Research Article

Talking About Walking

Biomechanics and the Language of Locomotion

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ABSTRACT—***What drives humans around the world to converge in certain ways in their naming while diverging dramatically in others? We studied how naming patterns are constrained by investigating whether labeling of human locomotion reflects the biomechanical discontinuity between walking and running gaits. Similarity judgments of a student locomoting on a treadmill at different slopes and speeds revealed perception of this discontinuity. Naming judgments of the same clips by speakers of English, Japanese, Spanish, and Dutch showed lexical distinctions between walking and running consistent with the perceived discontinuity. Typicality judgments showed that major gait terms of the four languages share goodness-of-example gradients. These data demonstrate that naming reflects the biomechanical discontinuity between walking and running and that shared elements of naming can arise from correlations among stimulus properties that are dynamic and fleeting. The results support the proposal that converging naming patterns reflect structure in the world, not only acts of construction by observers.***

Cross-linguistic differences in how languages carve up the world by name are striking. For instance, languages differ markedly in what distinctions of contact, support, and containment their spatial terms discriminate (Bowerman, 1996) and what dimensions of inner experience their emotion terms capture (Wierzbicka, 1992). Nevertheless, patterns of naming are not completely unconstrained. Shared elements of naming patterns have been found in domains including color (Kay, Berlin, Maffi, & Merrifield, 1997), body parts (Majid, Enfield, & van Staden, 2006), and cutting and breaking actions (Majid, Bowerman, van Staden, & Boster, 2007), and these commonalities occur to a greater extent than would be expected by chance (Kay & Regier, 2003).

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The search for shared tendencies across languages holds the promise not only of illuminating how word meanings are constructed, but also of revealing something fundamental about the nature of human experience across cultures and languages.

What drives humans around the world to converge in certain ways in their naming while diverging dramatically in others? Documentation of synchronic variation or shared tendencies does not by itself reveal origins of these patterns; one can only speculate on the basis of the patterns observed. The goal of the current work was to advance understanding of the origins of cross-linguistic similarities in naming patterns.

At the broadest level, two main sources of constraint surely influence the construction of naming patterns: the input the world presents to the human observer and the human observer who interprets that input. Any shared naming tendency will inevitably be a reflection of both. The world provides input of some sort, and the perceptual and cognitive systems that process the sensory input from the world filter and interpret that input.

The few studies aimed at investigating the origins of shared naming tendencies have typically focused on the contributions of the observer. For instance, there has been interest in whether the visual system yields a segmentation of the continuous light-wave input that is reflected in cross-linguistic commonalities in color-naming patterns (Kay & McDaniel, 1978) or whether general principles of categorization create such segmentation (Regier, Kay, & Khetarpal, 2007). There has also been interest in how attention operating across space may constrain the application of spatial terms (Regier & Carlson, 2001).

Yet the world does more than present unstructured, undifferentiated input to be segmented and interpreted by the perceptual and cognitive machinery. Drawing on principles of scientific taxonomy, Hunn (1977) and Berlin (1992) argued that there are regularities in the distribution of properties across plants and animals such that certain properties tend to co-occur with one another and not with others, creating discontinuities in nature that are so salient to the human observer that they "cry out to be named" (Berlin, 1982, p. 11). Hunn and Berlin proposed that these salient discontinuities produce cross-cultural commonalities in the labeled distinctions among plants and animals (see also Atran, 1990; Malt, 1995). Work investigating labeling of human body parts also implicates the influence of structured input. Human limbs are segmented by the joints, and lexicons tend to reflect that physical segmentation. Languages often lexically distinguish the hand from the arm, the legs from the torso, and so on (Brown, 2005a, 2000b; Majid et al., 2006).

Of course, structure in the world can constrain naming patterns only to the extent that observers perceive that structure and are driven to reflect it in their communications. To understand how naming patterns are constrained, it is necessary to know what types of structure the human observer is sensitive to and driven to encode in words. In this article, we contribute to this understanding by reporting the results of studies investigating labeling of two forms of human locomotion: walking and running.

The domain of locomotion is of particular interest for several reasons. First, a key challenge for understanding how structure in the world constrains naming is the difficulty of specifying the structure that may exist. Intuition is insufficient. For instance, it may seem evident to English speakers that clusters of correlated properties distinguish things called *bottle* from things called *jar*, but the fact that labels in other languages divide the same objects differently (Malt, Sloman, Gennari, Shi, & Wang, 1999) leaves the actual property distribution in question. In contrast, the literature on the biomechanics of gait, described in the introduction to Study 1, provides an independent account of the structure available to perceivers. This literature shows the structure to be one of clusters of exemplars with sharp discontinuities between them and provides the basis for a prediction about where structure may constrain naming.

Second, in the domains most commonly studied by psychologists—artifacts and natural kinds—the particular exemplars experienced vary regionally. This fact makes it difficult to separate exposure effects from other potential sources of divergence. In contrast, human bodies are universally capable of the same set of gaits, and speakers of different languages see or engage in the most common ones—walking and running—universally. Thus, the domain of gait provides shared inputs for languages to discriminate among.

Third, locomotion allowed us to investigate the possibility of sensitivity to a more complex form of structure than previous studies had examined. The work on body-part terms suggests that humans are sensitive to the physical segmentation of the body created by the joints. The work on plants and animals suggests that humans encode naturally occurring clusters of co-occurring properties such as size, shape, and mode of reproduction by abstracting across individual instances. In the current research, we asked whether languages reflect correlations among properties that are dynamic and fleeting, rather than static and enduring. Dimensions of locomotion such as speed, direction, properties of the surface being traversed, and effort and inferred goals of the agent are more constant and enduring than the properties of movement across a stride that define the biomechanical gait categories, and they provide alternative bases for lexicalized distinctions (e.g., in English, *hiking* and *strolling* imply certain goals or attitudes, level of exertion, and perhaps type of surface).

Finally, languages differ in the type of information they tend to encode in the main verb of a sentence. Some languages (e.g., Germanic ones) most often encode manner of motion, as in the English verbs *walk*, *run*, *slide*, *slink*, and so on. Other languages (e.g., Romance languages, Greek) more often encode path or direction of movement, as in Spanish *subir* and *salir* ("ascend" and "exit," respectively), although these languages do use manner verbs in some constructions. Slobin (2004) has suggested that manner is more salient in languages that routinely encode it in the main verb than in those that do not, and also that "high-manner-salient" languages tend to develop more elaborate manner vocabulary than "low-manner-salient" languages. We investigated whether the biomechanical discontinuity of manner between walking and running is so obvious to observers that not only high-manner-salience languages, but also low-manner-salience languages, develop verbs marking the distinction.

STUDY 1: NAMING

Human gaits, including walking and running, are characterized biomechanically by clusters of co-occurring properties. Gaits can be distinguished by their characteristic energy requirements, relative phase of the feet, speed, and other variables, such as the fraction of the stride for which a given foot is on the ground, stride frequency, and stride length (Alexander, 1982, 1992; Bennett, 1992). Human gaits are highly constrained by the dynamics of motion (e.g., Alexander, 1982, 1992; Collins & Stewart, 1993), and these constraints result in abrupt transitions between gaits as speed increases, rather than gradual shifts through intermediate versions (e.g., Schoner, Jiang, & Kelso, 1990). On a treadmill, humans switch from a walking to a running gait without any transitional stages (Diedrich & Warren, 1995, 1998).

If this biomechanical discontinuity is universally perceived and constrains naming, it should be reflected in the naming patterns of languages. Languages should tend to have terms that are applied to instances of locomotion in a categorical rather than graded fashion, and the particular instances segregated by these terms should tend to correspond across languages. However, if a shared perception of the gaits does not contribute to naming patterns, the patterns should fail to consistently reflect the biomechanical distinction, and languages may make cuts at different places, using different dimensions or combinations of them. In Study 1, we examined naming patterns in four languages to determine whether they reflect the segmentation of the domain given by the biomechanical analysis.

We studied speakers of English, Dutch, Spanish, and Japanese. The first three languages are in the Indo-European family, Dutch and English in the Germanic branch and Spanish in the Romance branch. Japanese is most often classified as Altaic (Crystal, 1987). Although the first three languages belong to the same family, the standard language taxonomy is based on structural considerations, not similarities of word meaning. The histories of these languages are different enough that the languages exhibit substantial variation in their patterns of naming for common household objects (Ameel, Storms, Malt, & Sloman, 2005; Malt et al., 1999), spatial relations (Bowerman, 1996), and events of consumption, carrying, and dressing (Bowerman, 2005). These differences occur even for cognate words, such as English *bottle* versus Spanish *botella* or English *on* versus Dutch *aan* versus Spanish *en* (see Majid, Gullberg, van Staden, & Bowerman, 2007). Also contributing to the potential for divergences in the gait domain are the differing verb typologies of these languages, which cut across the family classification. In English and Dutch, verbs tend to express manner of motion; in Spanish, verbs tend to express direction of motion; and in Japanese, verbs tend to express directional path or path plus ground (Muehleisen & Imai, 1997). Thus, according to Slobin (2004), English and Dutch are high-manner-salient languages, and Spanish and Japanese are not.

Method

The stimuli in this study were twenty-four 3- to 4-s video clips of a female college student locomoting on a treadmill that varied in speed and slope. Speed variations were expected to induce gait shifts; slope variations increased the diversity of other properties of the stimuli. The student maintained whatever gait was natural at each speed-slope combination. The three levels of slopes were flat, approximately 4° of tilt, and approximately 8° of tilt. The speeds began at 1.5 mph and were increased in 1-mph increments at each slope until the student could no longer keep up, a procedure that yielded nine speeds at the flat slope, eight at the 4° slope, and seven at the 8° slope. We refer to the speeds by number, with clips at 1.5 mph designated speed 1, clips at 2.5 mph designated speed 2, and so on. Still frames extracted from several clips are shown in Figure 1.

Pretest

To verify the psychological reality of the structural discontinuity between running and walking, we asked 24 American undergraduates to sort the video clips according to the physical similarity of the motions. If viewers perceive a discontinuity between walking and running, a cluster solution of such simi-

Fig. 1. Frames extracted from the video clips used as stimuli. In the clips, both the slope and the speed of the treadmill varied. The slope was flat (top row), approximately 4° (bottom left), or approximately 8° (bottom right). Speeds ranged from 1.5 mph (designated speed 1) to 9.5 mph (designated speed 9). Illustrated here are speed 2 (top left), speed 4 (bottom left), speed 5 (bottom right), and speed 7 (top right).

larity judgments should show two clusters corresponding to instances of walking and running as defined biomechanically. The clips were presented in a 4×6 array on a computer screen, with each clip running in a continuous loop. Participants were asked to drag and drop clips (still running) into boxes on the right side of the screen, creating as many boxes as they wished. When all the clips were sorted into boxes, participants performed a second sort. If they had created five or fewer boxes in the first sort, they were asked to divide the boxes further; if they had created more than five boxes, they were asked to combine boxes.

For each participant, this sorting procedure yields a two-level similarity tree in which a clip is zero, one, or two nodes from each other clip (Boster, 1987, 1994). We constructed a group similarity matrix by summing the distance values for each pair of clips across participants. The matrix was then entered into the SAS hierarchical cluster program (SAS Institute, 1999). The resulting solution revealed two major clusters, corresponding to the biomechanical distinction between walking and running. We randomly generated 10,000 sets of two clusters of the same sizes and found that the probability of obtaining a larger mean difference between within-cluster and between-cluster similarity was less than .005. Thus, the observers perceived the biomechanical discontinuity between the gaits.

Naming Study

The video clips were embedded in a Web page with instructions in the relevant language. Participants viewed each clip and typed into a response box whatever word or phrase they felt was the best or most natural way to describe the action. The response box was preceded by the following text: "What is the woman doing? She is . . ." or its appropriate translation, according to the language of the participant.

Native speakers of American English (n = 25), Argentinean Spanish (n = 24), Japanese (n = 23), and Belgian Dutch (n = 23) viewed and named the video clips. All participants were university students or research employees resident in their native country. The Americans, Japanese, and Argentineans generally had only limited knowledge of another language and used their native language exclusively in daily life. Six of the Argentineans reported good to very good knowledge of another language; however, their data did not differ from the data of Argentineans who reported little or no knowledge of another language. The Belgians generally had good to very good knowledge of English and some knowledge of additional languages (typically French or German), but Dutch was their dominant language.

Results and Discussion

For each language, we tabulated the frequency of the verbs produced to describe each clip. We then focused on the distribution across clips of those verbs that were the dominant (i.e., most frequent) response for at least one clip.

Japanese speakers produced the simplest naming pattern, with only two different verbs emerging as dominant for at least one clip. Figure 2 shows the distribution of these two verbs across clips. The distribution of *aruku* was consistent with the grouping of stimuli in the cluster solution; *aruku* was applied to the clips showing speeds 1, 2, and 3 at each slope, as well as to the clip showing speed 4 on the flat surface, but not to the clips showing speed 4 on the two tilted surfaces (the added difficulty

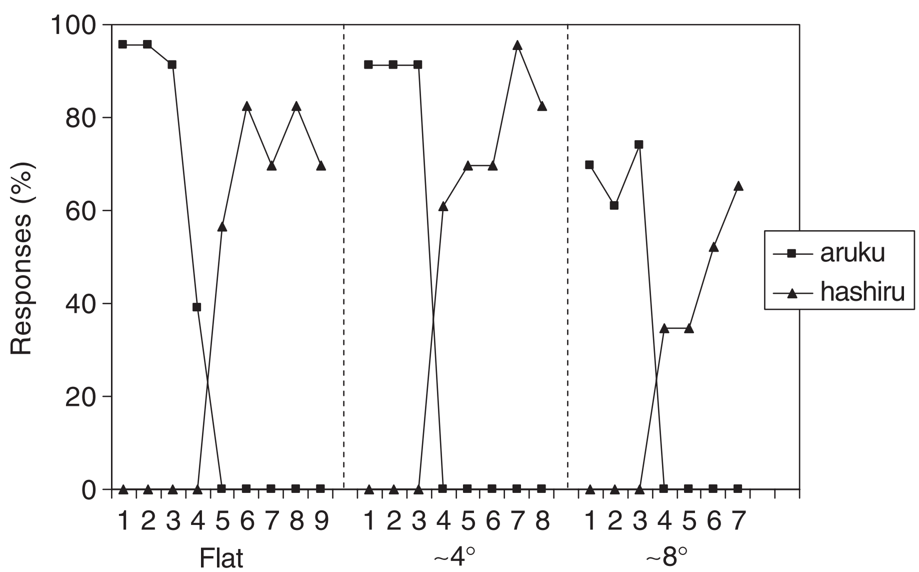

Fig. 2. Results for Japanese speakers in Study 1. The graph shows the percentage of total responses accounted for by each of the two dominant Japanese verbs (i.e., the verbs that were the most frequent response for at least one stimulus), as a function of speed and slope of the treadmill. (See Fig. 1 for an explanation of the designations of speed.)

of the slopes had forced the model to switch gaits in those clips). The distribution of *hashiru* was also consistent with the grouping of stimuli in the cluster solution; *hashiru* was applied to the clips showing speed 4 with approximately 4° and 8° of tilt and to all the clips showing higher speeds. The pattern is unambiguously categorical: For all clips for which *aruku* was the dominant verb, there were no responses of *hashiru*, and conversely, for all clips for which *hashiru* was the dominant verb, there were no responses of *aruku*. The application of the verbs corresponds cleanly to the biomechanical distinction between walking and running.

The other languages yielded from three (Spanish) to seven (Dutch) different verbs that were dominant for at least one clip, demonstrating considerable cross-linguistic diversity. But what was the nature of these differences? If the four languages encode the same gait distinctions, the verb distributions obtained for English, Spanish, and Dutch should have observed the categorical boundaries of the Japanese verbs while making finer distinctions within them. If the languages do not reflect the biomechanical discontinuity, the verb distributions obtained should have cut across the Japanese boundaries. Also, the distributions within a language might have overlapped, instead of showing clean categorical boundaries.

When we superimposed the response distributions of the other languages onto the Japanese distributions, each of the verbs in the other languages showed a distribution that fell entirely within the boundaries of one of the Japanese verb distributions. Figure 3a presents the distributions of verbs that fell within the distribution of *aruku*,[1] and Figure 3b presents the distributions of verbs that fell within the distribution of *hashiru*. Figure 4 presents the summed distributions of all the different verbs for each language.[2] These figures show that the languages differ in how finely they distinguish lexically within a given category. Furthermore, they show that within each category, the use of terms is graded; the distributions of the terms overlap. However, critically, the figures also make it clear that speakers of all four languages observe the same major distinction between gaits, and they treat this distinction strictly categorically in naming. Verbs associated with one gait and verbs associated with the other were not applied to the same clips.

The correspondence across the languages that is evident in the graphs was substantiated by extremely high correlations of the English, Spanish, and Dutch distributions with the Japanese distributions: The percentage of English *walk* responses for each clip correlated .94 across clips with the percentage of *aruku* responses; Spanish *caminar* responses correlated .97 with *aruku* responses; and the four Dutch responses *snelwandelen*, *stappen*, *wandelen*, and *slenteren* combined correlated .96 with *aruku* responses. The percentage of English *jog*, *run*, and *sprint* responses combined for each clip correlated .94 with the percentage of *hashiru* responses; Spanish *trotar* and *correr* responses combined correlated .94 with *hashiru* responses; and Dutch *rennen*, *lopen*, and *joggen* responses combined correlated .88 with *hashiru* responses. Thus, the lexicons of all four languages, low-manner-salient as well as high-manner-salient, appear to respect the discontinuity in manner of motion between walking and running.

STUDY 2: TYPICALITY

Although Study 1 showed that the four languages have gait terms corresponding closely in their boundaries, languages may differ in which examples of gaits they consider the best, and which they consider more peripheral. That is, the terms of the four languages we analyzed in Study 1 may have different prototypes and typicality distributions even though their range of application is the same. To obtain more detailed information about the meanings of the terms, we collected ratings of the typicality of each clip as an example of two or three gait terms in each language.

Method

Native speakers of American English ($n = 23$), Argentinean Spanish ($n = 12$), Japanese ($n = 33$), and Belgian Dutch ($n = 23$) who did not participate in Study 1 participated in Study 2. They were drawn from the same populations as before, except for 1 Spanish speaker who was not resident in Argentina.

The 24 video clips from Study 1 were used. For the gait terms, we selected English *walk* and *run* (the verbs discussed in the English-language gait literature as capturing the main biomechanical distinction), along with their rough translation equivalents (as given by native speakers' intuitions) in the other languages: *aruku* and *hashiru* for Japanese, *caminar* and *correr* for Spanish, and *wandelen*, *rennen*, and *lopen* for Belgian Dutch. Each clip was presented on a Web page similar to that used in Study 1 except that participants were asked not what the woman was doing in each clip, but how typical the action was of particular verbs. For instance, for English, each clip was followed by the two questions, "How typical is this of walking?" and "How typical is this of running?" Participants answered by selecting a number from a drop-down menu with options ranging from 0 (*not an example*) to 6 (*highly typical*).

Results and Discussion

Figure 5 plots the mean typicality ratings across clips for *walk*, *run*, and the corresponding verbs in the other languages. The typicality distributions for the related terms were remarkably similar, with correspondence across the languages almost perfect for both walking terms and running terms. Ratings for *walk* and the related terms in the other languages—*aruku*, *caminar*, and *wandelen*—corresponded essentially perfectly across the clips (for each possible pair of languages, $r = .99$). Ratings for

[1]Belgian Dutch gait vocabulary differs from that of Netherlands Dutch; however, the categorical use of terms holds equally for both.

[2]Responses not represented on the graph include non-gait descriptors such as *cooling down*, *speeding up*, and *exercising*, and lower-frequency gait terms such as *trotting*.

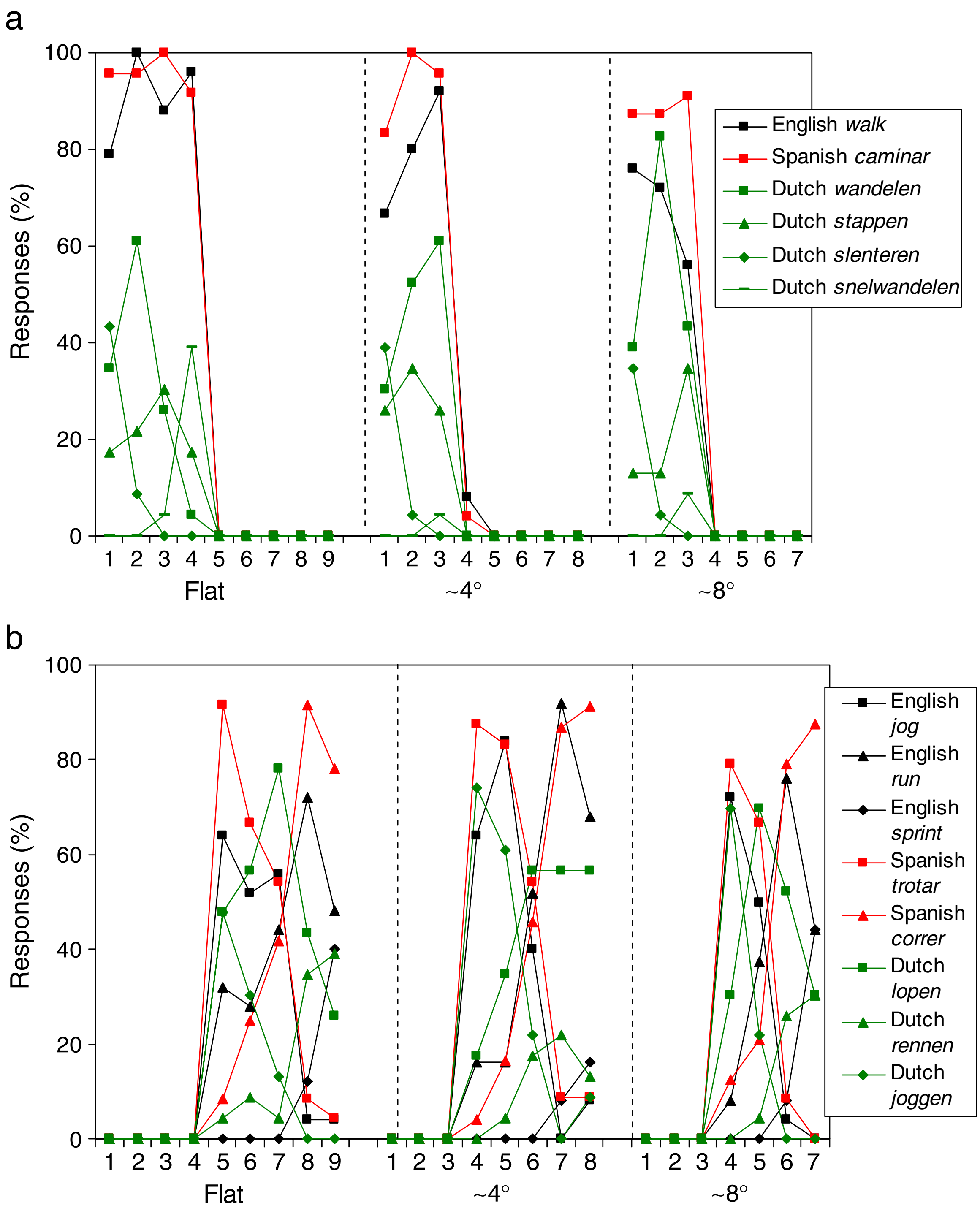

Fig. 3. Results for English, Spanish, and Dutch speakers in Study 1. The graph in (a) shows the percentage of total responses accounted for by the English, Spanish, and Dutch dominant verbs (i.e., all verbs that were the most frequent response for at least one stimulus) falling within the boundaries of Japanese *aruku*, as a function of speed and slope of the treadmill. The graph in (b) shows the percentage of total responses accounted for by the English, Spanish, and Dutch dominant verbs falling within the boundaries of Japanese *hashiru*, as a function of speed and slope of the treadmill. (See Fig. 1 for an explanation of the designations of speed.)

run and the related verbs—*hashiru*, *correr*, *rennen*, and *lopen*—were also strongly correlated. The typicality of clips as exemplars of *run*, *hashiru*, and *correr* corresponded essentially perfectly (r = 1.0 for *run* with *hashiru*, r = .99 for the other two pairings). Ratings for *rennen* showed slightly lower but still very strong correspondence (r = .90 with *run*, .90 with *hashiru*, and .93 with *correr*), as did ratings for *lopen* (r = .90 with *run*, .92 with *hashiru*, and .87 with *correr*).

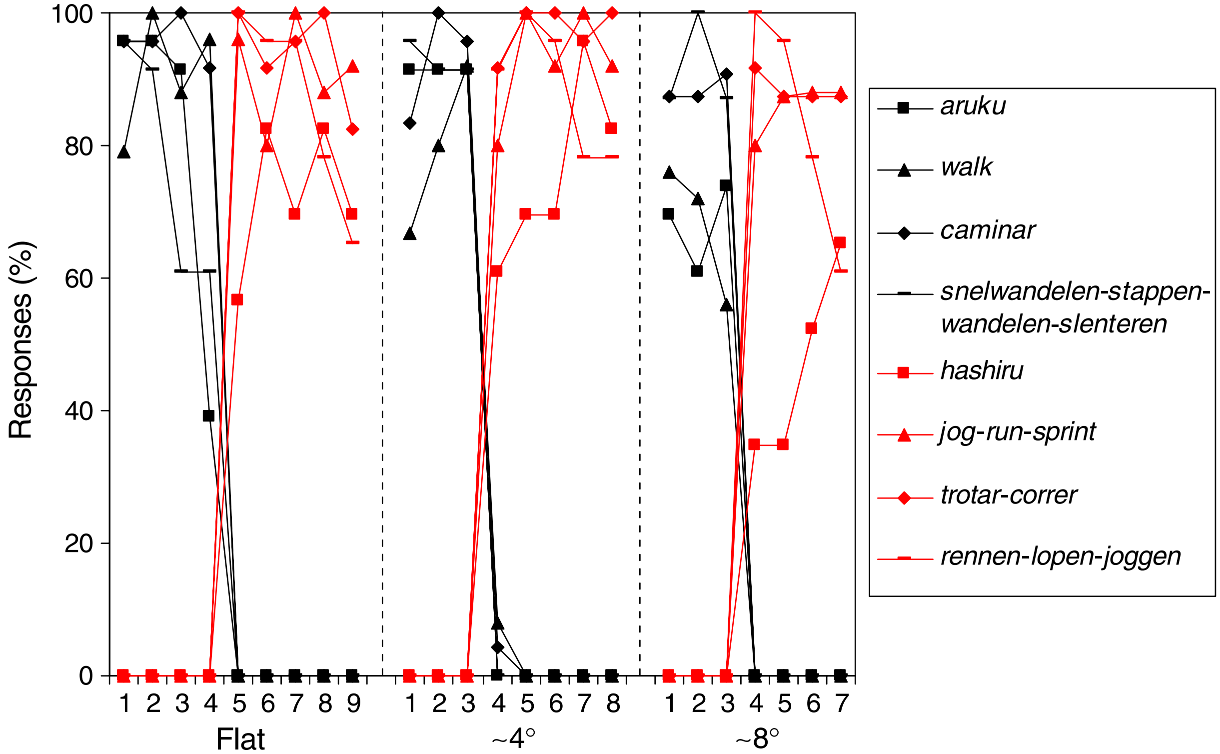

Fig. 4. Percentage of total responses accounted for by the Japanese, English, Spanish, and Dutch dominant verbs (i.e., all verbs that were the most frequent response for at least one stimulus) for both walking and running gaits, as a function of speed and slope of the treadmill. In cases in which a language had more than one dominant verb for a gait, the distributions are summed. (See Fig. 1 for an explanation of the designations of speed.)

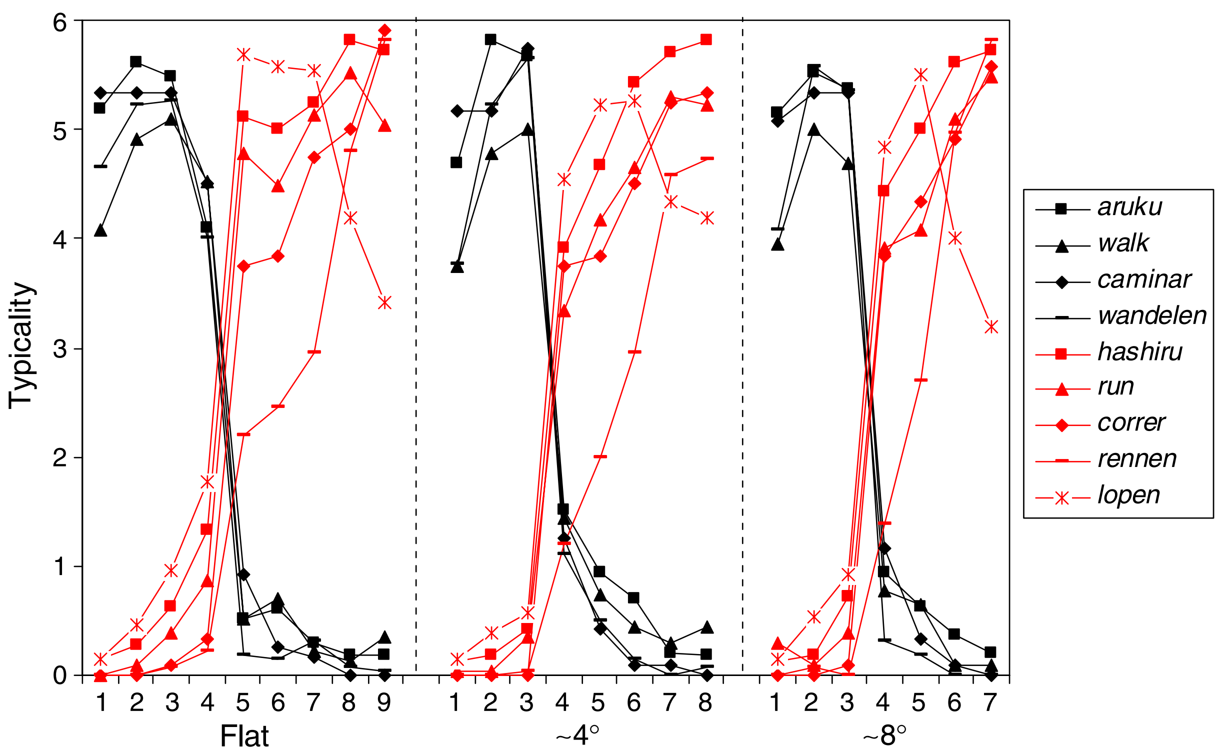

Fig. 5. Mean typicality ratings for the Japanese, English, Spanish, and Dutch gait terms in Study 2, as a function of speed and slope of the treadmill. (See Fig. 1 for an explanation of the designations of speed.)

In Study 1, the slowest running clips at each slope had often received the labels *jog* in English and *trotar* in Spanish, but the typicality ratings reveal that the actions were nevertheless seen as moderately good examples of *run* and *correr*, respectively. In contrast, it seems that Belgian Dutch verbs partition the running space more definitively; *rennen* was high in acceptability only for the faster clips, and *lopen* covered the slower speeds, a distinction reflected in a correlation of only .65 between ratings for these two verbs. Nevertheless, the typicality peaks of *rennen* were quite comparable to the peaks for the other languages' terms.

The ratings therefore show that the shared tendency across languages extends beyond distinguishing two categories of gait. The gait terms share best examples and to a very large extent the gradation of goodness of example. This tendency may be driven by a shared frequency distribution of input to the observer. That is, the close similarity of human bodies and physical capabilities across cultures may result in a tendency for certain speeds of movement within each gait category to be most useful and common.

GENERAL DISCUSSION

These studies were aimed at evaluating whether naming patterns in different languages reflect the independently specified, universally experienced structure inherent in human locomotion. We found that despite substantial structural differences among English, Spanish, Japanese, and Dutch (as well as cultural differences among their speakers), names for two common human gaits follow the same categorical pattern across these languages. This is true even though the languages show notable divergence in the extent to which they carve up gait space with further distinctions. These findings support the proposal that structure in the world provides constraints on how category labels are assigned. Shared tendencies are not reflections solely of acts of construction on the part of observers. Where strong structure exists, broad categories may tend to be shared across languages (cf. Levinson, 2003; Roberson, Davies, & Davidoff, 2000). Furthermore, a structural constraint can be driven by correlations among stimulus properties that are dynamic and fleeting.

Are there languages that do not follow the pattern observed here? It is possible that some do not have separate verbs for walking and running gaits, just as some do not have separate nouns for hands versus arms (Brown, 2005b; Majid et al., 2006) or mice versus bats and shrews (Hunn, 1999). However, we predict that few languages crosscut the biomechanical distinction, by, for instance, having a verb grouping fast walks with slow runs and segregating those from slower walks and faster runs. The data do not tell us exactly what cues our participants were responding to. Todd (1983) suggested that the angle of the lower leg may be important; however, responses to our clips in which the treadmill was at a tilt, and knee bend was increased for walking, suggest that observers perceive additional, emergent qualities of the gaits, such as the characteristic bounce-and-recoil motion present in running but not walking (Alexander, 1982). Because gaits are biomechanically defined by clusters of correlated properties, speakers of different languages may tend to observe the same distinction even if they vary somewhat in the weights they give to different properties (Boster & D'Andrade, 1989).

The typicality data demonstrate, further, that the best examples of the gait terms are highly comparable across languages. It is possible that languages diverge more in how far they extend their "walk" and "run" terms to less common actions (e.g., to shuffling or marching) or in how they lexically partition less frequent forms of motion (e.g., distinguishing jumping from skipping). Indeed, preliminary data we have gathered suggest this is true. Research in other domains (e.g., artifacts; Malt et al., 1999) suggests that in domains in which structure in the world is weaker, or less attention is given to that structure, cultural and historical forces have greater influence on naming patterns. These lines of work together indicate that lexical categories are subject to multiple forces, some of which cause convergence across languages and some of which cause divergence. The work we have reported here contributes to understanding the nature of those forces that yield convergence.

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