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Cognitive change without linguistic change: The rise of egocentric frames of reference in the Hai||om

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ABSTRACT

Human cultures differ in how they think about space: some primarily use egocentric frames of reference, thinking about space in relation to the body, while others privilege geocentric frames, thinking about space in relation to the environment. The origins of this cognitive diversity remain largely unknown. Here, we provide evidence suggesting an ongoing shift in spatial thinking—but not language—within a culture, providing insight into the origins of this cognitive diversity. Hai||om people, a rural forager community in Namibia, have traditionally privileged geocentric frames of reference in cognition and language. Comparing new data to historical data from the same community, we found that contemporary Hai||om show a greater preference for egocentric frames of reference compared to previous reports, suggesting an egocentric shift in their cognition. Surprisingly, we document no such shift in their language, showing that Whorfian views are insufficient on their own to explain cognitive diversity in spatial frames of reference. We discuss material culture, rather than language, as a key driver of diversity in spatial thought.

1. Introduction

A long Western tradition in philosophy, psychology, and neuroscience has assumed a human cognitive universal: Humans think about space primarily egocentrically, i.e. relative to the left, right, front and back of their own bodies (Kant, 1768 [1991]; Piaget, 1928; Wang & Spelke, 2002). In contrast, allocentric ways of thinking about space, that is, thinking of spatial relations *not* with respect to one's body, but in terms of the environment, are thought to be secondary and more effortful (see Levinson, 2003 for a review).

This presumed primacy of egocentric spatial cognition has been challenged by the documentation of substantial cross-cultural variation in spatial cognition and language (Levinson & Wilkins, 2006). Using egocentric frames of reference (FoR) to talk about space (i.e., using words like left, right, front, and back; see Fig. 1) seems to be limited to globalized, industrialized societies, or groups that are heavily influenced by such societies (Bohnemeyer et al., under review). Outside such groups, countless indigenous languages around the world do not prefer to use egocentric words. Instead, they prefer to use different types of allocentric FoR (see Fig. 1), using coordinate systems not anchored to the body, but to some aspect of the world. In particular, many indigenous languages use geocentric systems to talk about space, referring to cardinal directions (north, south, east, west) or large-scale environmental features (e.g., rivers, mountains) — even for talking about small-scale space. Using geocentric FoR in language is neither rare nor exclusive to a specific place or culture: it can be found in a third of all human languages (estimate by Levinson, 2003) across Latin America, Africa, Australia, Asia, and beyond (see Majid et al., 2004 for a review).

Past work showed that speakers of geocentric languages not only *talk* geocentrically, but also *think* geocentrically, at all spatial scales — even small-scale space around the body. Non-linguistic tasks often involve having people memorize a spatial configuration, for example, a set of animals-in-a-row with all of them facing one direction (see Fig. 2a) and then rotating people, for example, 90 degrees, and asking them to rebuild the animals the same way at another location. There are at least two correct solutions for what counts as the same. If people memorized the spatial relationships of the animals egocentrically, as all facing leftward, they should rearrange the animals egocentrically the same way after rotation, that is, all facing leftward. Indeed, this is what speakers of egocentric languages such as English or Dutch prefer to do (Haun et al., 2011). By contrast, speakers of geocentric languages rearrange the animals geocentrically the same way, that is, for example, all animals facing southward. To date, there have been many studies demonstrating that people's linguistic preferences typically align with their cognitive

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preferences across many different cognitive tasks: Geocentric speakers prefer to use geocentric FoR to remember object locations, to infer spatial relations, to remember paths, to recognize shapes, to imagine and gesture about events, and even to remember their body movements (Pederson et al., 1998; Levinson, 2003; Haun & Rapold, 2009; Haun et al., 2006; Haun et al., 2011; Marghetis et al., 2020; but see Li et al., 2011).

Far from being universal, preferring to use egocentric FoR for thinking seems to be limited only to groups that prefer to talk egocentrically. Using a form of allocentric FoR for thinking may be the default for speakers of languages with no preference to speak egocentrically or geocentrically (Bohnemeyer et al., 2022). The widespread and long-held assumption that human spatial cognition is primarily egocentric may simply result from a drastic overrepresentation of participants and scholars from urban-industrialized (e.g., WEIRD) communities (Henrich et al., 2010). Some even claim that using egocentric spatial thinking is a historically recent phenomenon that has spread only with the global rise of literate, educated, and urbanized societies (Bohnemeyer et al., under review).

If so, why do some humans prefer to think about space egocentrically? Where does this cognitive diversity in one of the fundamental domains of cognition come from? The most influential hypothesis explaining the origins of egocentric spatial thinking has been the 'Whorfian' hypothesis (Levinson, 2003; Majid et al., 2004; Pederson et al., 1998): The robust correlation between preferring to talk and think egocentrically led to the idea that preferring to talk egocentrically might cause people to also think egocentrically, even when not using language. Under this hypothesis, the global rise of egocentric thinking may be associated with the spread of egocentric, mainly colonial, languages such as English, Spanish, or French.

Cross-cultural data is insufficient to discover how human groups become egocentric thinkers and whether egocentric language plays a role. Instead, we need to show how cultural change in spatial cognition and language unfolds, for example, by leveraging historical data. If the 'Whorfian' hypothesis explains the worldwide shift toward egocentric cognition, then spatial language and cognition should either change synchronously over historical time, or language change should precede cognitive change, but not vice versa. Here, we report evidence suggesting a historical change in spatial cognition among a Namibian Hai||om community which occurred without any change in spatial language — a pattern of results that the 'Whorfian' hypothesis cannot explain.

Hai||om people from rural Namibia are known to prefer geocentric FoR both in language (Neumann & Widlok, 1996) and cognition (Neumann & Widlok, 1996; Haun et al., 2006; Widlok, 2007; Haun & Rapold, 2009; Haun et al., 2011). Linguistically, Hai||om have all three FoRs available, including egocentric words such as left (||are) and right (am). But, they have been shown to heavily prefer geocentric words, even to talk about small-scale tabletop space: Using words like sunrise (soresa ǂoa) and sunset (soresa ǂga) to describe directions corresponding to east and west, and using neighboring places and peoples to refer to directions corresponding to north and south (Neumann & Widlok, 1996). Cognitively, Hai||om have been shown to have a preference for geocentric FoR across different age ranges and paradigms, to remember arrays of objects (Haun et al., 2011; Neumann & Widlok, 1996), to remember where something is hidden (Haun et al. 2006), to infer spatial relations (Widlok, 2007), and to remember their own body movements (Haun & Rapold, 2009).

In the current study, we returned to the same Hai||om village roughly two decades after the original research. Our goal was to conceptually replicate the robust pattern that Hai||om prefer to talk and think geocentrically, using the most standard and widely used frame-of-reference tasks and drawing on a wide, age-diverse sample of adults. So, in Study 1, we tested Hai||om participants using adapted versions of two standard FoR tasks: the linguistic, director-matcher, task from Neumann and Widlok (1996), reporting that Hai||om preferred to talk geocentrically in 1990s, and the cognitive, animals-in-a-row, task from Haun et al. (2011) reporting that Hai||om preferred to think geocentrically in 2005. Much to our surprise, contemporary Hai||om participants showed a clear *egocentric* preference in the cognitive task, while their linguistic preferences remained largely geocentric.

In Study 2, conducted two years after study 1, we ran a direct replication of the cognitive task by Haun et al. (2011) to rule out explanations based on measurement changes or sampling differences across the two time points. Testing both age-matched participants (children ages 7–11) and retesting the original participants now as adults two decades later in the same paradigm, we found robust evidence that Hai||om show a greater preference for egocentric FoR compared to the past. Together, these results show that cognitive shifts

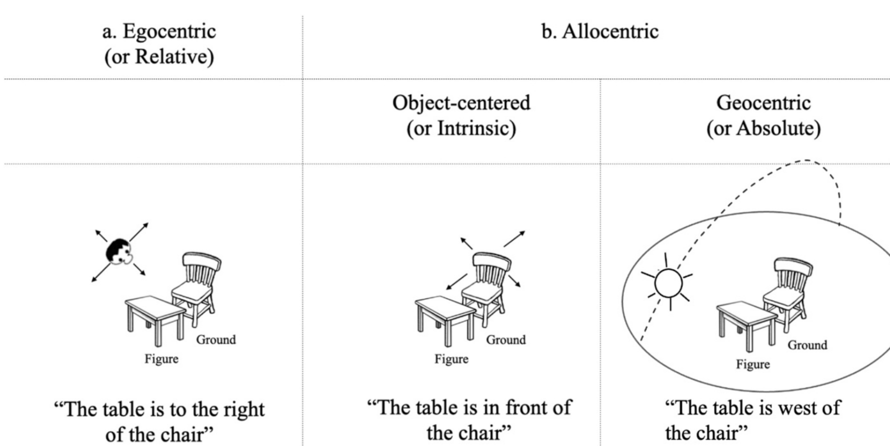

Fig. 1. Types of linguistic frames of reference (i.e. FoR) available to languages.
Note. The spatial relationship between objects in small-scale space can be described in different ways. (a) Egocentric FoR, the viewer's body axes are used to define the spatial relationship between a figure and a ground (e.g., "The table is to the right of the chair"). Egocentric descriptions are dependent on the perspective of the viewer. That is, if the speaker goes around to the other side of the table and chair, then the proper egocentric description flips (e.g., "The table is to the left of the chair"). (b) With allocentric FoR, the coordinate system that defines the spatial relationship between a figure and a ground is based on some feature of the environment. Two major types of allocentric FoR are distinguished and different languages may use each form to a different extent. The first is object-centered or intrinsic FoR, which uses the coordinate systems of objects (e.g., "The table is in front of the chair"). Some languages rely exclusively on intrinsic FoR to talk about small-scale space (see Majid et al., 2004 for a review). The second type of allocentric FoR is geocentric or absolute FoR, which uses geocentric coordinates such as north, south, east, west (e.g., "The table is west of the chair"). With geocentric descriptions, the same description can be applied to the spatial relationship independent of the perspective of the viewer.

in spatial reference frames can occur without parallel changes in language and that language diversity and cognitive diversity can occur out of sync. In our case, non-linguistic factors appear to be at play in promoting the rise of egocentric thinking in Hai||om people.

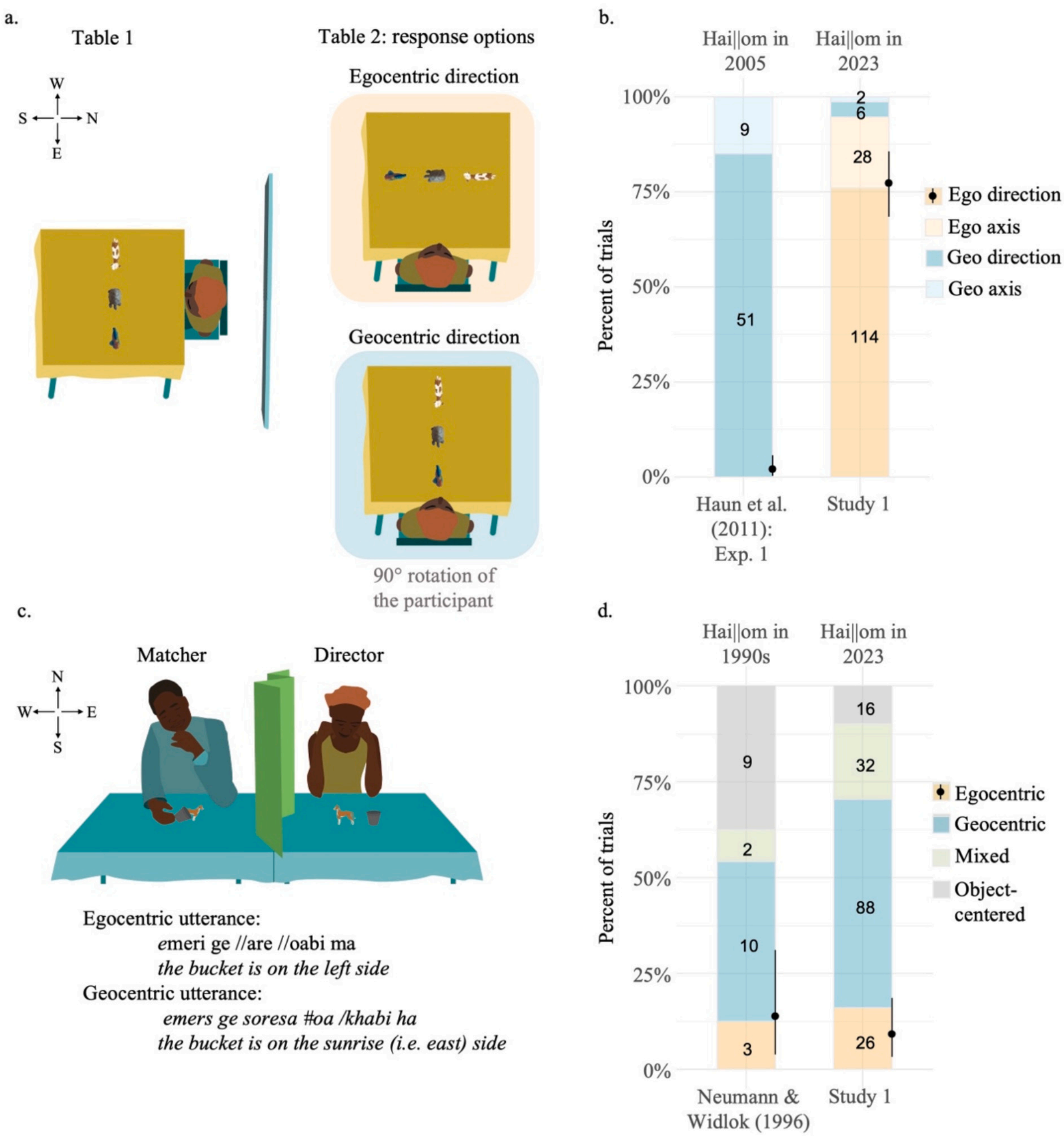

Fig. 2. Study 1: Hai||om's preferred spatial frames of reference in cognition and language across time.
Note. (a) In the animals-in-a-row task, participants were asked to remember three animals placed in a row before them, they are then asked to turn around 90 degrees and asked to rebuild the sequence of the three animals as they remember them at another table. At least four response solutions are possible: Egocentric direction: All animals facing the egocentrically same side (i.e. left); Egocentric axis: All animals facing the egocentrically opposite side (i.e. right for a leftward array), but nevertheless placed on the egocentrically same axis; Geocentric direction: All animals facing the geocentrically same side (i.e. east); Geocentric axis: All animals facing the geocentrically opposite side (i.e. west for a eastward array), but nevertheless placed on the geocentrically same axis. (b) Historical comparison of Hai||om people's cognitive preferences in the animals-in-a-row task as reported in Haun et al. (2011) and in the current Study 1. Error bars show the 95% highest posterior density intervals from the brms model for the Egocentric Direction outcome. (c) In the director-matcher task, the director was asked to describe simple scenes (i.e. different spatial relationships between a toy bucket and a toy dog) to the matcher so that the matcher can build the same scene. The scenes can be described using Egocentric (e.g. “the bucket is to the left of the dog”), Geocentric (e.g. “the bucket is to the east/sunrise of the dog”), Mixed (e.g. “the bucket is to the left, east/sunrise of the dog”), or Object-centered language (e.g. “the bucket is behind the dog”). (d) Historical comparison of Hai||om people's linguistic preferences in the director-matcher task in Neumann and Widlok (1996) and in the current Study 1. Error bars show the 95% highest posterior density intervals from the brms model for the Egocentric Direction outcome.

2. Study 1

2.1. Method

2.1.1. Participants

All participants were Hai||om adults from Mangetti West, a rural village with around 200–300 inhabitants in northern Namibia. Hai||om people are traditionally foragers, who nowadays engage in mixed subsistence consisting of occasional wage labour, foraging, and small-scale gardening (see Widlok, 1999 for a detailed ethnography of the community). Their language is part of the Khoekhoe cluster within the Central Khoisan language family. Most participants (66%) were monolingual Hai||om speakers, with little or no formal schooling. All participants gave verbal informed consent before participating in the study. The study received ethical approval from the MPG Ethics Commission in Munich, Germany, falling under the umbrella ethics application (Appl. No. 2021_45). The study was conducted according to the ethical guidelines for good practice in cross-cultural research (Bruno et al., 2022). The research was approved by the National Commission on Research, Science and Technology (NCRST) of the Republic of Namibia. All participants received small gifts for participation.

First, 32 Hai||om adults (17 female; 15 male) participated in the animals-in-a-row task, testing their cognitive preferences — aged between 23 and 66 ($M = 40.81$; $SD = 12.93$; $Mdn = 39$). Two participants did not complete the task, one due to hearing problems and the other due to needing more than 10 practice trials. The analyses were done with data from the remaining 30 participants (15 female; 15 male).

Twenty-four participants who completed the animals-in-a-row task also participated in the director-matcher task, testing their linguistic preferences—always as their second task and always on a different day than the animals-in-a-row task. In total, 31 Hai||om adults (16 female; 15 male) participated in the director-matcher task, aged between 20 and 66 ($M = 38.03$; $SD = 12.85$; Mdn = 34). The participants were recruited in pairs of matching sex, one serving as the director and one serving as the matcher. After a participant completed the task as a director, he/she became the matcher for the next director, resulting in a total of 28 same sex pairs. For cases where a director was not available to serve as the matcher for the next director, a new person was recruited to serve as the matcher.

2.1.2. Procedure

The experimenter was a native speaker of Khoekhoe, residing in a neighboring community about 50 km distant to Mangetti West, and well known to the community from prior research projects. Khoekhoe and Hai||om are highly related variants of the Khoekhoe language cluster. The experimenter translated the instructions from English to Hai||om, so the tasks were run in Hai||om.

2.1.2.1. Cognitive preferences: Animals-in-a-row task. To test Hai||om people's cognitive preferences in FoR, we used the animals-in-a-row task. The animals-in-a-row task is the FoR task that is most widely used across cultures to test for cognitive diversity in spatial frames of reference (see for example Majid et al., 2004). Previously, slightly different versions of the task have been used with Hai||om and showed that they exhibit a clear preference for geocentric FoR in this task (Haun et al., 2011; Neumann & Widlok, 1996; Widlok, 2007). Here, we closely followed the setup and the instructions of the version of the task used by Haun et al. (2011; Experiment 1).

The task involved memorizing a spatial array, a row of toy animals, and reconstructing the spatial array at a different location from memory (see Fig. 2). Half of the participants were tested indoors, inside an empty, two-bedroom house belonging to the local cattle farm. The other half of the participants were tested outdoors. The two contexts were included to see whether the cognitive preferences would be stable across different contexts. Two tables were placed within 4–5 m distance with a barrier blocking the view from each other. For the indoors setup, one of the tables was placed in one room, and the other table was placed in an adjacent room with a wall between the rooms serving as a barrier. For the outdoors setup, the two tables were separated by a wooden board mounted on two chairs.

Participants were told that this was a memory game and that toy animals would be placed on a table for them to memorize how they stand. Once the participants indicated that they were done memorizing, the animals would be removed so they could rebuild them on the same table (Table 1 in Fig. 2a). Once the participant was able to reconstruct the animals exactly the same way on Table 1, he/she would be guided to another table (Table 2 in Fig. 2a) to again rebuild the animals from memory. At Table 2 the participants were asked to "put the animals back as they were".

Participants were always facing South during memorisation at Table 1 and were then guided behind a barrier to Table 2, where they always faced West, therefore rotated 90 degrees relative to their facing direction at Table 1. Each trial started at Table 1, with the experimenter placing three out of four animals (e.g. a tortoise, an elephant, a rooster, a cow) on a spatial array on Table 1 — all facing either right/West or left/East of the participant (see Fig. 2 for an example spatial array on Table 1). After participants indicated that they had memorized the arrangement of the animals, the experimenter removed the animals and then placed them back on Table 1 in a pile for the participant to rebuild. Participants were given a maximum of 10 attempts at rebuilding the array correctly — picking the right set of animals and placing and orienting them correctly. When the participant made a mistake, the experimenter corrected it by fixing the array and then asked them to memorize and rebuild the animals again. Once the participant rebuilt the array on Table 1 without errors, they were guided to Table 2, where they sat at a 90-degree rotation compared to Table 1. The experimenter placed all four animals on Table 2 in a pile. The experimenter did not give any feedback to the participant for their reconstruction on Table 2 and the participant was simply guided back to Table 1 to start a new trial. Participants completed 5 trials, each involving a different array of animals, presented in a random order (see https://osf.io/chvwt/?view_only=881f7c8c3fc54df6881b79f2ff71ed0e for pictures of the stimulus arrays used).

Participants' spatial reconstructions of the array of toys (5 trials per participant) were categorized according to their frame of reference. Following Haun et al. (2011), we coded the facing direction of the animals to determine which FoR participants used to preserve orientation across tables. Responses were categorized as Egocentric Direction if the animals were rearranged using the same egocentric direction on the egocentrically same axis at Table 2 as on Table 1 (i.e., all animals facing leftward on the left-right axis relative to the participant; see Fig. 2a). Responses were categorized as Geocentric Direction if the animals were rearranged using the same geocentric direction on the geocentrically same axis (i.e., all animals facing eastward on the east-west axis; see Fig. 2a).

In 20% of trials (30 out of 150), participants reversed the facing direction of the animals in their reconstructions (e.g., right instead of left) but nevertheless preserved the relevant spatial axis (e.g., the left–right axis relative to the participant). Rather than excluding these trials, we coded them separately as axis-preserving responses, as they reflect preservation of a spatial dimension within a particular FoR despite reversal of direction along that axis. This resulted in two additional categories. Responses were categorized as Egocentric Axis if the animals were rearranged along the same left–right axis relative to the participant, but with reversed egocentric direction (e.g., animals facing right instead of left on the left-right axis). Responses were categorized as Geocentric Axis if the animals were rearranged along the same east–west axis, but with reversed geocentric direction (e.g., animals facing west instead of east on the east-west axis). To ensure comparability with Haun et al. (2011), our primary inferences rely on direction-preserving trials (Egocentric Direction and Geocentric Direction). Nevertheless, for an overview of which FoR participants used to think about the axis regardless of direction, one can sum all egocentric responses (Egocentric Direction + Egocentric Axis) and all geocentric responses (Geocentric Direction + Geocentric Axis).

Following Haun et al. (2011), we coded and analyzed the animals' facing direction rather than their positions. Importantly, direction and position were highly aligned. Of the 120 trials with a correct direction (e.g., all animals facing left; see Fig. 2a)—categorized as Egocentric or Geocentric Direction—111 trials also had a correct position (e.g., rooster–turtle–cow, with the rooster on the left and cow on the right). Errors consisted either of a flipped position (e.g., cow–rooster–turtle instead of rooster–turtle–cow) or of including a wrong animal in the array.

2.1.2.2. Linguistic preferences: Director-matcher task. To test Hai||om people's linguistic preferences in FoR, we used the director-matcher task—the standard test for documenting linguistic diversity in spatial frames of reference (see, for example, Levinson, 2003). Here, we adapted the version of the task with which Neumann and Widlok (1996) documented a clear preference for geocentric FoR in language among the Hai||om.

Eighty percent of the participants who completed the animals-in-a-row task also participated in the director-matcher task, always on a separate day. The order of tasks was the same across all participants, with the linguistic, director-matcher task being always the second one, to ensure that the results from the more explicitly spatial, linguistic task do not affect the results of the less explicitly spatial, cognitive task (i.e. animals-in-a-row task).

The director and the matcher sat next to each other, but were separated by a barrier so they did not see each other's scenes (see Fig. 2c). The task involved the director describing the arrangement of two toys in front of him/her, so that the matcher could make the same scene in front of him/her. Because of the barrier occluding the view, the matcher could only rely on the director's words to build the same scene. Half of the pairs were tested indoors, inside the same house belonging to the local farm where the animals-in-a-row task was done. The other half of the pairs were tested outdoors. Also, half of the pairs were tested facing North, and the other half were tested facing South.

There were six trials, each involving a scene with the toy and a bucket with a different spatial arrangement (see https://osf.io/chvwt/?view_only=881f7c8c3fc54df6881b79f2ff71ed0e for the pictures of the scenes used). The scenes involved the same spatial arrangements as the ones used by Neumann and Widlok (1996), with the only difference being the use of a bucket as an object without an inherent front, instead of a tree, and the use of a dog as an object with an inherent front instead of a man. Each trial started with the experimenter making a scene in front of the director and then being asked to describe this scene to the matcher using only their words. Once the director was done describing, the director and the matcher compared their scenes to see if they had a match. They each received a bead if they achieved a match. At the end of all the trials, the participants exchanged their beads for a gift. The gift was not contingent on how many beads they collected.

Participants' speech was transcribed in Hai||om and then translated to English by the experimenter. For each trial, Coder 1 (the first author) identified the utterances that include spatial descriptions distinguishing the different scenes presented (i.e. distinguishing utterances) and the FoR used in these distinguishing utterances to describe the scenes, using the coding scheme of Neumann and Widlok (1996) (see https://osf.io/chvwt/?view_only=881f7c8c3fc54df6881b79f2ff71ed0e for the coding manual). A trial was coded as *Geocentric* if only geocentric words or phrases were used to talk about the scenes, and no egocentric words or phrases were used. Geocentric utterances included words or phrases such as "the bucket is to the sunrise (east) of the dog" or "the dog is facing the sunset (west)" to describe a scene like the one in Fig. 2c. A trial was coded as *Egocentric* if only egocentric words or phrases were used to talk about the scenes, and no geocentric words or phrases were used. Egocentric utterances included words or phrases such as "the bucket is to the left of the dog" or "the dog is facing the right hand side" to describe a scene like the one in Fig. 2c. A trial was coded as *Mixed* if speech during that trial included both geocentric and egocentric words or phrases. A trial was coded as *Object-centered* if only object-centered (i.e. intrinsic) words or phrases were used "the bucket is behind the dog" (see https://osf.io/chvwt/?view_only=881f7c8c3fc54df6881b79f2ff71ed0e for the coding manual including more examples). The utterances for each trial mostly included speech from the director, but we also included the matcher's utterances which mostly involved clarifying questions. Ten percent of the trials were re-coded by Coder 2 for frame of reference types and the coders had 100% agreement.

2.1.3. Analyses

Data and analysis scripts can be found in an online repository (https://osf.io/chvwt/?view_only=881f7c8c3fc54df6881b79f2ff71ed0e). We used the brms R package (v2. 14.4; Bürkner, 2017) for our analyses. To analyze the frame of reference Hai||om prefer to use in the animals-in-a-row task, we fit a Bayesian categorical regression model to our data at the trial level, with 5 trials per participant. Our categorical outcome variable had four possible values: *Egocentric Direction, Geocentric Direction, Egocentric Axis,* and *Geocentric Axis*. We included random intercepts for participants. We included a fixed effect of with Sample as a dummy variable to test for differences in the categorical outcome across the two samples over time: (i) The historical sample from 2005 by Haun et al. (2011; Experiment 1) and (ii) the current sample from 2023 (Study 1).

To analyze the frame of reference Hai||om prefer to use in the director-matcher task, we fit a Bayesian categorical regression model to our data at the trial level, with 6 trials per participant. Our categorical outcome variable had four possible values: *Egocentric* (i.e. a trial that involved egocentric language only), *Geocentric* (i.e. a trial that involved geocentric language only), *Mixed* (i.e. a trial that involved both egocentric and geocentric language), and *Object-centered* (i.e. a trial that involved object-centered language only). We included random intercepts for participant and trial type (i.e. the spatial arrangement that the participants were asked to describe) to account for variation across different participants and across different types of spatial relationships described. We fit the same model to the historical data from 1990s by Neumann and Widlok (1996) and computed contrasts using the posterior samples from the two models to test for an effect of Sample across the two studies: (i) The historical sample from 1990s by Neumann and Widlok (1996) and (ii) the current sample from 2023 (Study 1).

Regularising prior distributions were used for all model parameters (normal distributions centred on zero for intercepts, exponential distributions for random effect variances, see analysis scripts on https://osf.io/chvwt/?view_only=881f7c8c3fc54df6881b79f2ff71ed0e for full model specification).

2.2. Results

2.2.1. Cognitive preferences: Hai||om now show a greater preference to think egocentrically about small-scale space

We first analyzed the spatial FoR Hai||om people prefer to use for thinking, to remember the spatial relationship of the animals in the animals-in-a-row task. Our numerical results showed a clear preference for egocentric FoR: At the trial level, participants preferred the egocentrically same direction on 76% of the trials (114 out of 150) and the egocentrically same axis on 19% of the trials (28 out of 150) – resulting in 95% of the trials including a response with egocentric direction or axis, with only the remaining 5% of the trials including a response with geocentric direction or axis (see Fig. 2b). At the subject-level, 28 (93%) of the 30 participants preferred rearranging the animals on an egocentrically same direction or axis after rotation, rather than on a geocentrically same direction or axis (see Fig. 2b). The preference for egocentric FoR was strikingly consistent within participants: 28 participants used egocentric direction or axis in all five trials. Only 2 out of 30 participants deviated from this pattern—one arranged the animals geocentrically (in terms of direction or axis) in all five trials, while another produced a mixed pattern with three trials with geocentric direction and two trials with egocentric direction.

This pattern of results is in stark contrast to past data from the same community collected in 2005 by Haun et al. (2011), showing 100% of the trials with a preference for geocentric direction or axis in the same task – with no egocentric responses at all (see Fig. 2b for the results of the current study compared to Haun et al., 2011).

To more directly compare our cognitive data to the data from Haun et al. (2011), we coded their data in the same way as our data, at the trial level and with the same four categories (*Egocentric Direction, Egocentric Axis, Geocentric Direction, Geocentric Axis*), and analyzed it using the same Bayesian categorical regression model, with Sample (Hai||om in 2005 from Haun et al., 2011 and Hai||om in 2023 in current Study 1) as a fixed effect.

Our model results showed very strong evidence for a population-level preference for egocentric FoR over geocentric FoR in the current study: the 95% HPD interval for the difference in posterior predictive probabilities between Egocentric Direction and Geocentric Direction outcomes excluded zero, with a posterior mean difference of 0.74 favoring Egocentric Direction (95% HPD interval: [0.63, 0.84]). The posterior mean estimate was 0.77 for Egocentric Direction (95% HPD interval: [0.68, 0.86]), 0.16 for Egocentric Axis (95% HPD interval: [0.09, 0.24]), whereas it was only 0.03 for Geocentric Direction (95% HPD interval: [0.01, 0.07]) and only 0.04 for Geocentric Axis (95% HPD interval: [0.01, 0.06]).

Additionally, our model results revealed very strong evidence for a shift between the two studies: Hai||om participants showed a markedly stronger preference for egocentric FoR in the current data compared to the historical data. The 95% HPD interval for the difference in the probability of Egocentric Direction outcomes when comparing the current data to the historical data excluded zero ([0.66, 0.84]) and indicated a mean increase of 0.75. Overall, these results suggest a shift from a geocentric to an egocentric frame of reference in Hai||om people's spatial cognition within the two decades in between the two studies.

2.2.2. Linguistic preferences: Hai||om still prefer to talk geocentrically about small-scale space

Second, we analyzed the spatial FoR Hai||om people prefer to use for speaking, in the director-matcher task. Our numerical results indicate a preference for geocentric FoR, with 88 trials involving only geocentric language compared to 26 trials involving only egocentric language (see Fig. 2d). This result is highly similar to past data from the same village collected in 1990s by Neumann and Widlok (1996), showing a preference for geocentric language in the same task (see Fig. 2d).

Our model results also showed very strong evidence for a population-level preference for geocentric FoR over egocentric FoR: the 95% HPD interval for the difference in posterior predictive probabilities between Geocentric and Egocentric outcomes excluded zero ([0.3, 0.64]), with a posterior mean difference of 0.49 favoring Geocentric outcomes. The posterior mean estimate was 0.58 for Geocentric (95% HPD interval: [0.46, 0.7]), 0.09 for Egocentric (95% HPD interval: [0.03, 0.18]), 0.21 for Mixed (95% HPD interval: [0.14, 0.29]) and 0.11 for Object-centered (95% HPD interval: [0.06, 0.17]).

To more directly compare our linguistic data collected in 2023 to the historical data from 1990s by Neumann and Widlok (1996), we coded their open-access data in the same way as our data, at the trial level, and analyzed it using the same Bayesian categorical regression model that we fit to our current data. Our results did not show strong evidence for a historical change in any of the relevant language categories. Critically, unlike what we observed in the cognitive task, we did not observe a greater preference for egocentric FoR in language: the 95% HPD interval for the difference in the probability of Egocentric outcome when comparing the current to the historical data did not exclude zero ([−0.22, 0.09]) and had a negative posterior mean (−0.05).

Similarly, none of the other language types showed evidence for historical change. Neither using geocentric language nor using a mixture of geocentric and egocentric language was more likely in the current data compared to the historical data. The 95% HPD interval for the difference in the probability of Geocentric outcome when comparing the current to the historical data included zero (posterior mean difference of 0.24; 95% HPD interval: [−0.05, 0.51]). The 95% HPD interval for the difference in the probability of Mixed outcome when comparing the current to the historical data also included zero (posterior mean difference of 0.07; 95% HPD interval: [−0.08, 0.19]). Overall, our results show a clear stability in Hai||om people's preferences to talk geocentrically.

2.3. Discussion

Hai||om people from rural Namibia have traditionally been described as strong users of geocentric FoR in both language (Neumann & Widlok, 1996) and cognition (Neumann & Widlok, 1996; Haun et al., 2006; Widlok, 2007; Haun & Rapold, 2009; Haun et al., 2011). In Study 1, we returned to the same village about two decades later with the aim to conceptually replicate these findings using adaptations of the original linguistic (Neumann & Widlok, 1996) and cognitive (Haun et al., 2011) tasks. Contrary to earlier results, contemporary Hai||om participants displayed a clear preference for egocentric FoR in the cognitive task, while their linguistic preferences remained predominantly geocentric. Our unique historical comparison therefore suggests that cognitive change in spatial FoR preferences can occur in the absence of linguistic change in the same domain.

Using close adaptations of the original task, we observed a difference in cognitive preferences among the Hai||om across two time points, suggesting that the group has undergone a change in their spatial cognition over time. However, there could be an alternative explanation: The cognitive differences could potentially reflect differences in sampling or measurement across the two time points, rather than a true historical change in the underlying cognitive system. First, Haun et al. (2011; Experiment 1) tested children aged between 7 and 11, whereas we tested adults aged between 23 and 66. Second, even though we used a very close adaptation of the animals-in-a-row task in Haun et al. (2011), there were small differences between the tasks across the two time points: Participants were standing in Haun et al. (2011), whereas they were sitting on a chair in the current study; participants had to walk 20 m between the tables in Haun et al. (2011), whereas they had to walk about 5 m between the tables in the current study; participants had one practice trial in Haun et al. (2011), whereas participants had practice trials before each trial in the current study, to aid memory for the older participants. In principle, it is possible that some of these differences could lead to our failure to replicate the results of Haun et al. (2011).

However, we believe these sampling and measurement differences are unlikely to cause a complete reversal in frame of reference preferences across two time points. First, we consider it very unlikely that the higher average age of participants in the current study explains the stronger egocentric preference. Previous research tested Hai||om adults on the animals-in-a-row task (Neumann & Widlok, 1996) as well as on several other spatial tasks (Haun et al., 2006; Widlok, 2007), and consistently found a robust preference for geocentric FoR across ages. Second, the measurement differences are unlikely to explain the cognitive differences observed across the two time points, since Hai||om preferred geocentric FoR in both in different versions of the animals-in-a-row task (Haun et al., 2011; Neumann & Widlok, 1996) and also in other cognitive tasks, regardless of differences in measurement (Widlok, 2007; Haun et al., 2006; Haun & Rapold, 2009; Haun et al., 2011; see Table 1 in supplemental materials for a summary of measurement differences across all studies that measured Hai||om people's cognitive preferences in frames of reference).

Despite these considerations, only by doing a direct replication of the original study, we can be sure that what we measure reflects a true cognitive change, rather than a failure to replicate due to sampling or measurement differences. Therefore, we went back to the same village in 2025, two years after Study 1, to do a direct replication of Haun et al. (2011). We tested both age-matched participants (children aged 7–11) and retested some of the original participants of Haun et al. (2011) now as adults two decades later in the same paradigm.

3. Study 2

3.1. Method

3.1.1. Participants

Twelve children (4 female; 8 male) aged 7–11, matched to the age and sex of the participants in Haun et al. (2011), took part in Study 2. In addition, 9 of the 12 individuals (4 female; 5 male) originally tested in 2005 by Haun et al. (2011) were re-tested as adults two decades later, in 2025. The remaining three participants had permanently moved away from the village, so could not be tested.

3.1.2. Procedure

We conducted a direct replication of the animals-in-a-row task from Haun et al. (2011) Experiment 1, using the same instructions, procedure, and setup, in the same location, and even with the very same individuals. The task involved memorizing a spatial array, a row of toy animals, and reconstructing the spatial array at a different location from memory (see Fig. 3). We tested the participants in the same location as in Haun et al. (2011) with two tables placed on opposite sides of the school building in the village.

Participants watched an instruction video explaining the game, recorded by a teacher at the local school. The instruction video was a direct replica of the instruction video used by Haun et al. (2011), but recorded with a new teacher. The instructions stated that an array of toys would be placed on a table and that they should pay attention, because the toys would be removed and they would be asked to rebuild the arrangement later.

Just like in Haun et al. (2011), participants were standing and always facing South during memorisation at Table 1 and were then guided around the school to Table 2, where they always stood facing West, therefore rotated 90 degrees relative to their facing direction at Table 1 (see Fig. 3).

Because we were unable to obtain the exact animal toys used by Haun et al. (2011), we employed the same animal arrays used in Study 1. The animal toys we used were nevertheless used in another experiment reported in Haun et al. (2011), where they produced very similar results. Each trial started at Table 1, with the experimenter placing three out of four animals (e.g. a tortoise, an elephant, a rooster, a cow) on a spatial array on Table 1 — all facing either right/West or left/East of the participant (see Fig. 3 for an example spatial array on Table 1). After participants indicated that they had memorized the arrangement of the animals, the experimenter removed the animals and guided the participant to Table 2. The experimenter placed all four animals on Table 2 in a pile. Participants completed 5 trials, each involving a different array of animals, presented in a random order. Participants' spatial reconstructions of the array of toys (5 responses per participant) were categorized according to their frame of reference, following the same coding scheme as in Study 1.

3.1.3. Analyses

To analyze the frame of reference Hai||om prefer to use in the animals-in-a-row task, we fit a Bayesian categorical regression model to our data at the trial level, with 5 trials per participant. Our categorical outcome variable had four possible values: *Egocentric Direction, Geocentric Direction, Egocentric Axis,* and *Geocentric Axis*. We included random intercepts for participants. We included a fixed effect of Sample as a dummy variable to test for differences in the categorical outcome across the three samples: (i) The historical sample from 2005 by Haun et al. (2011) Experiment 1, (ii) the current age-matched sample from 2025 (Study 2), and (iii) the current participant-matched sample from 2025 (Study 2).

3.2. Results

3.2.1. Direct replication of cognitive preferences: Hai||om are more egocentric compared to the past

We analyzed the spatial FoR Hai||om people prefer to use for thinking in a direct replication of the paradigm used by Haun et al. (2011; Exp. 1) in two samples: children of the same age as the original study and adults who are the very same people tested by the original study. Our numerical results showed no clear preference for egocentric or geocentric FoR in neither of the two samples: At the trial level, children preferred egocentric direction on 47% of the trials (28 out of 59) and the egocentric axis on 8% of the trials (5 out of 59) – resulting in 55% of the trials including a response with egocentric direction or axis, with the remaining 45% of the trials including a response with geocentric direction or axis. Similarly, adults preferred egocentric direction on 30% of the trials (13 out of 43) and the egocentric axis on 14%

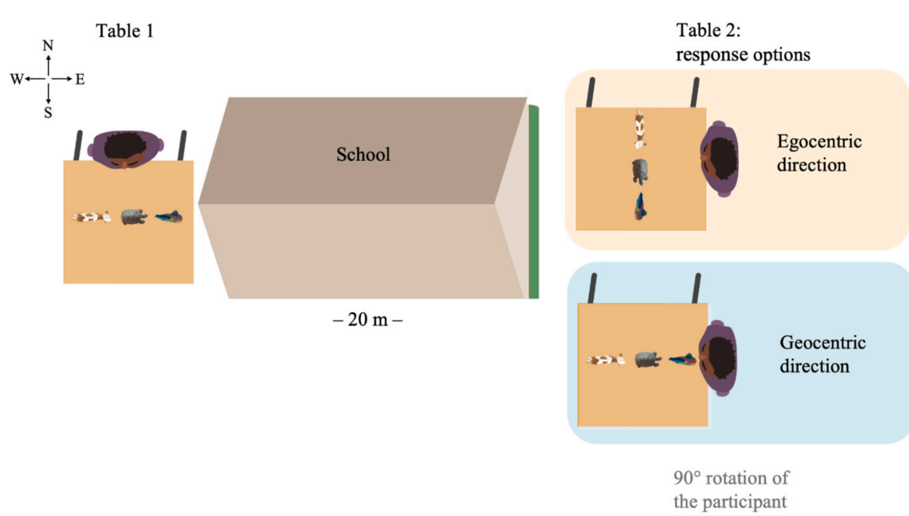

Fig. 3. Experimental setup for Study 2.
Note. Participants were presented with a spatial array on Table 1, were then guided around the school to Table 2, where they were rotated 90° and asked to reproduce the array on Table 2.

of the trials (6 out of 43), with the remaining 56% of the trials including a response with geocentric direction or axis (see Fig. 4).

At the subject level, responses were relatively evenly distributed across FoR types. Of the 12 children, 6 produced exclusively egocentric responses (axis or direction), 3 produced exclusively geocentric responses, and 3 showed a mixture. The same pattern appeared among the 9 adults: 3 responded only egocentrically, 3 only geocentrically, and 3 gave mixed responses.

Our model results likewise provided no evidence for a clear FoR preference in either contemporary Hai||om children or adults. The 95% HPD intervals for the differences in posterior predictive probabilities between Geocentric Direction and Egocentric Direction responses included zero (children: [−0.27 to 0.53]; adults: [−0.5, 0.3]). For children, the posterior mean estimate was 0.47 for Egocentric Direction (95% HPD interval: [0.24, 0.69]), 0.09 for Egocentric Axis (95% HPD interval: [0.03, 0.21]), 0.32 for Geocentric Direction (95% HPD interval: [0.14, 0.54]), and 0.12 for Geocentric Axis (95% HPD interval: [0.05, 0.23]). For adults, the posterior mean estimate was 0.3 for Egocentric Direction (95% HPD interval: [0.13, 0.54]), 0.14 for Egocentric Axis (95% HPD interval: [0.04, 0.29]), 0.43 for Geocentric Direction (95% HPD interval: [0.21, 0.66]), and 0.12 for Geocentric Axis (95% HPD interval: [0.05, 0.23]).

Although the current samples show no overall preference for either frame of reference, the frequency of egocentric responses among both children and adults contrasts sharply with data collected in the same village in 2005 by Haun et al. (2011), where not a single egocentric response was observed. Notably, 67% of the same individuals who responded exclusively geocentrically in 2005 now produced at least some egocentric responses (axis or direction) twenty years later (see Fig. 4).

Our model results likewise provided strong evidence for a shift toward a greater preference for an egocentric FoR—both among children matched in age to those in the original study and among the very same individuals retested two decades later. On average, the posterior probability of Egocentric Direction outcome showed a mean increase of 0.45 when comparing contemporary Hai||om children compared to children of the same age in 2005 (the 95% HPD interval [0.22, 0.67], excluding zero). A similar pattern emerged in the longitudinal comparison: the same individuals tested again after 20 years showed a mean increase of 0.28 (95% HPD interval [0.11, 0.51], also excluding zero). On the other hand, the two contemporary samples were not different from each other in terms of Egocentric Direction: The 95% HPD interval for the difference in posterior predictive probabilities of Egocentric Direction between contemporary Hai||om children and adults included zero ([−0.17, 0.45]). Overall, these results point to a clear shift toward greater use of egocentric FoR in Hai||om people's spatial cognition over

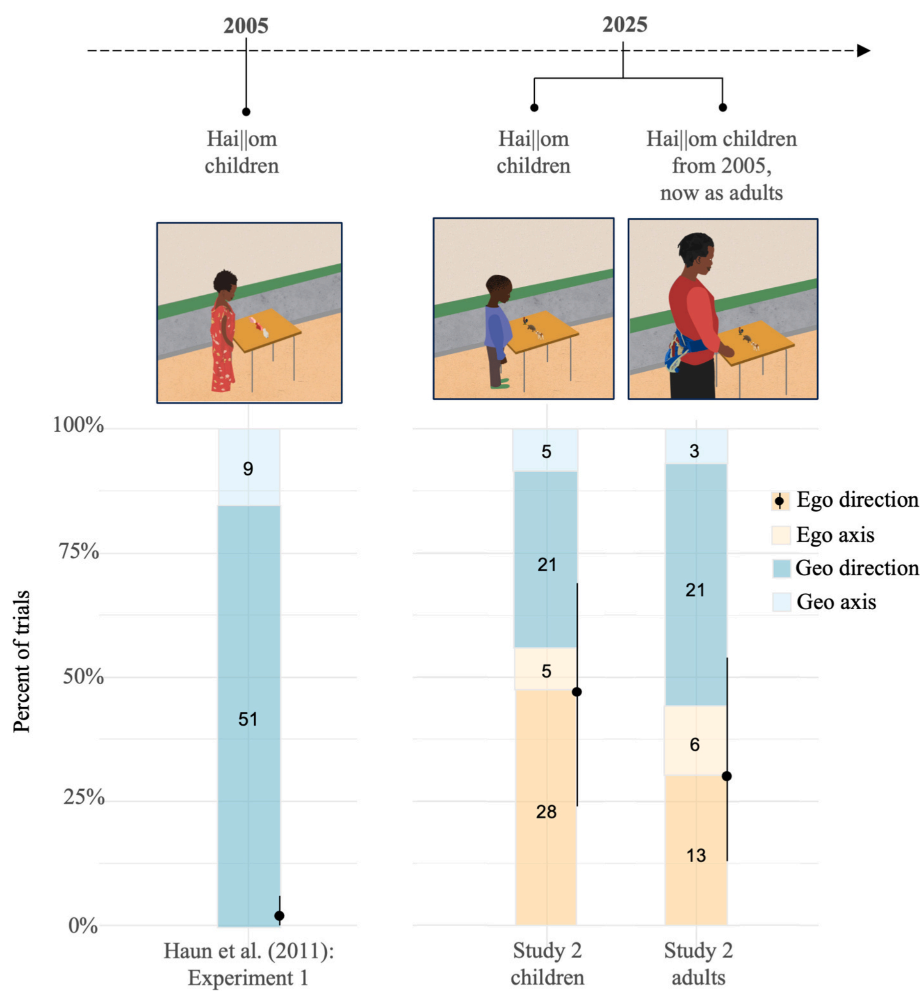

Fig. 4. Study 2: Hai||om's preferred spatial frames of reference in cognition across time in direct replications of the same task.
Note. Historical comparison of Hai||om people's cognitive preferences in the animals-in-a-row task as reported in Haun et al. (2011) and two direct replications of it in Study 2. Three samples are compared: (i) Hai||om children in 2005 as reported in Haun et al. (2011; Experiment 1), (ii) Hai||om children in 2025 tested in a direct replication of the original paradigm by Haun et al. (2011), age-matched to the children in the original study, and (iii) Hai||om adults in 2025 retested twenty years later in a direct replication of the original paradigm by Haun et al. (2011). Error bars show the 95% highest posterior density intervals from the brms model for the Egocentric Direction outcome.

the two decades between the studies.

3.3. Discussion

Study 2 aimed to determine whether the greater preference for egocentric thinking observed among contemporary Hai||om in Study 1 reflects a genuine cognitive change, or whether it resulted from a failure to conceptually replicate earlier findings due to sampling or measurement differences. To address this, in Study 2, we aimed to directly replicate Haun et al.'s (2011) cognitive task, testing both age-matched children (7–11 years) and the original participants now as adults. We found robust evidence that Hai||om exhibit a stronger preference for egocentric frames of reference than was observed two decades earlier.

Unlike in our conceptual replication in Study 1, our direct replication in Study 2 did not reveal an overall preference for egocentric FoR. Why might this be? As we noted earlier, the two task versions differed in several seemingly minor ways—such as participant posture (sitting vs. standing), the distance walked before recall, and the number of practice trials. Any of these methodological differences could, in principle, have changed how participants construed the spatial relationships and thereby increased or decreased their reliance on an egocentric FoR. For example, sitting in a chair in Study 1 might have promoted egocentric responding because, after rotation, the chair turns with the participant and may highlight the chair, thus the sitter's own perspective. However, without additional targeted testing, we cannot determine which of these factors, if any, played a role in shifting participants toward greater egocentric FoR use.

Even if our direct replication in Study 2 did not reveal an overall preference for egocentric FoR, the frequency of egocentric responses among both children and adults contrasts sharply with the 2005 data, where not a single egocentric response was recorded. Notably, twenty years later, the majority of individuals who had responded exclusively geocentrically as children now produced at least some egocentric responses as adults. Overall, this direct replication suggests that egocentric spatial thinking among Hai||om has increased over the last two decades.

One possible alternative explanation is that the earlier findings were less robust than assumed, raising the possibility that Hai||om were never strongly geocentric to begin with and that the observed difference reflects a replication failure rather than genuine cognitive change. This explanation, however, is difficult to sustain given the breadth and consistency of the existing literature. The established claim that Hai||om prefer geocentric FoR is supported not by a single experiment that we failed to replicate here, but by a substantial body of data across five published articles. Even just the article by Haun et al. (2011) does not only include one experiment that we reanalysed here, but includes additional experiments, all of which showing a preference for geocentric FoR in Hai||om children. Additionally, beyond Haun et al. (2011), Hai||om people consistently showed geocentric preferences across different versions of the animals-in-a-row task (Neumann & Widlok, 1996) and a range of other spatial reasoning paradigms—including spatial rule learning tasks (Haun et al., 2006), a spatial inference task (Widlok, 2007), and a task measuring memory for body movements (Haun & Rapold, 2009). Although our comparison focuses on Experiment 1 of Haun et al. (2011), chosen for its classic task design and clear methodological documentation, our interpretation rests on a cumulative body of evidence rather than on any single dataset. So, the claim that Hai||om spatial cognition may have shifted over time does not hinge on the non-replication of one experiment; rather, it arises from the striking contrast between a comprehensive contemporary sample and decades of geocentric preferences documented in the same village.

4. General discussion

Human cultures differ in how they think about space: some primarily use egocentric frames of reference, thinking about space in relation to the body, while others privilege geocentric frames, thinking about space in relation to the environment. Despite extensive cross-cultural documentation of this variation, its origins remain poorly understood. Here, we provide unique historical evidence offering a window into how such cultural differences may arise. Specifically, we showed that a traditionally geocentric community, the Hai||om of rural Namibia, has shifted toward a greater preference for egocentric thinking over the past two decades, a change that occurred in the absence of any corresponding change in language.

Given the widespread preference for egocentric spatial thinking among urban populations worldwide, and the absence of such a preference in many rural populations, it has been suggested that egocentric spatial thinking is a historically recent phenomenon, spreading primarily with the rise of urbanized societies (Bohnemeyer et al., under review). Across two studies, we indeed find evidence for such cognitive change. In Study 1, Hai||om adults across a broad age range showed a stronger preference for egocentric frames of reference in a conceptual replication of the classic animals-in-a-row task, which had previously revealed robust geocentric preferences in this community (Haun et al., 2011; Neumann & Widlok, 1996). In Study 2, we directly replicated one of the earlier studies, testing age-matched children (7–11 years) as well as the original participants two decades later (now adults). Both groups showed a greater preference for egocentric thinking compared to the past. Together, these findings provide the first historical evidence of a rural population undergoing measurable change in spatial cognition and lend support to the proposal of an ongoing global shift toward egocentrism.

If there is indeed a worldwide shift toward egocentrism, what experiences may lead communities to adopt egocentric FoR for thinking about small-scale space? The most influential idea of what makes some human groups egocentric thinkers has been the 'Whorfian' hypothesis: Preferring to talk egocentrically causes people to also prefer to think egocentrically. Here, we documented a divergence between language and thought over time which goes against the predictions of the 'Whorfian' hypothesis. In Study 1, contemporary Hai||om showed a greater preference to use egocentric FoR to think about small-scale space, showing a clear difference compared to their preference for geocentric spatial thinking in the past (Neumann & Widlok, 1996; Widlok, 2007; Haun et al., 2006; Haun & Rapold, 2009; Haun et al., 2011). However, the rise in Hai||om people's egocentric thinking cannot be explained by a shift to egocentric language: In Study 1, the same people who preferred to use egocentric frames of reference for *thinking*, preferred to use geocentric frames of reference for *speaking* about small-scale space, with no increase in their use of egocentric language compared to the past. Our unique historical comparison therefore suggests that cognitive change in spatial FoR preferences can occur in the absence of linguistic change in the same domain.

The Whorfian claim that linguistic differences drive cognitive differences in spatial FoR relies on a mere correlation: Communities that prefer egocentric language also prefer egocentric cognition (but see Li et al., 2011). But, this correlation leaves open many possibilities, namely that language may simply reflect rather than cause egocentric cognition, or that a third variable might shape both language and cognition. To date, the available data came from comparisons across different cultural groups: For example, comparing an urban European society to a rural, hunter-gatherer community in Africa (Haun et al., 2011). This approach holds merit, but between-group comparisons limit causal inference: Cultural groups differ in many, uncontrolled ways and differences in language is only one among them.

Here, rather than comparing across cultures, we compared spatial FoR preferences across time within the same culture. This unique historical contrast narrows down the possible causal mechanisms, allowing us to focus on a limited set of cultural changes within the Hai||om community as potential drivers of cognitive change. Cognitive science rarely has the opportunity to examine how cognitive systems change over time, but such cases are essential for understanding the origins of cross-cultural variation in cognition (Muthukrishna et al., 2021). Our results show that linguistic change is not the driver of contemporary Hai||om's increasingly egocentric thought, suggesting that the widely observed correlations between language and cognition may instead be due to a third variable shaping both language and cognition, but at different rates – with cognition changing more rapidly than language. Alternatively, a third variable could shape cognition, which can then shape language – with cognitive change driving language change, rather than vice versa.

Our findings do not rule out the possibility that language shapes cognition in spatial frames of reference. It is possible that in other communities around the globe, adopting a certain linguistic practices might drive a preference to think egocentrically, or at least strengthen existing cognitive preferences. Nevertheless, our results do offer evidence against a strong 'Whorfian' view in which language is the primary driver of cognitive diversity in spatial frames of reference. This point is important because influential accounts have argued that linguistic variation outweighs non-linguistic factors—such as differences between rural and urban environments—in explaining cross-cultural patterns in frame use (e.g., Levinson, 2003; Majid et al., 2004). More broadly, spatial frames of reference are frequently cited as a canonical case of how language shapes cognition (see Blasi et al., 2022). Against this backdrop, our case study provides a powerful counterexample: for the first time, we observe a community shifting its cognitive frame of reference without a corresponding change in language. This pattern suggests that language is neither the sole—nor necessarily the primary—force shaping diversity in spatial frames of reference and that we need to look beyond language to understand cognitive diversity in this domain.

If it is not language, what might explain the rise of egocentric thinking among Hai||om, then? Apart from language, living in an urban environment has been found to be associated with using egocentric FoR both in language and cognition (Dasen & Mishra, 2010; Marghetis et al., 2024; Pederson, 1993, 1995). But, it remains unclear what specific aspects of urban life may promote egocentric thinking. Many claimed that increased literacy associated with urbanism might promote egocentric language and thought, because learning to read and write would enhance distinguishing egocentric directions (Brown, 2006; Li & Gleitman, 2002). There are some communities, such as Tamil speakers, where being literate correlates slightly with greater use of egocentric FoR for thinking (Levinson, 2003), but not leading to an overall preference of egocentric FoR. However, other communities, such as Tzeltal, Kgalagadi and Yucatec, show no such correlations between literacy and egocentric FoR (Levinson, 2003). In current Study 1, nearly all of the Hai||om participants were illiterate, but they overwhelmingly preferred egocentric thinking. Therefore, literacy cannot by itself explain why contemporary Hai||om think more egocentrically and why urban populations around the world show a clear preference for egocentric FoR.

If literacy cannot be the whole story, then what other aspects of urban life may promote egocentric thinking? Literacy is only a small aspect of how urban, industrialized environments are structured egocentrically. Many other cultural artifacts, such as roads, cars, house appliances, photos, maps or screens, have been proposed to promote egocentric thinking (Bohnemeyer et al., under review; Li & Gleitman, 2002; Neumann & Widlok, 1996; Pitt et al., 2022).

We can categorize these cultural artifacts into two kinds to understand how they might require or encourage egocentric thinking. The first are cultural artifacts that make egocentric distinctions meaningful: For example, to go on the road, you should always travel on the same egocentric side of the road (i.e., left or right, depending on the country). Urban environments are filled with cultural artifacts where an egocentric side has an important meaning: Riding a car requires sitting on the left side, reading a book requires turning the pages rightward, turning up the volume on the radio requires turning the dial rightward, seeing the next photo on a smart phone requires swiping right.

The second category of cultural artifacts does not necessarily give different meanings to egocentric directions, but they represent space from an egocentric perspective. A good example of this is photos (others are drawings, screens). Unlike a road, the left side of a photo does not have a different canonical meaning compared to the right side of a photo. However, photos can still encourage egocentric thinking because they present spatial layouts from a single, fixed viewpoint. Moreover, this viewpoint must always be aligned with the viewer's own: a photo has one correct, body-oriented orientation and is therefore consistently encountered in the same egocentric relation to the viewer.

Hai||om people, like many other indigenous populations, are nowadays increasingly exposed to egocentric material culture coming from urban centers. Relevant to our case, a primary school was established in 2002 in Mangetti West, which brought to this community a lot of egocentric cultural artifacts (e.g. books, maps) that previously were not part of everyday life. Additionally, travel to and from the urban centers is more common compared to the past due to the efforts of the Namibian state to register Hai||om (Widlok, 2023). This increased interaction with the urban centers led to a greater exposure to egocentric cultural artifacts such as cars, roads, and many more. Another recent change in material culture is the higher presence of screens in the community, especially among the young (Bohn et al., 2025). Having more interaction with egocentric cultural artifacts, Hai||om might suspend their geocentric ways of thinking about these artifacts. This could then potentially lead to the use of egocentric FoR even when not interacting with these artifacts, and make egocentric FoR a general strategy to think about small-scale space.

4.1. Conclusions

Why do human cultures differ in how they think about space, and in particular, what factors cause some human groups to prefer an egocentric FoR? We observed a historical contrast in FoR preferences among Hai||om people, a rural forager community in Namibia: Compared to past data, contemporary Hai||om participants showed a greater preference for egocentric FoR in their cognition, but not in their language. The presence of a potential cognitive change in the absence of a linguistic change undermines the role of language in promoting egocentric thinking, therefore shows that Whorfian views are insufficient on their own to explain cognitive diversity in spatial frames of reference. We suggest that increased exposure to egocentric material culture from urban centers may foster egocentric thinking for Hai||om, potentially also driving the rise of egocentric thinking around the world.

Research transparency statement

Preregistration: No aspects of the study were preregistered. Materials: Study materials are publicly available (https://osf.io/chvwt/?view_only=881f7c8c3fc54df6881b79f2ff71ed0e). Data: All primary data are publicly available (https://osf.io/chvwt/?view_only=881f7c8c3fc54df6881b79f2ff71ed0e). Analysis scripts: All analysis scripts are publicly available (https://osf.io/chvwt/?view_only=881f7c8c3fc54df6881b79f2ff71ed0e).

CRediT authorship contribution statement

Yağmur Deniz Kısa: Writing – review & editing, Writing – original draft, Visualization, Supervision, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Roman Stengelin:** Writing – review & editing, Supervision, Resources, Project administration. **Luke Maurits:** Writing – review & editing, Software, Formal analysis, Data curation. **Daniel B.M. Haun:** Writing – review & editing, Supervision, Resources, Methodology, Funding acquisition, Conceptualization.

Ethics approval

The study obtained ethical clearance from the MPG Ethics

Commission in Munich, Germany, under an umbrella ethics application (Application No. 2021_45). The research was also approved by the Namibian San Council and the Namibian Commission on Research, Science and Technology (permit number RPIV01112021).

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used Google Docs' spell and grammar check features in order to correct typos and ChatGPT to provide language editing suggestions for increasing clarity. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

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Declaration of competing interest

Authors declare no conflicts of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cognition.2026.106522.

Data availability

I have shared the link to the data and analysis files in the manuscript.

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