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Understanding cultural variation in cognition one child at a time

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Cross-cultural developmental research is crucial for understanding the roots of human cognition. Although group-level analyses can reveal how culture co-varies with cognition, individual-level analyses are needed to discern how specific cultural and ecological factors influence cognitive development.

As humans develop, their cognitive systems respond to external inputs. Developmental trajectories and outcomes therefore co-vary with specifics of the ecological and cultural environment, and are shaped in part by the affordances of local living conditions. For instance, the developmental timing of the acquisition of skills such as reading and writing is usually determined by the structure of formal education, and children in small-scale societies acquire botanical knowledge earlier than children in industrialized societies — presumably because they are involved in foraging for food from a very young age[1]. Cognitive development also reflects cultural norms and beliefs. For example, gross motor development varies with cultural beliefs about the need for early stimulation during caregiving routines[2], and the development of false belief reasoning is related to variations in local norms concerning public discourse around the mental states of others[3].

Analyses of cultural differences in cognition and cognitive development are usually conducted at the group level. They typically postulate the universality of cognitive developmental processes whenever variation across communities is small, and variability in cognitive developmental processes whenever variation across communities is large. However, the distribution of cognitive measures across cultures alone says little about the developmental processes that happen in individual children; to understand how cognitive systems adapt to the cultural environment, individual cognition must be linked with individual experience.

Children's everyday experiences differ markedly across cultures. Factors such as climatic, economic and political conditions influence housing, public infrastructure and the nature of extramural childcare and formal education. For instance, the availability of educational programmes influences the time that children spend with family members[4]. Moreover, cultural norms, values and beliefs influence how children interact with the world around them. For example, the amount of time for which children interact with the world — the time they spend awake versus sleeping — is influenced by cultural practices[5]. Cultural norms and beliefs also influence the emergence of prosocial and helping behaviours[6] and the context in which children learn language. For example, in the Tseltal Mayan community, parents do not regularly speak to their children before they begin to talk themselves[7], whereas American parents regularly directly address their children before they can speak[8].

A prevailing challenge in understanding these cultural influences is the predominance of aggregate-level descriptions: 'children in community X experience more A compared to children from community Y'. Of course, individuals who are exposed to the same or similar ecological and cultural environments necessarily share more experiences than those who inhabit different ones — shared environments create experiential clusters. Nevertheless, there are still substantial differences in experience between children growing up in the same cultural communities, and children growing up in historically and geographically distant cultural settings might share certain experiences associated with similar cultural ecologies (for example, subsistence styles or social organization). Moreover, cultural settings are multifaceted, and myriad dimensions might influence cognitive development. Thus, attributing cognitive variation to a single environmental or cultural dimension in group comparisons can only ever be speculative.

From group-level to individual-level variation

To quantitatively assess the influence of environmental variables on cognitive development, researchers need to move to the individual as the main level of analysis and examine the distribution of individual differences within and between cultural settings. If researchers want to claim that experience A causes behaviour B because communities X and Y differ in their prevalence of A and B, then the correlation between A and B should hold within each community (Fig. 1a). In other words, if experience directly influences cognitive development, the relationships observed across cultural settings should also manifest within cultural settings.

This general statement needs to be qualified, because the way in which individual differences are distributed within settings is key for interpretation. For example, if researchers were to find that spatial navigation skills co-vary with urbanization on a group level, they might infer that spending time in nature increases navigational skills. If they were then to find that this relationship is absent across individuals within each cultural setting, there are two options. If the within-group variation in experience is very small, they might conclude that all people who live in this setting have highly similar spatial experiences that are also markedly different from experiences in other settings, so the original interpretation still holds (Fig. 1b). However, if they were to find substantial overlap between distributions of experience from different settings, the original interpretation becomes implausible because the same amount of experience with nature would lead to different navigation skills in different cultures (Fig. 1c). To be clear, the absence of an individual-level association does not explain away the group-level association between the two variables; it only suggests that the implied developmental interpretation — the more time an individual spends in nature, the better their navigational skills — does not hold.

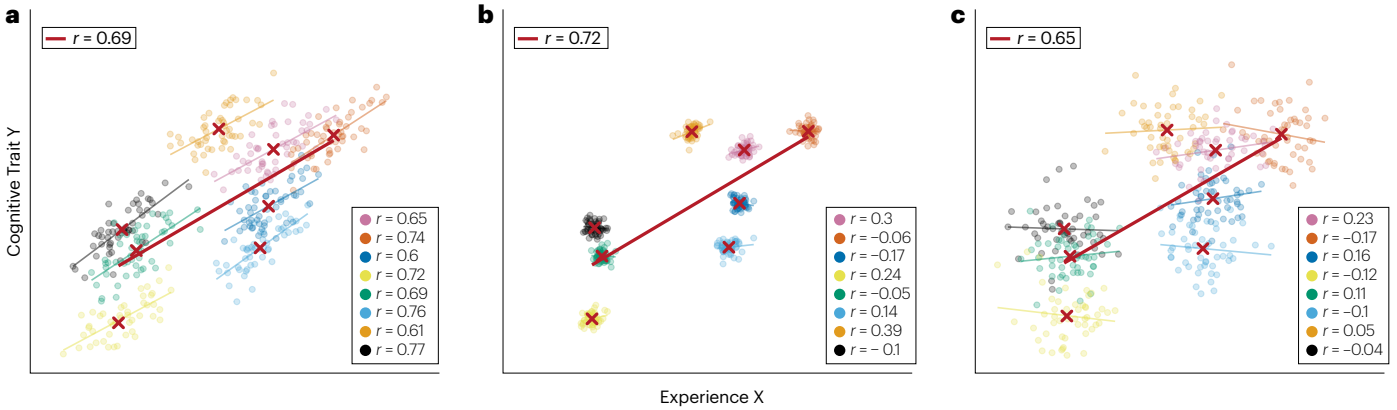

Fig. 1 | Relationships between variables within and between cultural settings. **a**, Between-setting and within-setting variation are aligned. **b**, Between-setting and within-setting variation are not aligned, and within-setting variation is small. **c**, Between-setting and within-setting variation are not aligned, and within-setting variation is large. Transparent dots show simulated individual data points; colour denotes hypothetical cultural settings; and coloured lines show associations between variables within settings. Red crosses show setting-level averages and the red line shows the association across settings.

In some cases, the relationship between two variables within a cultural setting might even be inverse to that observed across cultural settings (Simpson's paradox). Such cases are important to detect and highlight, because they suggest that the individual developmental processes might be different from what the group-level comparison suggests. For example, whereas a positive group-level association between physical exercise and inhibitory control suggests that children who exercise more have better inhibition, a negative individual-level association would show the exact opposite.

Adopting an individual-level approach also has a crucial advantage for causal inference. Studies that compare cultural groups are necessarily quasi-experimental because groups always differ along multiple — potentially co-varying — dimensions, and participants cannot be randomly assigned to culture. For example, groups that differ in subsistence style are also likely to differ in the prevalence of formal education. Causal designs such as longitudinal studies or experimental interventions are much easier to implement on an individual level within groups than for entire groups across settings. Cross-cultural studies can then be used to test the generalizability of causal relationships.

Finally, large-scale cross-cultural studies often use methods originally developed in one setting without thoroughly addressing their appropriateness in others. By shifting emphasis from absolute comparisons across societies — which requires standardized measures — to relative comparisons, researchers gain the flexibility to use or design measures that are tailored to each setting. The focus then lies not on group-level differences but on whether the relationship between different culture-sensitive measures holds across settings[9].

Linking experience and cognition at scale

Cultural groups represent average points within experiential distributions; these averages are accompanied by substantial variability and are embedded within a broader, overarching distribution across all real and hypothetical populations. From this perspective, studying different cultural settings increases the range and diversity of interindividual differences in children's lived experiences. However, detailed insights into the nature of these experiences is lacking — even (or especially) within settings that are commonly studied in the developmental literature, such as urban middle-class families from university towns in the USA or Europe. Drawing inspiration from the effect that genotyping had on evolutionary biology, we suggest an individual-level, phenotyping approach to understanding everyday experience. This approach would focus on defining cultural experience from direct, firsthand accounts (for example, the real frequency of social interaction seen in daylong video recordings) instead of relying on aggregate measures or indirect reports (for example, the opportunities for social interaction approximated by the number of household members reported in a questionnaire). Such an approach promises theoretical advancement: constructing universal models of developmental processes necessitates verifying whether the hypothesized relationships between specific drivers (experiences) and their corresponding outcomes (developmental trajectories) are consistent across diverse cultural settings.

However, there are challenges to implementing such an individual-level approach. Phenotyping experience on an individual level works best when experience is continuously recorded for long periods of time in situ. Traditional stationary cameras or microphones placed in fixed locations in a room might work for recording specific experimental sessions or observing behaviours in a fixed space but become impractical when trying to capture behaviour in naturalistic settings. In many communities, a large part of children's experience occurs outside, in public. Recording devices need to be mobile and move around with the child. Advances in wearable technology, such as small and durable cameras, audio recorders and even eye trackers, now make this feasible.

If researchers succeed in collecting experiential data in situ, the practicality of data analysis will present another problem, given the sheer volume of data. Machine learning and computer vision methodologies can address this challenge by efficiently identifying patterns of interest in extensive audio and video data. Indeed, the introduction of the LENA (Language Environment Analysis)[10] device, with its small recording unit and automated processing algorithms, had a transformative effect in the field of language acquisition. There are now international cross-cultural collaborations that are aimed at understanding the linguistic environments of children in different cultural settings[11]. Concurrently, other research aims to capture children's visual experiences, which offers further depth to our understanding of children's everyday experiences and the links to cognitive development[12,13].

However, phenotyping experience represents only half of the equation; the subsequent challenge lies in accurately measuring cognitive development. Alarmingly, measures used in research on early cognitive development, particularly in cross-cultural contexts, frequently have unknown psychometric properties and characteristics (such as a small number of trials, single conditions tested in between-subject research designs, and a lack of variation in trial difficulty) that probably compromise their ability to capture individual differences accurately[14]. If the bulk of developmental measures capture predominantly noise, then the extent to which they can be meaningfully related to aspects of everyday experiences is limited. Thus, researchers need to

seriously invest in developing new methods, and put the implications of cross-cultural data collection centre stage when doing so.

In sum, the cost and challenges associated with an individual-level perspective on development across cultures are well worth bearing given the insights the approach offers: understanding how and why individuals differ from one another is the key to understanding the structure and ontogenetic origins of the human mind.

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Competing interests

The authors declare no competing interests.