted in their being placed

¹⁵ In this community, literacy is in Central American English, the language of schooling. Children enter school as Mopan monolinguals, and Mopan remains the language of the home and of wider public life for adults.

Table 3

Comparison of 2D and 3D results from Mopan: mirror-images classified together on five trials.

	0, 1 or 2	3, 4 or 5	Total
Mopan 2D literates	10	9	19
Mopan 3D literates	9	5	14
Total	19	14	33

Table 4

Comparison of 3D results from Mopan and US English speakers: mirror-images classified together on five trials.

	0, 1 or 2	3, 4 or 5	Total
Mopan 3D literates	9	5	14
US 3D literates	24	0	24
Total	33	5	38

in Group 1 (those who tend to discriminate mirror-images from one another). A total score of 3, 4, or 5 Mirror matches classified as 'not different' out of 5 for any participant resulted in their being placed in Group 2 (those who tend not to discriminate mirror-images from one another). This grouping strategy was applied to data from all the literate participants in both the earlier 2D and the current 3D experiment, to yield a 2×2 matrix (Table 3)

A Fisher's exact test applied to this matrix yields a two-tailed p -value of 0.7228. The difference in Mopan responses on the three-dimensional mirror-image task is therefore not significantly different from their responses on the two-dimensional task.

When compared to the performance of the US English speakers on the 3D mirror-image task however (Table 4), the performance of Mopan speakers is statistically very significant. A Fisher's exact test applied to this matrix yields a highly significant two-tailed p -value of 0.0040.

9. Discussion

Mopan observations from this task yield the perhaps surprising conclusion that the intuition to consider mirror-image forms as alike occurs well beyond the kinds of domains in which it could be considered purely an artifact of literacy or of 2D task conditions. Intrinsic-style cognitive encoding of spatial coordinates can apply not only to two-dimensional outlines but to three-dimensional objects – even when consultants are encouraged to handle and rotate the objects. The results strongly suggest that earlier observations showing a Mopan tendency toward classifying a form and its mirror-image reflection together cannot be dismissed as artifacts of the two-dimensional fiction (no rotation of forms through the third dimension) that was present in that task. Even in three-dimensional space, Mopan speakers apparently cognize the real world in the same way that they describe it: using frames of reference in which the spatial anchor is always internal to the figure-ground array. The present result is compatible with the possibility that reliance on intrinsic strategies in the linguistic representation of space has an influence on spatial cognition.

Direct attribution of the difference between the performance of the Mopan group and that of the US English speakers on the 3D mirror-image task to differences in habitual use of linguistic FoRs is perhaps premature in light of the many other cultural differences between the two groups. The US English speakers' result does serve, however, to provide a minimum cross-cultural demonstration that—even when it comes to three-dimensional objects—mirror-image classification tendencies are under cultural influence, and are not alike in every human population.

Many questions remain. The most important, from the point of view of the Whorf hypothesis, is to discover whether language use could indeed be a contributing factor to the observed Mopan cognitive pattern. Although we now know that preferences in mirror-image classification are under cultural influence, and are not a simple and universal output of the visual system, nor an artifact of the task requirements in the 2D version, we do not know for certain whether language use in particular is a cultural factor that could be responsible for differences across populations in such preferences. One way to approach this would be to conduct further investigations into mirror-image classification, identifying populations in which sociocultural factors such as education and mode of subsistence were held constant, while linguistic FoR usage was allowed to vary. Alternatively, FoR usage might be held constant across populations, while educational level and other sociocultural characteristics were varied. Other avenues of approach involve finer-grained examination of language patterns within intrinsic-dominant populations, and development of cognitive methods to test Whorfian predictions within populations based on these analyses. Levinson and Brown (1994) for instance, suggest that there are differences in Tzeltal language and thought between encoding the parts of a single object (intrinsic; mirror-images not distinguished), and encoding relations between two distinct entities related as spatial figure and ground (extrinsic). A close analysis of Tzeltal speech (or that of other languages where both intrinsic and extrinsic frames are in play), could yield predictions about the sorts of task conditions in which consultants from that language community might and might not be expected to distinguish mirror-image objects from one another.

10. Conclusion

The first observed cases of cultural variation in spatial FoR language (Laughren, 1978; Haviland, 1998) documented the use of an allocentric extrinsic FoR (absolute) in contexts where Euro-American speakers were more accustomed to using an egocentric extrinsic one (relative). Early cognitive tasks, accordingly, were designed to pit egocentric against allocentric problem-solving strategies, but tacitly assumed that the fact of extrinsic encoding could be held constant (Danziger, 2001). The major linguistic contrast between many Mesoamerican languages and those of Europe however, is very often not a matter of one extrinsic FoR contrasted with another. Instead, it is characteristic of Mesoamerica as a linguistic region that speakers often favor intrinsic over extrinsic FoR in spatial description. Needed for language and thought research in this region then, are cognitive tasks that pit against one another, not egocentric and allocentric frames of reference (intrinsic FoRs always come in both egocentric and allocentric varieties), but intrinsic versus extrinsic ones. The distinction of an original form from its mirror-image reflection is such a task, since only in extrinsic but not in intrinsic space are mirror-images differentiated from one another. Further development of such tasks, and investigation of what they reveal in Mesoamerica, is clearly a high priority for neo-Whorfian research in the region.

11. Role of the funding source

This research was funded by an award from the University of Virginia. The author/researcher is an employee of the University of Virginia. Those who made the decision to award the funding played no role in the study design, in the collection, analysis, and interpretation of the data, in the writing of the report, or in the decision to submit the paper for publication. The opportunity to discuss ideas relevant to this research was provided in part by the National Science Foundation (Award No. BCS-0723694) *Spatial language and cognition in Mesoamerica* (PI J. Bohnemeyer).

Acknowledgments

Thanks are due to Michael Frazier, Suzanne Gaskins, Dedre Gentner, the members of the Cognitive Anthropology Research Group of the Max Planck Institute for Psycholinguistics 1991–1997, and the members of the Spatial language and cognition in Mesoamerica project. Fig. 1 is copyright of the Max Planck Institute for Psycholinguistics, and is reprinted with permission. Photographs in Figs. 2 and 3 are copyright of Dale Blue, and are reprinted with permission. Fischer's exact test calculations are from <http://www.graphpad.com/quickcalcs/contingency1.cfm>. The Department of Archaeology, Belmopan, Belize facilitated the research. Without the welcome and the assistance of the people of San Antonio village, Toledo District, Belize, this research would not have been possible. Special thanks in this case to the Mopan and US consultants who agreed to work with me using 3D mirror image materials.

Appendix A. Description of stimuli for three training trials, 3–6 practice trials, and 14 actual trials

Three 6-long red, three 4-long yellow, and 12 2-long blue DUPLO[®] pieces. For clarity, the descriptions below use cardinal direction terms to specify orientation of component parts to one another. These cardinal directions are of course subject to change when the completed piece is rotated.

A.1. Training and practice trials (6–9)

TRAINING TRIAL 1

- i. Long red piece running north–south. One blue square on extreme south end, and two blue squares piled on extreme north end. Medium yellow piece laid ACROSS the pile of two blues so that the yellow piece is flush with the blue piece that supports it on the east side. Yellow piece points out to the west.
- ii. Same as above except that the yellow piece runs north–south, above the red piece, instead of east–west.

TRAINING TRIAL 2

- i. Same as (i) in training trial 1.
- ii. Identical copy of (i) in training trial 1.

TRAINING TRIAL 3

- i. Same as (i) in training trial 1.
- ii. Manipulate yellow piece to make mirror-image copy of (i) in training trial 1.

PRACTICE TRIAL 1

- i. One long red piece running north–south. At south end and in middle, two square blue pieces. At southeastern corner, a yellow 2×4 , so that the yellow sticks out into the space to the east of and above the red piece.
- ii. One red piece running north–south and single blue squares at north end and at south ends. There is a yellow square on top of the northern blue square. There is a yellow 2×4 in the midsection of red piece, so that the yellow sticks out 1×2 both east and west.

PRACTICE TRIAL 2

- i. Same as (i) in practice trial 1.
- ii. Identical copy of (i) in practice trial 1.

PRACTICE TRIAL 3

- i. Same as (i) in practice trial 1.
- ii. Manipulate yellow piece to make mirror-image copy of (i) in practice trial 1.

PRACTICE TRIAL 4 (optional)

- i. One long red piece running north–south. At north end, a square blue piece. Yellow 2×4 at south end of red, sticking out to west.
- ii. One long red piece running north–south. In middle, a square blue piece. Yellow 2×4 at north end of red, sticking out equally east and west.

PRACTICE TRIAL 5 (optional)

- i. Same as (i) in practice trial 4.
- ii. Identical copy of (i) in practice trial 4.

PRACTICE TRIAL 6 (optional)

- i. Same as (i) in practice trial 4.
- ii. Manipulate yellow piece to make mirror-image copy of (i) in practice trial 4.

A.2. *Control (bad match) trials (3)*

TRIAL ONE

- i. Red piece with long axis north–south. Yellow piece attached symmetrically across the center of the red piece, and one blue piece in the center where the red and yellow pieces cross.
- ii. Red piece with long axis north–south. Yellow piece along red piece also north–south, fitting the south, east, and west faces of the red piece. One blue piece in center of the yellow piece.

TRIAL TWO

- i. Red piece with long axis north–south. Three stacked blue pieces at extreme north end, fitting east, north and west faces of the red piece.
- ii. Red piece with long axis north–south. Three stacked blues in middle of red piece, fitting its east and west faces.

TRIAL THREE

- i. Yellow piece with long axis north–south. Underneath it two blue pieces, so that they fully cover its base, and together fit all north south east and west faces of the yellow piece. On top of the yellow piece, in the center, one blue piece.
- ii. Yellow piece with long axis north–south. Underneath it two blue pieces, but attached so that they fit only the east and west faces. At the north and south, the blue protrudes from under the yellow. There is a third blue piece on top of the yellow one, in the center.

A.3. *Mirror image trials (5)*

TRIAL FOUR

- i. Four stacked blue pieces. Red piece is flush with the south face of the bottom blue piece, and projects out to the north. Yellow piece is flush with the east face of the top blue piece, and projects out to the west (Classic Shepard object).
- ii. Mirror image of above.

TRIAL FIVE

- i. Red piece with long axis north–south. Yellow piece at south end, fitting west and south faces and pointing east. Stack of four blue pieces under the red piece at the north end, fitting west, north and east faces of the red piece.
- ii. Mirror image of above.

TRIAL SIX

- i. Red piece with long axis north–south. Yellow at extreme south end, pointing east. Two blues on top of the yellow where it joins the red. Two more blues on top of the red at the extreme north end, fitting west, north and east faces of the red.
- ii. Mirror image of above.

TRIAL SEVEN

- i. Yellow piece with long axis north–south. One blue piece at extreme north end, fitting east, west and north faces of yellow. Another blue piece under the south edge of the yellow, protruding to the east, so fitting only the south face of the yellow.
- ii. Mirror image of above.

TRIAL EIGHT

- i. Red piece with long axis north–south. Yellow piece in middle of red piece, fitting west face and pointing east. One blue piece at extreme north end of red, fitting west, north and east faces of red.
- ii. Mirror image of above.

A.4. *Identical match Trials (6). Note that three of these (9, 10 and 11) use the originals also presented with mirror matches, and three (12, 13, 14) use originals also presented with bad matches*

TRIAL NINE (same original as trial four)

- i. Classic Shepard object. Red and yellow pieces leave a “trunk” formed of four stacked blue pieces at right angles to one another.
- ii. Identical to above.

TRIAL TEN (same original as trial five)

- i. Red piece with long axis north–south. Yellow piece at south end, fitting west and south faces and pointing east. Stack of four blue pieces under the red piece at the north end, fitting west, north and east faces of the red piece.
- ii. Identical to above.

TRIAL ELEVEN (Same original as trial seven)

- i. Yellow piece with long axis north–south. One blue piece at extreme north end, fitting east, west and north faces of yellow. Another blue piece under the south edge of the yellow, protruding to the east, so fitting only the south face of the yellow.
- ii. Identical to above.

TRIAL TWELVE (Same original as trial one, with identical copy)

TRIAL THIRTEEN (Same original as trial two, with identical copy)

TRIAL FOURTEEN (same original as trial three, with identical copy)

Appendix B. Results

Mopan Participant	M/F	Lit/Non	# Mirror-image-parts accepted (of 5)
M1.	F	Y	4
M2.	F	Y	4
M3.	F	Y	4
M4.	M	Y	3
M5.	F	Y	3
M6.	F	Y	2
M7.	F	Y	2
M8.	F	Y	1
M9.	F	Y	1
M10.	F	Y	1
M11.	F	Y	1
M12.	F	Y	1
M13.	F	Y	0
M14.	F	Y	0
M15.	F	N	5
M16.	F	N	5
M17.	F	N	5
M18.	F	N	4
M19.	F	N	0

US English Participant	M/F	Lit/Non	# Mirror-Image-Parts Accepted (of 5)
US1.	F	Y	1
US2.	F	Y	0
US3.	F	Y	0
US4.	F	Y	0
US5.	F	Y	0
US6.	F	Y	0
US7.	F	Y	0
US8.	F	Y	0
US9.	F	Y	0
US10.	F	Y	0
US11.	F	Y	0
US12.	F	Y	0
US13.	M	Y	1
US14.	M	Y	1
US15.	M	Y	0
US16.	M	Y	0
US17.	M	Y	0
US18.	M	Y	0
US19.	M	Y	0
US20.	M	Y	0
US21.	M	Y	0
US22.	M	Y	0
US23.	M	Y	0
US24.	M	Y	0

References

- Bohnenmeyer, J., Levinson, S.C., 2011. Framing Whorf: a response to Li et al. 2011. Manuscript, University at Buffalo.
- Benveniste, E., 1966 [1958]. De la subjectivité dans le langage. In: Benveniste, E. (Ed.), *Problèmes de Linguistique Générale*. Gallimard, Paris, pp. 258–266.
- Brown, P., Levinson, S.C., 1993. 'Uphill' and 'downhill' in Tzeltal. *Journal of Linguistic Anthropology* 3 (1), 46–74.
- Bühler, K., 1990 [1934]. *Theory of language: The representational function of language*. Foundations of Semiotics, vol. 25, John Benjamins, Amsterdam, Philadelphia (Translated by D.F. Goodwin).
- Campbell, L., Kaufman, T., Smith-Stark, T.C., 1986. Meso-America as a linguistic area. *Language* 62 (3), 530–570.
- Danziger, E. (Ed.), 1992. *Manual: Space Stimuli Kit 1.0*. Cognitive Anthropology Research Group, MPI Psycholinguistics, Nijmegen.
- Danziger, E. (Ed.), 1993. *Manual: Cognition and Space Kit 1.0*. Cognitive Anthropology Research Group, MPI Psycholinguistics, Nijmegen.
- Danziger, E., 1996. Parts and their counter-parts: social and spatial relationships in Mopan Maya. *Journal of the Royal Anthropological Institute* (NS), incorporating MAN 2 (1), 67–82.
- Danziger, E., 1999. Language, space and sociolect: cognitive correlates of gendered speech in Mopan Maya. In: Fuchs, C., Robert, S. (Eds.), *Language Diversity and Cognitive Representations*. Benjamins, Amsterdam, pp. p 85–106.
- Danziger, E., 2001. Cross-cultural studies in language and thought: is there a metalanguage? In: Moore, C.C., Mathews, H.F. (Eds.), *The Psychology of Cultural Experience*. Cambridge University Press, Cambridge, UK, pp. 199–222.
- Danziger, E., 2010. Deixis, gesture and cognition in spatial frame of reference typology. *Studies in Language* 34 (1), 167–185.
- Danziger, E., Pederson, E., 1998. Through the looking-glass: literacy, writing systems and mirror-image discrimination. *Written Language and Literacy* 1 (2), 153–164.
- England, N.C., Elliott, S.R., 1990. *Lecturas Sobre la Lingüística Maya*. Centro de Investigaciones Regionales de Mesoamérica, Guatemala.
- Haviland, J.B., 1998. Guugu Yimithirr cardinal directions. *Ethos* 26 (1), 25–47.
- Kolinsky, R., Morais, J., Verhaeghe, A., 1994. Visual separability: a study on unschooled adults. *Perception* 23, 471–486.
- Laughren, M., 1978. Directional terminology in Warlpiri. In: Le, T., McCausland, M. (Eds.), *Working Papers in Language and Linguistics*, vol. 8. Tasmanian College of Advanced Education, Launceston, pp. 1–16.
- Levelt, W.J.M., 1984. Some perceptual limitations on talking about space. In: van Doorn, A., de Grind, W., Koenderink, J. (Eds.), *Limits in Perception*. VNU Science Press, Utrecht, pp. 323–358.
- Levinson, S.C., 1994. Vision, shape and linguistic description: Tzeltal body-part terminology and object description. *Linguistics* 32 (4), 791–855.
- Levinson, S.C., 1996. Frames of reference and Molyneux's question: cross-linguistic evidence. In: Bloom, P., Peterson, M., Nadel, L., Garrett, M. (Eds.), *Language and Space*. MIT Press, Cambridge, MA, pp. 109–169.
- Levinson, S.C., 2003. *Space in Language and Cognition*. Cambridge University Press, Cambridge.
- Levinson, S.C., Brown, P., 1994. Immanuel Kant among the Tenejapans: anthropology as empirical philosophy. *Ethos* 22 (1), 3–41.
- Levinson, S.C., Kita, S., Haun, D.B.M., Rasch, B.H., 2002. Returning the tables: language affects spatial reasoning. *Cognition* 84, 155–188.
- Li, P., Abarbanell, L., Gleitman, L., Papafragou, A., 2011. Spatial reasoning skills in Tenejapan Mayans. *Cognition* 120, 33–53.
- Li, P., Abarbanell, L., Papafragou, A., 2005. Spatial reasoning skills in Tenejapan Mayans. In: *Proceedings from the 27th Annual Meeting of the Cognitive Science Society*. Erlbaum, Hillsdale, NJ, pp. 1272–1277.
- Li, P., Gleitman, L., 2002. Turning the tables: language and spatial reasoning. *Cognition* 83, 265–294.
- Majid, A., Bowerman, M., Kita, S., Haun, D.B.M., Levinson, S.C., 2004. Can language restructure cognition? the case for space. *Trends in Cognitive Sciences* 8, 108–114.
- Palmer, S.E., 1977. Hierarchical structure in perceptual representation. *Cognitive Psychology* 9, 441–474.
- Pederson, E., 2003. Mirror-image discrimination among nonliterate, monoliterate, and biliterate Tamil speakers. *Written Language and Literacy* 6 (1), 71–91.
- Pederson, E., Danziger, E., Levinson, S.C., Kita, S., Senft, G., Wilkins, D.P., 1998. Semantic typology and spatial conceptualization. *Language* 74 (3), 557–589.
- Pinker, S., 2007. *The Stuff of Thought: Language as a Window into Human Nature*. Viking Press, New York.
- Shepard, R.N., Metzler, J., 1971. Mental rotation of three-dimensional objects. *Science, New Series* 171 (3972), 701–703.
- Talmy, L., 1983. How language structures space. In: Pick, H., Acredolo, L. (Eds.), *Spatial Orientation: Theory, Research and Application*. Plenum Press, New York.
- Tanz, C., 1980. *Studies in the Acquisition of Deictic Terms*. Cambridge University Press, Cambridge.
- Van Cleve, J., Frederick, R. (Eds.), 1991. *The Philosophy of Left and Right*. Kluwer Academic Publishers, Dordrecht, Boston, London.
- Verhaeghe, A., Kolinsky, R., 1991. Discriminação entre figuras orientadas em espelho em função do modo de apresentação em adultos escolarizados e adultos iletrados. *Actas das I Jornadas de Estudo dos Processos Cognitivos*, Sociedade Portuguesa de Psicologia, Lisbon.
- Whorf, B. L., 1956 [1940]. Science and linguistics. In: Carroll, J.B., (Ed.), *Language, Thought, and Reality: Selected Writings of Benjamin Lee Whorf*, MIT Press, Cambridge MA, pp. 207–219.