

# A universal of human social cognition: Children from 17 communities process gaze in similar ways

## Supplemental material

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## Participants

A total of 1377 children between 2.38 and 10.95 provided data for the study. Children lived in 17 different communities, located in 14 different countries. Table 1 gives the sample size per community together with some basic demographic information. The recruitment strategy for each community is reported in the respective site descriptions. Figure 1A shows the age distribution in each setting. For some children, the

Supplementary Table 1: Participant demographics.

Community	Country	Continent	N	Sex (male)	Age (range)
Buenos Aires	Argentina	Americas	105	53	4.72 ( 3.00 - 6.96 )
Ocuilan	Mexico	Americas	127	63	4.96 ( 2.57 - 6.95 )
Stanford	USA	Americas	98	54	4.99 ( 2.52 - 7.90 )
Akure	Nigeria	Africa	114	54	5.07 ( 2.57 - 7.33 )
BaYaka	Rep. Congo	Africa	29	13	7.80 ( 3.94 - 10.56 )
Bandongo	Rep. Congo	Africa	30	11	7.45 ( 3.50 - 10.95 )
Chimfunshi	Zambia	Africa	22	5	5.98 ( 2.88 - 8.00 )
Hai  om	Namibia	Africa	60	38	5.85 ( 2.74 - 8.34 )
Khwe	Namibia	Africa	59	24	5.84 ( 3.38 - 8.63 )
Nyabyeya	Uganda	Africa	125	62	5.94 ( 2.67 - 8.92 )
Windhoek	Namibia	Africa	39	17	5.69 ( 2.66 - 8.66 )
Leipzig	Germany	Europe	100	48	4.88 ( 2.53 - 6.95 )
Plymouth	UK	Europe	70	30	6.02 ( 2.38 - 8.94 )
Beijing	China	Asia	123	62	5.47 ( 2.69 - 8.48 )
Malatya	Türkiye	Asia	85	40	5.02 ( 2.75 - 7.12 )
Pune	India	Asia	148	73	6.14 ( 3.06 - 8.83 )
Auckland	New Zealand	Oceania	43	19	5.14 ( 2.81 - 8.75 )

exact birthday was unknown. In such cases, we set the birthday to the 30th of June of the year that would make them fall into the reported age category.

Data from children was only included in the study when they contributed at least four valid test trials. We also excluded the data from children with a diagnosed developmental disorder. In sum, in addition to the sample size reported above, 74 additional children participated in the study but did not contribute data. The main reasons for exclusion were: contribution of less than four valid test trials, technical failures, and missing or implausible demographic information (e.g., when the number of children living in the household was reported to be larger than the household itself or when the number of children reported to live in the household equaled the number of children younger than the child being tested). We did not exclude any participants for performance reasons. A detailed description of each site and the way children were recruited can be found in the respective site description.

## Site descriptions

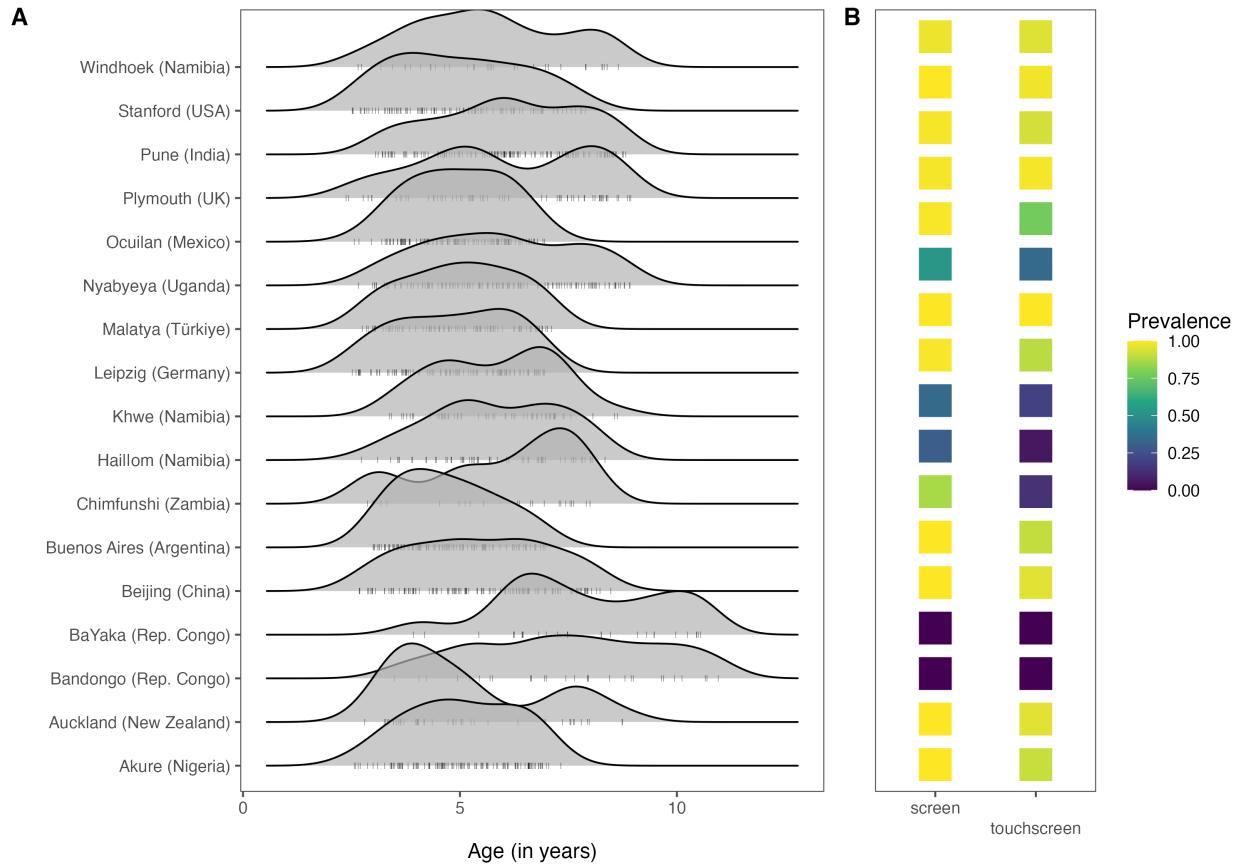
The descriptions below give detailed information about each data collection site, including the strategy used for recruiting children. The order is alphabetically.

### Akure (Nigeria) - Location

Akure is situated in the Ondo State in southwest Nigeria. About 800 000 people live in this medium-sized city. Most inhabitants moved from the nearby urban and rural areas to Akure.

There are two different seasons in Akure's tropical climate: the wet season, which runs from April to October, and the dry season, which runs from November to March. Rich vegetation, including deep forests and productive agriculture, defines the city.

Akure's natural surroundings are enhanced by the abundant vegetation that includes dense forests, farmlands, and vivid flora, which is fostered by the climate and fertile soils.



Supplementary Figure 1: A) Age distribution and B) prevalence of different types of technology by community. Left: dots show individual data points. Right: color shows the proportion of children with access to screens or touchscreens.

Akure boasts a diverse populace, representing a cultural mosaic where the Yoruba, Igbo, and Hausa communities coexist. While the Yoruba ethnicity predominates, English serves as a widely spoken language alongside the native tongue.

Over centuries, Akure has cultivated a sense of unity among its residents, transcending ethnic boundaries and nurturing a strong community spirit grounded in mutual respect and cooperation. This communal ethos extends from familial bonds – encompassing both nuclear and extended families – to broader social networks within neighborhoods, workplaces, and religious congregations. Akure's evolution from a traditional Yoruba kingdom to a thriving urban metropolis is deeply embedded in history and has a rich cultural legacy, highlighting the city's lasting influence and crucial role in the history of the area.

The primary industry of Akure is agriculture, with a large number of residents working in a variety of farming-related fields including agricultural cultivation, animal husbandry, and the extraction of palm oil. In addition to providing for livelihoods, this traditional subsistence approach maintains cultural customs and connections to the land, tying communities to their agricultural origins.

Akure offers a diverse range of housing options, including modern urban dwellings scattered across the city and ancient mud-brick homes tucked away in rural hamlets. These housing options can accommodate nuclear families, extended kin networks, and communal living arrangements.

Parents are essential in passing on cultural legacy and forming the identities of future generations because they emphasize reverence for elders, community cohesion, and the value of education. Cultural festivals, ceremonies, and rite of passage serve as platforms for imparting values and fostering social cohesion within the community.

The differences in parents' educational attainment in Akure are a reflection of their socioeconomic status and differences in access to formal education. Childcare practices often involve extended family members, particularly grandparents, who play significant roles in nurturing and guiding children. The city is home to a wide range of educational institutions including public and private schools, that provide extensive curriculum that incorporate standard academic disciplines along with enrichment and cultural education initiatives.

Akure has embraced technology in recent years, with a notable increase in digital adoption, especially among its younger population. The widespread availability of reasonably priced smartphones and other touchscreen devices has contributed to the growing integration of technology into everyday life, affecting both urban and peri-urban areas. This technological revolution has changed social interactions and cultural dynamics within the community by democratizing access to information, communication, and entertainment.

For this study, participants were recruited from churches during Sunday services and residences during community visits within the city of Akure, ensuring a wide representation of its vibrant population.

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- <https://worldpopulationreview.com/world-cities/akure-population>

#### **Auckland | Tāmaki Makaurau (New Zealand) - Location**

Auckland | Tāmaki Makaurau is the largest city of New Zealand | Aotearoa with a population of about 1.5 million people. The city is located on the North Island | Te Ika-a-Māui inbetween the Hauraki Gulf | Tikapa Moana to the East and the Waitākere Ranges to the West. The climate is defined as either oceanic (Cfb) or subtropical (NIWA). Temperatures are mild throughout the year, with an average temperature of 23.7°C during summer and 14.7°C during winter months.

The median age in the Auckland region was 34.7 years. 181 194 Māori people with a median age of 24.9 years were counted in the 2018 census. Overall the population is composed of 53.5% European, 28.2% Asian, 15.5% Pacific Peoples, 11.5% Māori, 2.3% Middle Eastern / Latin American / African and 1.1% Other ethnicity. 92.7% are English speakers, with 4.4% speaking Northern Chinese (Mandarin Chinese), 4.4% speaking Samoan and 2.4% speaking te reo Māori.

Māori peoples arrived in Auckland | Tāmaki Makaurau around 1350 from other Pacific Islands. Before the arrival of European New Zealanders | Pākehā New Zealand was populated by about 20 000 Māori. Aotearoa was colonized by the Dutch and British Empires in the 18th Century. The effects the British Monarchy had on Aotearoa have been at the center of long lasting societal disputes. The Treaty of Waitangi | Te Tiriti o Waitangi is a document signed by 240 Māori chiefs and representatives of the British Crown in 1840 trying to establish a cooperative relationship while redeeming some of the mistakes that have been made. This document is still important for the revitalization of Māori culture throughout Aotearoa.

51.9% of the people in Auckland are employed full time, with an unemployment rate of 4.1% and 30.4% retirees. The main occupations are professionals (25.9%) and managers (18.1%) with only 5.9% operating machinery and 7.9% laborers. The people of Auckland are part of a service society with a median income of 34 400NZD and 19.8% of the population earning more than 70 000NZD.

Auckland is made up of mainly sub-urban areas with single family housing. 45.4% of the population own or partly own a house. People mostly live with their core family in loosely separated areas of the city. Those areas commonly have an economical center with shops and restaurants as well as a mix of private and public education institutions. The socialization goals and cultural norms are comparable to most western, democratic societies. High education standards are deemed as vital for success. Success is determined by career paths, income and general success in professional and private aspects of life. The role of sports is viewed as essential for living a healthy and successful life and as such is a central part in education programs.

Education levels are generally high in Auckland. 18.6% of the population hold a Bachelor's degree. Interestingly, about 9.1% move overseas for their secondary education. Parenting and childcare practices are comparable to other western cultures, with some adjustments being implemented in recent years to include more Māori cultural practices in education programs. Such as starting the day or specific activities | hui with Karakia, a form of incantation to ensure a favorable outcome to important events and undertakings (see Literature for further information on early childhood education in New Zealand).

Aotearoa is an industrialized nation, nearly everybody has a smartphone and uses technology in their everyday life. Many administrative processes are digitized. There is no perceived mistrust towards technology and new developments are generally embraced with great interest.

For this study we reached out to early childcare centers and schools. Two early childcare centers and one primary school agreed to participate. Some additional children were tested during home visit sessions. All three educational institutions are visited by children from different cultural and socio-economic backgrounds. One early childcare center is affiliated with the University of Auckland and prioritizes children from University students and staff in their admission process. Testing sessions took place in separated spaces (office or break rooms) with one participant at a time. Participants received a certificate "for becoming a junior scientist" and a small gift (coloring book or sticker set) after their participation. (All numbers in the above description are from the 2018 census data report.)

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### **Bandongo and BaYaka (Rep. Congo) - Ethnic groups**

Both BaYaka and Bandongo populations live (seasonally) in a remote village located in the Likouala region of the Republic of the Congo. The Republic of the Congo is located in the central-western part of sub-Saharan

Africa along the equator. The Likouala department is located in the country's north, in the Congo River Basin, bordering the Central African Republic and the Democratic Republic of Congo. The region's climate is tropical, with temperatures ranging from 23°C to 34°C yearly and 148.73 mm of rainfall yearly (Weather and Climate, 2024). The dry season starts from December until March, with a mild, rainy season from April until August. Heavier rains happen between September and November.

The village is inhabited by approximately 300 BaYaka and 300 Bandongo people (estimates from 2019). The BaYaka and Bandongo people have co-inhabited the rain forests of the Congo basin for approximately 3,000 years (Takeuchi, 2014) and have developed inter-ethnic kin (or patronage) and commercial relationships with one another (Lewis, 2002). Despite this historical coexistence, each cultural group has distinct means of subsistence and speaks their own language; for the Bandongo, this is Bondongo (Bantu C142); for the BaYaka, this is Yaka (C104); although Lingala (Bantu C36d) is often used as lingua-franca between groups (Hammarström, 2019). The BaYaka are one of many hunter-gatherer societies living in the Congo Basin (Bahuchet, 2017). Like many other hunter-gatherer groups in the world, the BaYaka are egalitarian (Boyette & Hewlett, 2017; Woodburn, 1982), follow an autonomy foundational schema (Boyette & Hewlett, 2017), share resources and parental care (Lewis, 2016) and are characterized by an immediate-return economy with an absence of food storage techniques (Lewis, 2002). The BaYaka forage for food items in the forests they inhabit while supplementing their diets with some agricultural items (Boyette et al., 2020; Kitanishi, 1995). The Bandongo mainly rely on fishing and agriculture to obtain their nutrition (Komatsu, 1998). Although the Bandongo also practice hunting to some extent, it is mainly directed to smaller game species, often sourced with the intent to sell, while BaYaka focus on a wider range of species and bigger game for subsistence (Fa et al., 2016). BaYaka and Bandongo groups sometimes collaborate in their subsistence activities, such as hunting and fishing (Jang & Boyette, 2021; Kandza et al., 2023). Contrary to BaYaka, Bandongo live in a stratified and hierarchical society characterized by wealth accumulation and authority (Boyette et al., 2018).

In the forest camps, the BaYaka inhabit temporary houses (called mongulo or ekuta, depending on the region) built with Marantaceae leaves, lianas, palm tree leaves, etc. (see Lewis, 2002). These structures are occupied by several family members (usually, but not always, grandparents, parents, and their children). Older children may sometimes build their own ekuta, where they sleep alone or with other children. The area of forest camps varies, but usually they are small, leading to ekutas being built relatively close to each other (Lew-Levy et al., 2020). In the village, BaYaka tend to live in unoccupied Bandongo houses or build their own houses with branches and adobe. Bandongo families build permanent habitation with very clear delimitation, usually consisting of a house where the family lives and a kitchen, both built with adobe and thatch roofs (Boyette et al., 2018). Households in the village are usually organized based on patrilineal families.

In BaYaka and Bandongo communities, children acquire information through teaching and observational learning from adults and other children (Boyette & Hewlett, 2017; Lew-Levy et al., 2020). However, the types of teaching may differ between the two groups. Due to their focus on individual autonomy, BaYaka has been reported to show lower levels of direct instruction compared to farmer groups (Boyette & Hewlett, 2017). Both communities show alloparental care for children, but while BaYaka caregiving encompasses members of both sexes and different ages within the community, Bandongo alloparenting is provided mainly by women belonging to the extended family of the children (Boyette et al., 2018, 2020).

BaYaka children have limited to no exposure to formal education, and the same is true for most BaYaka parents. Bandongo children often attend primary school in the village. Some of those children choose to continue into higher levels of education, usually up to high school, in nearby towns. It is likely that the parents of the children tested completed at least primary school, but we did not directly ask them in this study.

In the village where this research was conducted, BaYaka and Bandongo people have limited access to market goods or electronic technology. BaYaka, in particular, may only have access to the goods brought by the market boat every two weeks (e.g., radios, flip-flops, machetes, torches) or those available through commercial exchange with their Bandongo neighbors. However, the Bandongo often have more access to commercial items when visiting nearby towns. Although exposure to display screens is rare, the research team found a television used communally by the village people in 2023 (time of data collection). A smaller

television was found in a BaYaka camp in 2022 (the television belonged to a Bandongo man). No touchscreen device has been observed to be used by either community outside of a research setting.

Children from both communities were recruited after their parents or guardians provided explicit informed consent. The experiment was conducted in the research house, which has a central location in the village. Before experimentation, children's consent was requested, at which point, children were free to opt out of participating. Children were paired with a same-cultural group experimenter. Children had the experiment presented in their primary spoken languages; for BaYaka, this was Yaka, and for Bandongo, this was Lingala. Children received pre-recorded instructions from the testing computer, as well as some additional instructions, reiterating the recordings when needed.

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## **Beijing (China) - Location**

Beijing, a municipality directly under the Central Government, is the capital of the People's Republic of China and the country's political, economic, cultural and transportation center. Beijing covers an area of 16 410 54 km<sup>2</sup> with a population of 21 843 000 in 2022. Beijing ranked second in Chinese cities in terms of GDP in 2022. Geographically, Beijing is located in the northern part of the North China Plain.

Beijing is an inland city and is surrounded by mountains to its west, north and northeast. Mountain areas occupy about 62% of the municipality's total area. The land is characterized by urban and suburban areas, with parks, squares, and historical buildings located mostly in the downtown districts, and flat agricultural land and mountains in the suburban districts. Beijing has a temperate, continental monsoonal climate, characterized by short spring and autumns, hot and rainy summers, and cold and dry winters. Its average annual temperature is 11 to 14°C. The coldest month in Beijing is January, with an average temperature of -9 to -4°C; the hottest month is July, with an average of 25°C. Around 75 percent of its annual precipitation occurs in summer, with the heaviest rainfall in July and August.

According to the 2021 National Census data, in Beijing, there were 20 845 166 (95%) Han Chinese along with 1 047 929 (4.8%) people in other minority nationalities (e.g., Manchu, Hui ethnic, Mongolian ethnic). Mandarin Chinese is commonly spoken by all ethnic groups though many of the minority nationalities also have their own national languages, such as Mongolian language used by Mongolian ethnic. (4)

Beijing is one of the birthplaces of Chinese Civilization and one of the five ancient capital cities in China. With but few interruptions, Beijing has been the capital of China for some eight centuries: including the capital of the State of Yan during the Western Zhou Dynasty (11th Century - 771 BCE), the capital of Jin Dynasty (1153 - 1215), the capital of Yuan Dynasty (1271 - 1368), the capital of Ming Dynasty (1421-1644), and the capital of Qing Dynasty (1644 - 1912). In 1949, Beiping (former name of Beijing) was renamed Beijing and became the capital of the People's Republic of China. Since then, it gradually develops into a modern metropolis.

From the early 1950s to the reform and opening up, Beijing aimed to build a modernized industrial base, and the secondary industry became the dominant industry in economic development. In 1954, the proportion of the secondary industry was 44.1%, exceeding the tertiary industry for the first time, and in 1978, the proportion reached 71%. Since the 1980s, Beijing has vigorously developed the tertiary industry, and the proportion of the tertiary industry once again exceeded that of the secondary industry in 1994, and the proportion of the tertiary industry exceeded 60% in 1998, 70% in 2005, and 80% in 2016, reaching 84% in 2022, making it the city's economic "leader". According to the statistical communiqué on the National Economy and Social Development of Beijing in 2022 the top three sectors in terms of absolute volume of GDP are finance (19.7%), information transmission, software and information technology services (17.9%) and industry (12.1%).

Beijing has various types of residential areas, ranging from traditional courtyard houses (siheyuan) in hutongs (narrow alleyways) to modern apartment buildings, gated residential complexes and detached houses. Household composition varies, ranging from single individuals and couples to families with children and multi-generational households. Notably, it is a strong tradition for grandparents to be involved in grandchildren care and household tasks. In big cities, such as Beijing, the involvement of grandparents in grandchild care is especially helpful since it relieves the high-pressure of a two-career family. Since China fully implemented the "two-child-per-family" policy in 2016, there are now usually one or two children per family in Beijing.

Parental socialization goals in Beijing (as well as in other cities) align with broader Chinese Confucianism cultural norms and typically emphasize the following seven developmental goals for children: Gaining knowledge, internalizing social norms, being modest about success and ashamed of failure, displaying self-restraint and filial piety, and maintaining harmonious relationships with others. Education and learning are seen as very important aspects of children's lives. For primary school children in Beijing, parents (also the education system) especially emphasize on academic achievement. Moreover, with China's growing exposure to western values, autonomy has been promoted by current educationalists during the last decade, and is especially emphasized in developed cities such as Beijing. As to parental education levels, according to the

data of 2020 population census, the average years of schooling for permanent population in Beijing aged 15 and above is 12.64 years, and among whom 48% have university degree (15 years of education and above). So, the percentage for the parents holding a university degree should be much higher than 48%.

It's common that parents spend large parts of the day away from home and children are cared for externally. Between 2 and 3 years of age young children can attend nurseries (very few nurseries accept children as young as 1.5 years old). Nurseries are largely commercialized and non-subsidized. Starting at age 3, children can attend either publicly subsidized kindergarten or private kindergarten. Children move on to primary school at six. Public primary education is free and compulsory. There are also private primary schools that cater to other groups, such as international primary schools that serve families catering to the expatriate community and families seeking an international education, as well as those who want to get prepared for studying abroad later. The samples of the current study were drawn from public kindergarten and public primary school.

Children growing up in Beijing have a high exposure to technology. Smartphones and other touchscreen devices are prevalent in most families in Beijing and are used widely for education, communication, and entertainment. In 2022, almost every Chinese citizen accessed the internet via mobile devices and Beijing has been fully covered by ultra fast 5G signals.

95% of the sampled children were recruited from local public kindergarten and primary school. We firstly introduced the experiment to the heads of the kindergarten/school. Once getting their permission, we asked the teachers to help send the printed letter (information about the study, informed consent, as well as the five questions) to the parents. A Mandarin speaking research assistant then tested kids whose parents signed the informed consent in a separate room in the kindergarten/school. A few of the youngest kids (5% of total) were recruited by directly introducing the experiment to the parents who we personally knew and tested the kids either in a separate room at our institute or at their home.

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## Buenos Aires (Argentina) - Location

Buenos Aires is the capital of Argentina and located in the North-East of the country, on the shores of the Rio de la Plata. Administratively, the city is autonomous (Autonomous City of Buenos Aires) and has a separate administration from the surrounding Province of Buenos Aires. The city has a population of about 3 million inhabitants and the larger metropolitan area of about 15 million inhabitants. The majority of the population are either of European descent or of mixed descent, and about 2% of the population is of indigenous descent (e.g., Quechua, Guaraní, Mapuche, Aymara). Spanish is the predominant language in Buenos Aires, and the local dialect is known as Rioplatense Spanish.

The city has a humid, subtropical climate and has generally mild weather. The average temperatures range from 11°C (July) to 25°C (January), but heat waves are common during the summer months (December to February).

Buenos Aires was first established during Spanish colonization in the 16th century and was involved in trans-Atlantic trade when it became the capital of the Viceroyalty of Rio de la Plata (1776). The War of Independence against the Spanish crown lasted from 1810 to 1816 and was followed by an internal civil war between federalists and centralists over the constitution of the nation state. In the present day, Argentina is a presidential federal republic and Buenos Aires is its political and cultural center.

Moreover, the city is the commercial, financial, and industrial hub of Argentina and a major site for tourism. Buenos Aires has a market economy and the main economic activities center on the service sector (e.g. finance, commerce, tourism, social services) and, to some extent, manufacturing. The city contributes about 20% to the Gross Domestic Product of Argentina. Most people in Buenos Aires live in apartment buildings, but informal settlements have been growing over the last decades. Argentina has experienced one of the highest inflation rates in the world in the past years and poverty has been steadily increasing — though poverty rates in the city of Buenos Aires tend to be lower than in the surrounding Buenos Aires Province.

Commonly, children grow up in nuclear families, but ties with extended family tend to be strong. Generally, family and closeness to family are important cultural values in Argentina. Traditionally, female caregivers had a central role in the family, but this has been undergoing change in recent years, particularly, in middle-class families, with male caregivers taking on caring responsibilities, too. Argentina was the first country in South America to legalize same-sex marriage in 2010 and Buenos Aires in particular is perceived as progressive and liberal city. Some parenting values in middle-class families in Argentina, such as being responsive to the child and providing stimulating encounters, are similar to western countries. Caregivers tend to control their children's schedules/activities, but children do not necessarily perceive this control as negative and caregivers are more permissive with younger children.

Caregivers in the current sample mostly came from a middle-class background and usually had completed tertiary education. In Argentina, children attend nursery/kindergarten from two to three years of age with the last year of kindergarten, from age 5, being compulsory. Children attend primary school from age 6 years and secondary school from age 12 (secondary school lasts 5 or 6 years). Children are schooled in Spanish and usually learn a second language (usually English) from the age of 9. Children in Indigenous communities in other Argentinian Provinces (e.g. Salta Province, Formosa Province) will often speak their respective Indigenous language (e.g. Wichi) as their primary language and schools often rely on bilingual teaching assistants to help during schools lessons (that are predominantly taught in Spanish). Smartphones, tablets, and computers are common, and children are exposed to these devices from early on. Children were recruited from one local kindergarten by sending out information letters and consent forms to parents. Children who had parental consent to take part in the study were tested in Spanish in a quiet room in their kindergarten by a local experimenter.

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### **Chimfunshi (Zambia) - Location**

Chimfunshi wildlife orphanage is an NGO providing a home for about 150 chimpanzees. The sanctuary is located in the Copperbelt region in the northern part of Zambia close to the DRC border. The Sanctuary provides education, housing and medical care for the employees and their families which are in total about 300 people living in 5 different compounds around Chimfunshi.

Chimfunshi itself was founded in 1983 by David and Sheila Siddle who lived in Zambia since the 1950's. In the past years they rehabilitated chimpanzees who were confiscated from poachers and from obsolete zoos and circuses worldwide. To ensure long-term sustainability, the sanctuary is managed by a Board of Trustees.

Zambia experiences a predominantly subtropical climate. The temperatures throughout the year are relatively mild but can be cold in winter due to the altitude of the country in the north. The countries' climate oscillates between a cool dry season (May to August) followed by a short hot and dry season which turns into a hot and humid rainy season lasting from November to April. The sanctuary is nestled amidst woodland and savanna, close to the Kafue River.

The country, with approximately 18 million inhabitants, consists of a diverse population primarily composed of Bantu-speaking groups. Among these, the Bemba ethnicity stands out as the largest, accompanied by other significant groups such as Chewa, Tonga, and Lozi. While English serves as the official language, it is spoken natively by only around 2% of the population. However, for those with higher education levels, English becomes the predominant second language. The patterns of migrations have contributed to a rich tapestry of linguistic and cultural diversity across the nation. Due to a robust mining industry in the Copperbelt region, the population hails from various corners of Zambia and even neighboring countries.

Zambia, predominantly a Christian nation, encompasses a diverse religious landscape. Due to the presence of an Asian community, Hindu and Muslim are represented beside the Christian denominations including Protestant, Roman Catholic, Jehovah's Witnesses, and various fundamentalist churches. Cultural traditions from the Congo basin significantly influence the northeast and northwest regions of Zambia. Despite modernization, Zambian society continues to uphold traditional norms within families, villages, and clans. These enduring values emphasize mutual respect and reciprocity as cornerstones of communal harmony.

Agriculture and copper mining and smelting, particularly in the northern Copperbelt region, are the primary sectors of Zambia's economy. Despite the abundance of copper deposits, Zambia ranks among the world's poorest nations. The majority of the impoverished, three-fourths to be precise, reside in rural areas. Similar to other African nations, there's a pronounced trend of migration from rural to urban areas, with men migrating more frequently while women often stay back in the villages. The architectural style in rural areas significantly differs across ethnic groups, with construction materials ranging from mud and thatch to brick and other resources.

People employed at the Chimfunshi wildlife orphanage reside in compounds. These compounds are small communities comprised of stone houses topped with corrugated iron roofs. They feature wells for clean water access, solar systems for power, and frequently, small gardens for crop cultivation and/or livestock rearing, such as chickens.

Since its Independence Day, Zambia has made significant investments in education. Currently, education is mandatory for children aged 7 to 14. The educational system is structured with a 7-year primary school program followed by a 5-year secondary level. In 2011, the Twampane School was established at Chimfunshi, providing the children of its employees the chance to pursue education up to the 9th grade. Approximately 120 students reside within the Chimfunshi area, while the rest commute from nearby farms and settlements, bringing the total student population to around 220. Sponsorship programs are in place to support academically outstanding students in attending secondary school. Additionally, Chimfunshi provides on-site vocational training and further education for students in the final grades.

The availability of touchscreen electronic devices like smartphones or laptops depends on each family's financial capacity. While many still utilize cellphones, the lack of smartphone ownership can pose challenges in accessing such devices for some children or households.

Prior to initiating a study at Chimfunshi, it must first be submitted to the Chimfunshi Scientific Advisory Board. The board members, along with the sanctuary directress, review and determine the feasibility of the proposed study. Once the necessary formalities are sorted, an on-site assistant assists in reaching out to the parents. The study program is explained to each family expressing interest in participating in the study. Written consent is obtained for participation, which can be withdrawn by the parents at any point. Depending on the nature of the study, the recruitment process is carried out in collaboration with the school teachers.

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#### **Hai||om (Namibia) - Ethnic group**

The Hai||om are an indigenous group primarily living in the areas in and around the Etosha Pan of northern Namibia. In the current research, participants were recruited in small communities of 150 to 300 people in the Oshikoto and Otjozondjupa regions.

They live in a dry Savannah of northern Namibia, characterized by the arid Namib Desert and the fringes of the Kalahari. The climate is hot and dry, with average temperatures exceeding 30°C and unsteady and minimal rainfall during summer. Vegetation is sparse, consisting mainly of drought-resistant shrubs and grasses with bloom of edible and non-edible plants during rain season.

The Hai||om (i.e., treesleepers), also referred to as Heikum or Hai//om, speak Hai||om, which belongs to the Khoekhoe language family often recognized for containing distinct consonants (i.e., "click" sounds). Local dialects (i.e., =Akhoe) differ across communities. They traditionally lived in small, semi-nomadic bands, loosely organized around kinship ties and shared leadership roles.

The Hai||om are the indigenous people of the Etosha pan, have been living in this area for centuries. During the colonial era and German and South-African occupation of their lands, the Hai||om faced forced relocation from Etosha to the neighboring farmlands. The dispossession of their traditional lands together with political and societal discrimination continue having lasting impact on their communities and livelihoods.

Traditionally, the Hai||om have been hunter-gatherers, relying on their vast knowledge of the desert environment to find food and water. They utilized a variety of techniques for hunting and gathering, including tracking, digging, and setting traps. They exhibited a semi-nomadic lifestyle, taking advantage of seasonal resource availability. This self-sufficient lifestyle has been impacted by factors like climate change and government programs, but many Hai||om continue to practice traditional subsistence activities whenever possible.

Today, the rural Hai||om communities participating in the current research practice a mixed subsistence combining seasonal and occasional farm work, small-scale gardening and animal husbandry, foraging, but also rely on government food programs.

Most of the Hai||om families participating in this research house in small huts constructed from branches, corrugated iron, and animal dung. These dwellings are easily portable and household mobility remains high in these communities. Household composition is flexible, with extended families often living together and individuals moving between and within communities based on kinship ties and resource availability.

Hai||om child-rearing emphasizes autonomy, egalitarianism, cooperation, and sharing on demand as foundational schemas. Children are actively involved in daily activities from a young age, learning essential skills primarily through observation and participation, rather than direct pedagogy. Parents also instill cultural knowledge and values through storytelling and traditional practices.

Due to their historical marginalization and remote location, access to formal education remains challenging for many Hai||om communities. In one community, children have access to a primary school from age 6 onward, whereas in the other community, children need to travel about 35km to access the next school. In both communities, school attendance rates are reported low by teachers, likely due to multiple reasons, such as cultural mismatches between often authoritarian teaching styles and foreign learning content at schools, children's autonomy in deciding on their learning environments, and secondary schools being located far away from their home communities. Traditional knowledge transfer remains vital, with elders playing a significant role in childcare and education. At the same time, children spend considerable amounts of their daily lives in mixed-age peer groups, which present important learning contexts for these children. Children learn through practical experience and participation in daily activities alongside adults and peers.

Exposure to technology, particularly smartphones and other touchscreen devices, is highly limited among the Hai||om due to their remote location and traditional lifestyle. Electricity is available through solar panels at schools, farm houses, and few households, but the importance of electricity in people's lives remains minimal. Some individuals, particularly younger generations, may have some exposure to technology through interactions with outsiders or limited access to shared devices, such as cellphones.

It is important to note that this depiction provides an overview on the communities participating in the current research and does not reflect the diversity of livelihoods among urban-dwelling Hai||om people more generally. Their experiences and adaptations vary depending on individual circumstances and ongoing socio-economic changes.

Children were recruited from their homes as part of a long term research project taking place in these communities. They were later tested in quiet locations either at the school building or vacant spaces in their communities. Testing was done by male adult experimenters and a research team known to the communities for about 8 years. The research was approved by the Max Planck Research Ethics Council, the Namibian Commission on Research Science and Technology (Permit Number RPIV01112021), the Namibian San Council, and the Ministry of Education, Arts and Culture of the Republic of Namibia. The study also adhered to guidelines for best practice in cross-cultural research (Bruno et al., 2022). Children received small amounts of candy as a compensation for their participation.

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### **Khwe (Namibia) - Ethnic group**

The Khwe (also referred to as Khoë, Khwedam, or Barakhoena) people reside in their ancestral lands within today's Bwabwata National Park in northwestern Namibia and the bordering regions in Angola and Botswana. There is also a Khwe community in today's South Africa that has moved there while Namibia became independent in 1990. The current research was conducted in the Namibian Zambezi region which is home to numerous small Khwe communities. There are an estimated 3 000 to 5 000 Khwe residing in Bwabwata as of today.

Due to its sub-tropical climate, inhabitants of Bwabwata National Park experience hot and humid summers, whereas other seasons are much more characterized by a hot and dry climate. Bwabwata is a dual-use National Park in which wild animals, including large predators, elephants, and other animals native to the Zambezi region roam freely around the Khwe and Hambukushu settlements in the Park.

The Khwe people speak Khwedam, which is part of the larger Khoë-Kwadi language spectrum. They traditionally lived in small, semi-nomadic bands with leadership based on a combination of age and experience. Today, people live in rural communities of varying size, ranging from one-household settlements to settlements of up to 600 people. Larger settlements have access to schools, medical centers, police stations, and small shops.

The Khwe of Bwabwata are the indigenous people of the region and have resided in the area for centuries. They faced similar historical injustices as other indigenous groups of Southern Africa, such as the Hai||om, resulting from colonization and political marginalization. This includes, but is not limited to, colonial dispossession, forced relocation, and the neglect of their traditional leadership systems. These continue to have lasting impacts on their community and land rights until today.

Traditionally, the Khwe lived as hunter-gatherers, relying on their extensive knowledge of the environment to hunt game, gather bushfood, and find water. This self-sufficient way of life has been impacted by various factors, including the migration of Hambukushu (Bantu) communities to the area, German colonization and South African occupation, governmental resettlement programs, and other environmental changes. Today, Khwe people are no longer allowed to leave their settlements freely as part of the anti-poaching regulations of the dual-use National Park. However, traditional subsistence activities continue being an integral part of the cultural identity of many Khwe people. Their traditional subsistence is today supplemented with wage labor, seasonal harvesting programs, small-scale gardening and animal husbandry, as well as governmental and non-governmental support.

Household composition is flexible, with extended families often residing together and individuals moving between groups based on kinship ties and resource availability. Before Namibian independence, the South African Military Forces had multiple camps in the region due to its proximity to the Angolan border. After independence, Khwe communities increasingly settled in the residential infrastructure they had left behind. Other communities live in small huts made of wood, dung, corrugated iron, and other building materials.

Similar to the Hai||om, Khwe child-rearing emphasizes autonomy, egalitarianism as well as strong norms on cooperation and demand sharing. Children actively participate in daily activities from a young age, learning essential hunting, gathering, and survival skills through observation and participation. Parents also transmit cultural knowledge and values through storytelling and traditional practices.

Access to formal education has been historically limited for the Khwe of Bwabwata due to their remote location and marginalization. As of today, formalized education presents a two-edged sword as it is perceived by many as an important opportunity for social improvement, while also contributing to the erosion of cultural and environmental knowledge and skills. In the community sampled here, children do have access to

a local kindergarten and a combined school. Many learners attending school did not experience kindergarten education as they grew up in the smaller communities surrounding this larger settlement. Especially in early childhood, traditional knowledge transfer and parenting practices remain crucial, with elders playing a significant role in childcare and education. Children learn through practical experience and participation in daily activities alongside adults. Additionally, recent initiatives aim to improve access to formal education within the national park.

Exposure to technology, particularly smartphones and other touchscreen devices, is generally limited among the Khwe of Bwabwata, also due to their remote location, economic hardships, and lack of access to electricity. However, similar to the Hai|om, the level of access can vary depending on proximity to towns and settlements. Some individuals, especially younger generations, may have some exposure through interactions with external communities or shared devices.

It is important to note that this is only an approximate depiction of the situation faced by the communities participating in the current research. It does by no means give credit to the diversity of livelihoods among the Khwe people more generally. Their experiences and adaptations vary depending on individual circumstances and ongoing socio-economic changes.

Children were recruited for a long-term research project after consulting with community elders and representatives. The project was conducted in local schools or kindergartens and received necessary approvals from relevant ethical bodies in Namibia and Germany: The Max Planck Research Ethics Council, the Namibian Commission on Research Science and Technology (Permit Number RPIV01112021), the Namibian San Council, and the Ministry of Education, Arts and Culture of the Republic of Namibia. Self-commitment regarding research ethics aligned with departmental guidelines for best practice in cross-cultural research (Bruno et al., 2022). Testing was carried out by a male adult from the community alongside a familiar research team. The study adhered to strict ethical guidelines for cross-cultural research, and children received small tokens of appreciation for their participation.

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#### **Leipzig (Germany) - Location**

Leipzig is a medium-sized city located in the east of Germany with a population of approximately 620 000. It serves as a significant urban center within the state of Saxony. Geographically, Leipzig is situated in the southernmost part of the North German Plain.

The city landscape is characterized by urban and suburban areas, with parks, squares, and historical buildings. Leipzig has an oceanic climate with continental influence. Winters are cold (average temperature around 1°C) and summers warm (average temperature around 19°C).

The majority of inhabitants of Leipzig are German, many of which have moved from other parts of Germany. Around 17% of the population have a migration background. The largest groups of migrants come from Syria, Ukraine, and the Russian Federation. In comparison to more rural areas in the region, Leipzig has a larger proportion of inhabitants with a migration background and is generally seen as more liberal and progressive. German is the primary language spoken in Leipzig. Additionally, due to its role as a major educational and cultural center, English and other foreign languages are also spoken by a significant portion of the population.

Historically, Leipzig gained prominence as a trade city during the Middle Ages and later became a major center of the Enlightenment and the arts in the 18th and 19th centuries. Following World War II, Leipzig was part of the socialist German Democratic Republic. Leipzig played a crucial role in the Peaceful Revolution of 1989, which ultimately led to the fall of the Berlin Wall and the reunification of Germany.

Leipzig has been a market economy for centuries. It has a modern and diversified economy that encompasses various sectors, such as manufacturing, services, and creative industries. The city is known for its trade fairs, music, and publishing industries.

The city has a combination of apartment buildings, detached houses, and residential complexes. Household composition varies, ranging from single individuals and couples to families with children and multi-generational households. Children mostly live in nuclear families with one or two children and their caregivers.

Parental socialization goals in Leipzig align with broader German cultural norms and typically emphasize the importance of children's independence, psychological autonomy, self-confidence and assertiveness. Education and learning are seen as important aspects of children's lives. Parental education levels are generally very high; adults have at least nine years of formal schooling and high school and university degrees are very widespread.

Parents spend large parts of the day away from home, and the majority of children are cared for externally: starting at nine months of age, children can attend nurseries, moving on to kindergarten at three and primary school around six. Institutional childcare is provided by the city and financially subsidized; institutionalized primary education is free and compulsory.

Children growing up in Leipzig have a high exposure to technology. Smartphones and other touchscreen devices are prevalent in most families and educational institutions, reflecting the widespread use of digital technology for communication, entertainment, and information retrieval.

Children were recruited via a database of children whose parents expressed interest in participating in studies of child development. They were tested in a separate room in their kindergartens by a German-speaking research assistant.

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#### **Malatya (Türkiye) - Location**

Malatya is a big city located in the Eastern Anatolia region of Türkiye with a population of approximately 800 000. Due to its strong economy based on agriculture, it is one of the biggest cities in eastern Türkiye.

The city landscape is characterized by mostly urban and some rural areas. Malatya has a temperate continental climate with very cold winters (average temperature around -3°C) and very hot summers (average temperature around 33°C).

The population of Malatya is diverse which include inhabitants with Turkish, Kurdish, Circassian, Armenian, and Zaza origins. Malatya is also a multilingual city. Although the dominant language is Turkish, around 40% of the population speaks Kurdish.

Malatya has a long history since the Hittite times. It has also been significant location for the Roman Empire, Byzantine Empire, and Ottoman Empire.

Malatya's economy depends on agriculture, and it is famous for apricot production. Recently, Malatya has also undergone some industrial development such as textile manufacturing.

The urban area of Malatya consists of apartment buildings. Household composition usually involves families with children and multi-generational households. Children live both in nuclear families (with parents and siblings) and in extended families (nuclear family and a set of grandparents). Parental socialization in Malatya aligns with broader Turkish cultural norms, and typically emphasize the importance of children's interdependence and the value of family. Education and learning are seen as important aspects of children's lives. Parental education levels are generally above the average of Türkiye; with most adults have high school or university degrees.

Fathers spend large parts of the day away from home, and the majority of children are cared at home by their mothers and grandparents until they start formal schooling at the age 7. Primary education is free and compulsory.

Children growing up in Malatya have some exposure to technology. Smartphones and other touchscreen devices are somewhat prevalent in most families, reflecting the widespread use of digital technology for communication.

Children were recruited through nurseries and schools who expressed interest in participating research. They were tested in a separate room in their nurseries/school kindergartens by a Turkish-speaking research assistant. Some children were also tested in parks and outdoor areas.

### **Nyabyeya (Uganda) - Location**

Nyabyeya Forestry College is situated in the Masindi district of western Uganda, approximately 25 km from Masindi Town and 240 km from Kampala, the capital city. The college is adjacent to Budongo Forest and 8 km from Budongo Conservation Field Station, where primatologists study habituated wild chimpanzees. The sample were invited to participate at the college from the surrounding villages, including Marram, Kyempunu, Nyabigoma, Nyabyeya 1 and 2 and Trading Center, Nyakafunjo, and Kyamasuka.

Nyabyeya village is characterized by tropical vegetation and a savanna climate, characterized by daytime temperatures reaching 32°C and cooler nights at 17°C. The region observes two distinct agricultural seasons - a wet season from late March to June and August to November, followed by a dry season from early December to March.

The studied villages are culturally very diverse and are home to different ethnic groups including Bantu, Luo, Nilotics, and Nilo-Hamites. Spoken languages depend on the tribe and include Alur, Lugbara, Runyoro, Lendu, Kakwa, Acholi, Langi, Luganda, Logo, Kebu, Madi, and many others. Kiswahili and English often serve as a common ground. For this study, children who understood Kiswahili were invited.

During the Second World War, many Polish refugees were brought to Uganda and located in Bunyoro on the fringes of Budongo Forest at Nyabyeya. When the refugees were evacuated after World War II ended, the forestry college was transferred into the facilities the Polish refugees had left behind. It now serves as an educational institute conducting training in Forestry, Agroforestry, Biomass Energy Technologies, and beekeeping.

The local communities predominantly practices subsistence farming, cultivating crops like maize, cassava, sweet potatoes, and beans. Wealthier families sometimes keep goats, pigs, chickens, or ducks. Additionally, sugarcane and coffee cultivation contribute significantly to the local economy, with the Kinyara Sugar Company playing a pivotal role in sugarcane harvesting. Salaried work is rare and many households struggle to provide essentials, including food, health care, and school materials for family members.

Living conditions in the community are characterized by extended families residing together, with an average of 10 people in each household. Households tend to inhabit several buildings within a compound, with buildings made from traditional materials (wood and mud walls; straw roof) or bricks with metal roofing.

Parental socialization goals vary, but a previous sample of mothers from these communities valued relational socialization goals over autonomous goals (Holden et al., 2022). Cultural practices include the belief in producing many children as a sign of respect, with specific tribes attaching wealth to the number of daughters. Twins are highly honored, and rituals are performed to welcome them. Often, young children take care of their siblings and carry them around on their backs. Children start to help their parents with chores from an early age (collecting fire wood or water, tending crops or animal care).

School is not mandatory and parental education levels in these communities is generally low, with a minority of mothers in the Holden et al (2022) sample having any secondary level education. The education system faces challenges such as overcrowding and lack of resources, leading to high dropout rates. Children start primary school at ages 5-9, and secondary education runs for four years, with options to pursue advanced levels. Lack of sanitary products to allow attendance of school during menstruation, early marriages and teenage pregnancies often result in girls performing worse than boys and leaving school earlier.

The community exhibits low exposure to technology, with smartphones and touchscreen devices considered luxuries. Limited internet access and power supply challenges contribute to this low adoption. However, technology is more prevalent in institutions like Nyabyeya Forestry College. Participating families were recruited by the local research assistants, for example, via personal contact, visiting them at home, or calling them. Families were invited to participate at the Nyabyeya Forestry College (transport offered via boda boda (motorcycle taxi)), and children participated in a quiet room in the College.

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#### **Ocuilan (Mexico) - Location**

Ocuilan is a municipality located in the center south of Mexico with a population of 36 223 inhabitants, distributed in 48 towns in an area of 344.84 km<sup>2</sup> inside the Mexican State (Ocuilan, n.d.). Geographically, Ocuilan has an altitude of between 1000 to 2600 m situated 80 km south of Mexico City (INEGI, 2010).

The communities in Ocuilan are distributed on a mountain range called Trans-Mexican volcanic Belt surrounded by valleys and mountains, the climate is semi-humid with summer rains, and average temperatures vary between 8°C and 22°C throughout the year. The higher elevations have mixed pine forests with more tropical vegetation in the lowlands. The distribution of the land is 31.91% agriculture, 0.48% urban zone and the rest forest (INEGI, 2010).

Historically, the municipality of Ocuilan was occupied by three different towns: Tlahuicas, Mazahuas, and Ocuiltecos. Besides being in the same territory, they had their own language, religion, and customs until the arrival of the Mexica people. Within 100 years, the Mexica dominated the area. The territory was under Mexican control until the arrival of the Spanish kingdom, which took advantage of the discontent of the towns dominated under the Aztec Empire. The Spanish kingdom allied itself with those towns and waged war on the Aztec Empire, succeeding in taking the Mexica capital on 13 August 1521. Although there was some resistance, all the towns within what is now the State of Mexico fell to the Spaniards shortly thereafter (Edo Mex, 2018). During the period of Spanish control, the municipality of Ocuilan was primarily characterized by agricultural activities. The presence of missionary friars played an important role in the dissemination of catholic religion and the Spanish language (Edo Mex, 2018). Over the course of the conquest, the Spanish

language gradually gained prominence, but it is still possible to find indigenous languages like Tlahuica, Nahuatl and Mazahua among the inhabitants (Ocuilan, n.d.).

Following the attainment of Mexican independence, Ocuilan continued to be a farming area and also emerged as an important religious center, attracting pilgrims from various regions of Mexico. During the Mexican Revolution, Ocuilan assumed significance as a stronghold of the Zapatistas which played an essential role in the enactment of the Political Constitution of 1917. The subsequent decades brought political stability, economic development, and population growth in the State of Mexico (Edo Mex, 2018). Nowadays, livestock farming and trout rearing are the dominant economic pursuits in Ocuilan (Ocuilan, n.d.).

Demographically, the average household in Ocuilan comprises 4.1 inhabitants, (Ocuilan, n.d.), primarily adhering to a nuclear family structure characterized by an authoritative rearing model. Parents assume a proactive role in establishing parental control, emphasizing the enforcement of rules and disciplinary measures (Delfín-Ruiz et al., 2021). The parent's education level generally extends to the middle school level, while the prevailing family values involve the mother's engagement in domestic responsibilities and the father's participation in occupational pursuits.

Children in Ocuilan typically begin their early schooling experience at around 3 years of age and attend kindergarten between 8 am to 12 pm. Afterwards, mothers or other family members take care of the children as formal childcare options are limited.

In terms of technology, approximately 77.9% of households possess at least one screen device, whereas access to the Internet is available to only 22.7% of households. Consequently, while a significant proportion of children have experienced digital technology a considerable segment of the population lacks exposure and accessibility to such resources (Ocuilan, n.d.).

For this study, we first obtained permission from Mexican school authorities to visit local kindergartens. Next, we contacted parents and invited them to take part in the research. Data of interested children was then collected in a separate area within their own kindergartens, overseen by a Spanish-speaking research assistant.

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### **Plymouth (UK) - Location**

Plymouth is a coastal city in the South West of England with a population of more than 260 000 inhabitants. About 91% of the population was born in the UK and of those born outside of the UK, the largest proportion comes from the EU (4.5%). 95% of residents identified as White, 2.3% as Asian, and 1% as Black. English is the predominant language spoken in the city.

The city has a temperate oceanic climate with average temperatures ranging from 4 to 20°C. Winters are generally mild, and temperatures rarely drop below 0°C. Rain is frequent and highest in autumn and winter.

The area was first settled in the Bronze Age. Plymouth is situated at the meeting point of two rivers (river Tamar, river Plym) and has a large natural harbour. Due to its location, the city has served as a shipping port and naval harbour throughout history. It played an important role in the Spanish-British war in the 16th century and was a departure port for settlers bound for North America in the early 17th century. Due

to its importance as a naval port, the city was heavily bombed during the 2nd World War and most of the city center needed to be re-build post-war.

In the present day, Plymouth is home to a major dockyard and the biggest naval base in Western Europe. The largest employers are the defence industry and the armed forces, the university, the national health service as well as maritime businesses. Tourism, particularly in the summer months, is another source of income. The city has some areas of very high deprivation (among the 1% of most deprived areas in England) and the median income (33k) is slightly below the UK median (35k).

The city has a large waterfront area and several harbours and docks, and there is a large inner-city park. Housing in the city mostly consists of terraced and semi-detached houses with few multi-storey buildings. Children mostly grow up in nuclear families. Children in the current study came mostly from middle class families. In Western middle-class families, care-giving is usually child-centered and parents are responsive to children's needs and wishes. Autonomy and independence are valued but, compared to countries such as Germany, children are somewhat less independent. As the UK is a multicultural country (and multiculturalism is increasing), parenting values are heterogeneous — though the population in Plymouth, as compared to the rest of the UK, is less heterogeneous and predominantly White British.

The UK has one of the highest childcare costs in Europe (52% of median female earnings). Nurseries will offer places for children from 3 months of age, but currently the government only subsidizes childcare from three years of age (caregivers receive 15 hours of free nursery care for three- and four-year-olds). Primary school starts at age 5 years, and secondary school at age 11 to 12 and lasts until 18 years. Education is compulsory in the UK, but children do not have to attend school and can be homeschooled instead.

Children are exposed to technology from early on, including mobile phones and other touch screen devices. Children were mostly recruited through a local primary school and some additional children were recruited through personal contacts of one of the experimenters. Parents received information letters and consent forms. Experimenters also visited the school during drop off times in the morning to answer any questions parents may have had. Only children whose parents had consented to their participation took part in the study. In the school setting, two experimenters usually conducted the study in parallel in quiet rooms in the school. Some children who were recruited through personal contacts participated in the study online, facilitated by one experimenter.

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#### **Pune (India) - Location**

Pune is located in the state of Maharashtra in western India. The city's total area is 15.642 km<sup>2</sup> and the municipal corporation area covers 518 km<sup>2</sup>. It lies on the western margin of the Deccan plateau at an altitude of 1840 feet. It is on the leeward side of the Sahyadri mountain range which forms a barrier with the Arabian

Sea. The population within city limits is 4.5 million while including the metro population, it stands at 7.1 million.

Pune experiences a tropical wet and dry climate with average temperatures ranging between 20 and 28°C. Summer, monsoon and winter are the three main seasons with May being the hottest month. During summer, i.e., mid-March to mid-June, temperatures can go as high as 42°C. Monsoon lasts from June to October with most of the annual rainfall of 722mm falling between June and September with July being the wettest month. In the months of December and January, temperatures remain around 29°C with overnight temperatures dropping to below 12°C.

Pune is considered to be the cultural capital of Maharashtra with emphasis on education, arts and crafts, music and theater. The most common language spoken is Marathi. Hinduism is the major religion practiced by just under 80% of the population. Other religions practiced are Islam, Buddhism, Jainism, Christianity, Sikhism and Zoroastrianism. Food is made of sorghum and pearl millets with a fairly large consumption of coconut, garlic and green chillies to spice up the food. Pune is referred to as the ‘Oxford of the East’ because of its reputed educational institutions and is also considered to be one of the most livable cities in India. The literacy rate in Pune is 86.15%.

Pune is one of the largest information technology hubs in India and is also an important automobile and manufacturing hub. Sixty-two percent of the population in Pune is under the age of 30. The top three industries that offer employment are automotive, manufacturing and information technology and start-ups. Automobile industries have their manufacturing plants in Chakan, an industrial area around Pune. A leading manufacturer of diesel and natural gas engines as well as a farm equipment company are other renowned investors. The manufacturing industry provides employment to over 600 000 people while the IT sector employs over 350 000 people. About 2.2 million migrant workers are employed in the automobile, construction and medium scale manufacturing industries.

During the 18th century, Pune was part of the Maratha empire and seat of the Peshwas. Besides, it has been ruled by dynasties such as the Rashtrakutas, Ahmednagar Sultanate, Mughals and Adil Shahi dynasty. The modern city of Pune is comprised of many distinct neighbourhoods. These include ‘peths’ [Marathi for locality] on the eastern bank of the Mutha river and the cantonment areas of Khadki and Camp. As a result of rapid industrialization since the 1960s, a large number of people moved to Pune. Since there was inadequate housing to meet the demand, there was an increase in the number of slum dwellers. Nearly half of the slum dwellers do not have in-house toilets and 10% do not have electricity.

Children are taught to address their elders (either in English or the equivalent term in a local language) as ‘older brother/sister’, ‘uncle’, ‘aunty’ or ‘grandmother’/‘grandfather’ even if they are not relatives. This is considered to be respectful. At times, children touch the feet of elders as a sign of respect. Parents encourage their children to visit family and friends particularly during festivals.

Children in Pune normally enter school between the ages of 2.5 and 3.5. The school leaving exam is taken between the ages of 17 and 18. Grades 11th and 12th (equivalent to AS and A levels in the UK) may be attended in school or ‘junior college’ with the latter offering education up to the postgraduate level. Following a school day, it is not uncommon for children to attend tuition or focussed coaching in sports or arts.

Most households will have at least one mobile phone as well as a laptop so children are exposed to technology fairly early.

For the current study, recruitment took place via personal contacts. Both schools have participated in previous research projects and the researcher is on the management committee of one of the schools. The researcher was given a separate quiet room to carry out testing. Normally, after one child finished the task, he or she would send their classmate who had volunteered for the project. In the case of very young children, the researcher would collect the children personally from their respective class and ensure that they were handed back to their teachers upon completion.

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### **Stanford (USA) - Location**

The sample was drawn from a children's museum in San Jose, California located in the western United States of America. San Jose is a large city with a population of approximately 983 000 people and geographically is within the Santa Clara Valley in the southern part of the Bay Area, California.

The city is a large metropolitan area with urban and suburban areas bordered by mountain ranges to the east and west. The land is characterized by bay flats and hills with several rivers running through the city. San Jose's climate is described as mild, semi-arid, and Mediterranean. A wet season typically occurs between November and March with combined rainfall and an average daytime temperature of 50°F. A dry season occurs between March and November where precipitation is minimal and the average daytime temperature is 70°F.

According to the most recent census data, the 3 largest groups by Race are Asian (Non-Hispanic) (37%), White (Non-hispanic) (25%) and Hispanic (31%). 40% of residents immigrated to the United States, with most residents originating from Mexico, Philippines, and China. Although English is the primary language used, more than half (58%) of people also speak a language other than English at home, including Spanish (20%), Chinese (7%), Tagalog (3%), Vietnamese (2%), and other Asian & Pacific Islander languages (19%).

San Jose was originally home to the Tamien people of the Ohlone from around 4000 BC. Around 1777 the Tamien people were displaced and enslaved, and San Jose became the first town in the Spanish colony Nueva California. San Jose would eventually become the first incorporated city and state capital when California became a state in the United States of America following the Mexican-American War.

San Jose historically is a large farming community with a major industry in food processing and agriculture. The Valley was especially known for its tree nuts, berries, and orchard fruits. The city soon became a hub for the manufacturing of electric machinery and motor vehicles, and would eventually become the modern technological hub that it is today. San Jose is presently centered in "Silicon Valley", a global center for technological innovation and entrepreneurs.

The city has a combination of apartment buildings, detached houses, and residential complexes. Household composition varies, ranging from single individuals and couples to families with children and multi-generational households. Children mostly live in nuclear families with one or two children and their caregivers.

Parental socialization goals in California typically emphasize tolerance, individualism, diversity, personal fulfillment, and holistic autonomy, but vary greatly as a result of its diverse population. Education and learning are seen as important aspects of children's lives. Parental education levels are generally very high; many adults have a graduate degree, and most adults have at least 12 years of formal schooling and a 4-year college degree.

It is common for parents to spend large parts of the day away from home, and typically rely on external care including family, nannies, and daycare for childcare. Daycares are largely commercialized and non-subsidized. Starting around age 2, children can begin attending preschool. At age 5, children can enter kindergarten in publicly subsidized schools and move on to primary school at age 6. While public primary education is typically free and compulsory, around 15% of children in San Jose are enrolled in private, non-subsidized institutions for primary school.

Children in San Jose have high exposure to technology. Nearly all households in San Jose have a computer (97%), with 93% of households having a broadband internet subscription. Smartphones and other touchscreen devices are used in most families and are used widely for education, communication, and entertainment.

Children were recruited in person at a children's museum in San Jose. Participants were randomly solicited from patrons visiting the children's museum. Parents were given information about the study activity and consented before beginning the study. Children completed the study in a separate research room centrally located in the museum.

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### Windhoek (Namibia) - Location

Windhoek is the capital city of Namibia and is situated in the Khomas region, in the central part of the country, at an elevation of 1700 m above sea level, with a total space of 645 km<sup>2</sup>. The Khomas region is further divided into 10 constituencies: John Pandeni, Katutura Central, Katutura East, Khomasdal, Moses //Garob, Samora Machel, Tobias Hainyeko, Windhoek East, Windhoek Rural and Windhoek West. The recent 2023 census indicates that the population of the Khomas region grew by 30.8%; from 342 141 in 2011 to 494 605 in 2023.

The urban part of the Khomas region is commonly known as Windhoek, made up of the nine constituencies of the region. Windhoek rural is the rural part of the Khomas region on the outskirts of Windhoek. According to the recent 2023 census, Windhoek has a population of 486 169 (250 142 female and 236 027 male) and a population density of 94.9 persons per km<sup>2</sup> (total area of 5124.2043 km<sup>2</sup>).

The name Windhoek is derived from the Afrikaans meaning „windy corner“. The former spelling at the beginning of the German colonial time “Windhuk” is not in use anymore. From its beginnings as a small settlement in the late 19th century, Windhoek has grown into a diverse and multi-ethnic community, home to a multitude of languages and cultures, including Nama, Owambo, Damara, Herero, Germans, Afrikaans, and British communities. Windhoek is the dominant economic and political centre of Namibia, accounting for more than 50% of the country's manufacturing activity, over 80% of its finance and business services, and two-thirds of its community and social services. Inherited from the colonial and apartheid era, the city maintains its distinctive dual spatial structure. The city is made up of three parts: the central part consisting of the central business district (CBD); the east, south and west consisting of various suburbs housing people from primarily middle and upper socio-economic households; and the northern and north-western part of the city where more than 70% of the Windhoek population lives on 25% of the land in crowded formal and informal settlements. CBD is modern and thriving with light industrial areas to the north and south. In the center of the CBD are government offices, courts, banks, the main post office, business centers, hotels, and new modern shopping malls and supermarkets; a blend of high and low-rise modern buildings.

The current study was conducted in Cimbebasia, a suburb situated in Southern Windhoek falling within the Windhoek West constituency. According to the recent 2023 census, the total population of Windhoek West is 59 907. The household population is 56 297 with a total of 17 132 households and an average of 3.3 persons per household and a population density of 287.9 persons per km<sup>2</sup> of which the area is 208.08 km<sup>2</sup>.

English serves as the primary medium of instruction within the educational system, but children often grow up with significant exposure to other indigenous languages like Herero and Damara within their communities. Socialization and parenting goals reflect that of urban communities in the Global South emphasizing “communal psychological autonomy and relatedness” (Keller & Kaertner, 2013). Children in such communities spend a significant portion of their time on activities related to school, family, and leisure with peers and siblings. Children’s exposure to smartphones, tablets, and computers begins at a relatively early age, mirroring a global trend in urban middle-class communities.

Participants came from predominantly middle-class communities and were tested at local Sunday schools (at churches) and at educational institutions.

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## **Method**

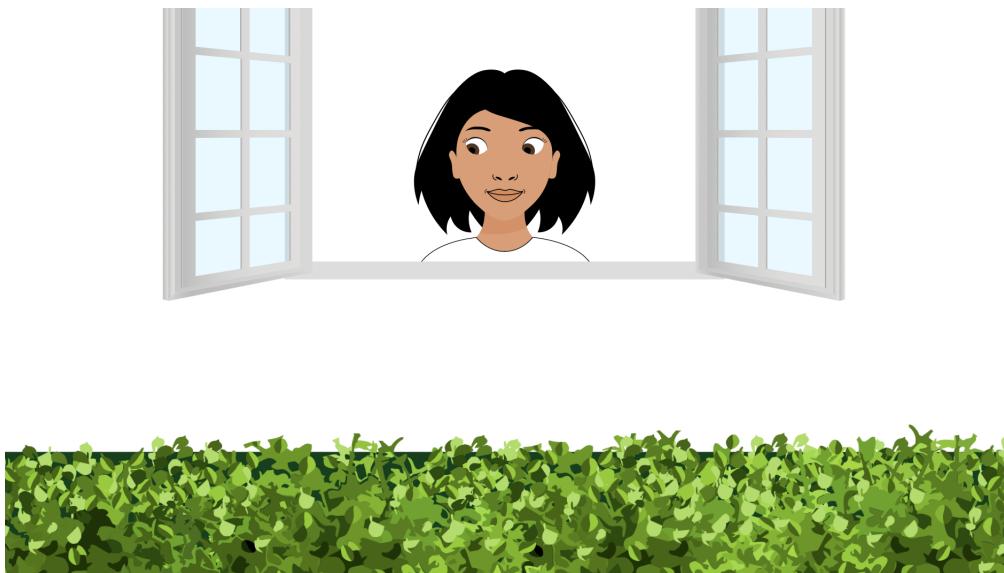
We adapted the task developed by Prein and colleagues (1). We refer to the original publication for a detailed description of its development, implementation and psychometric evaluation (in Germany). Below, we give an overview and focus on the cross-cultural adaptation of the task. The task itself, including all the versions used in the study, can be accessed via the following website: <https://ccp-odc.eva.mpg.de/tango-cc/>

## **Setup and Procedure**

The task was implemented as a browser-based interactive picture book using HTML and JavaScript. Participants saw animated agents on a touch screen device, listened to pre-recorded audio instructions and responded by touching the screen. In all communities, a research assistant, fluent in the local language(s), guided the child through the task.

Figure 2 shows a screenshot from the task. The task was introduced verbally by the assistant as the balloon game in which the participant would play with other children to find a balloon. On each trial, participants saw an agent located in a window in the center of the screen. A balloon fell down from its starting position just below the agent. The agent’s gaze followed the trajectory of the balloon. That is, the pupils and the iris were programmed to align with the center of the balloon. Once the balloon had landed on the ground, the agent was instructed to locate it, that is, to touch the location on the screen where they thought the balloon was. On each trial, we recorded the exact x-coordinate of the participant’s touch.

There were two types of familiarization trials. In fam1 trials, the balloon fell down and landed in plain sight. Participants simply had to touch the visible balloon. In fam2 trials, the trajectory of the balloon was



Supplementary Figure 2: Screenshot from the task. The scene depicts the choice phase in a test trial. Participants had to use the gaze of the agent to locate the balloon and click on the hedge where they thought the balloon was.

visible but it landed behind a small barrier (a hedge - see Figure 2). Thus, participants needed to touch the hedge where they saw the balloon land. Next came test trials. Here, the barrier moved up and covered the balloon's trajectory. That is, participants only saw the agent's eyes move, but not the balloon. They had to infer the location of the balloon based on the agent's gaze direction. During fam1, fam2 and the first test trial, children heard voice overs commenting what happened on the screen. Critically, the agent was described as wanting to help the child and always looking at the balloon (see section script for the English wording).

Children completed one fam1 trial, two fam2 trials and 16 test trials. We excluded the first test trial from the analysis because of the voice-over. Thus, 15 test trials were used in the analysis below.

Each child saw eight different agents, four male, four female. The agent changed from trial to trial, with alternating genders. A coin toss before the first trial decided whether the first agent was male or female. The order in which agents were shown was randomized with the constraint that all agents had to be shown once until an agent was shown again. The color of the balloon also changed from trial to trial in a random order, also with the constraint that all colors appeared once before any one was repeated.

The location (x-coordinate) where the balloon landed was determined in the following way: The screen was divided in ten equally sized bins. On each trial, one of the bins was randomly selected and the exact x-coordinate was randomly chosen within that bin. Constraints were that the balloon landed in each bin equally often and the same bin appeared no more than twice in a row.

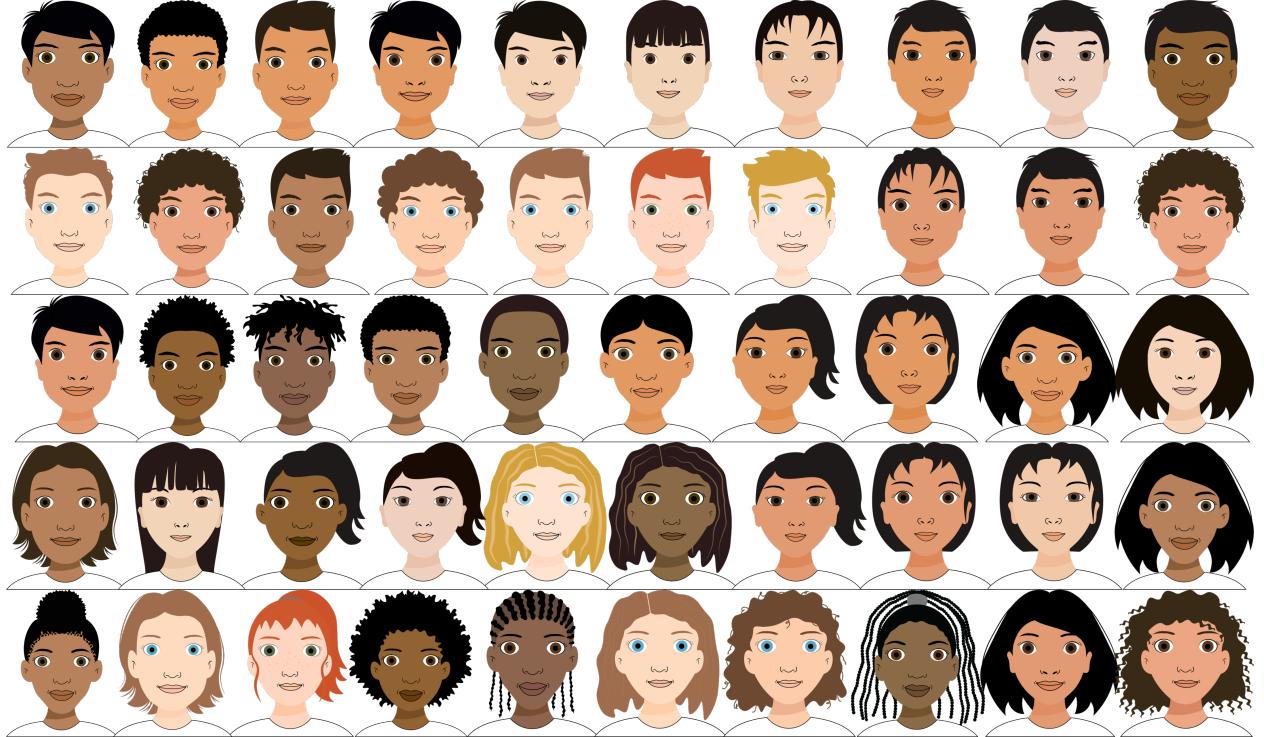
All children were tested with a touch screen device with a size between 11 and 13 inch equipped with a webcam. The data was either stored locally or sent to a server. In addition to the behavioral data, we stored the webcam recording of the session for verification purposes.

## Culture-specific adaptations

The following components of the task were adapted to each cultural setting: voice-overs, agents, background. The voice overs were originally formulated in British English and German (see section script). For each setting, they were first translated/adapted to the local language. In some cases (BaYaka and Bandongo), this was done by first translating them to French. The translations were done by native or near-native

speakers. They were not exact translations of the original text but were adapted so that children from the respective community would understand them. For example, the word “hedge” in the British English version was changed to “bush” for the Nigerian English version to adjust for how children in the respective community would refer to the thing they saw. The content of each utterance was comparable across languages.

The agents were drawn for each cultural setting in close collaboration with local researchers and/or research assistants. They were meant to show young adults and represent the diversity in appearance prevalent in the local population. Figure 3 shows the agents that were used in the study. Some agents were used in multiple cultural settings. All agents had roughly the same underlying eye-geometry (size of the pupil and the iris) and only differed in superficial features.



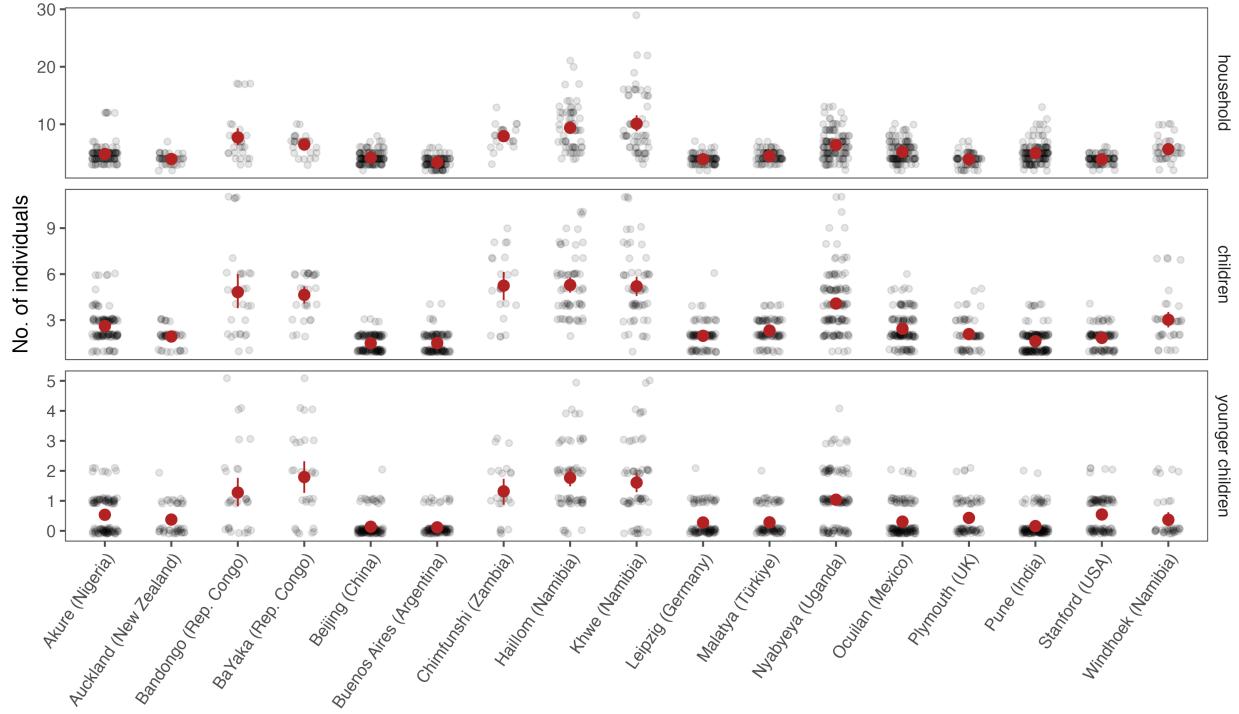
Supplementary Figure 3: Agents used in the task. Some agents were used for multiple cultural settings

## Questionnaire

The parents of children who participated in the task were asked to fill out a short questionnaire with the following questions (English version):

- Is there a device with a screen in your household? (answer: “yes” or “no”)
- Does your child have experience with touchscreens? (answer: “yes” or “no”)
- How many people live in your household (people residing and sleeping in one place e.g., a house)? (answer: number)
- How many children live in your household? (answer: number)
- How many children in your household are younger than the child participating in the study? (answer: number)

The questions were translated to parents’ native language by an assistant fluent in English and the parents’ language. Whenever parents were not able to read or write (most relevant for Chimfunshi, BaYaka, Bandongo, Khwe, Ha||om, Nyabyeya), research assistants asked the question and recorded the answer. Figure 4 summarizes the responses to the questions for each cultural setting.



Supplementary Figure 4: Household demographics by community. Points show individual data points with minimal vertical and horizontal jitter to avoid overplotting. Red points show means with 95% CI.

## Analysis

We analysed the data in three steps. First, we tested whether there was substantial cross-cultural variation in performance. Second, we looked for signatures in the data that children processed gaze in the same way across cultural settings. Finally, we related performance in the task (on an individual level) to aspects of everyday experience, in particular the exposure to screen-based technology and social interaction (approximated by household composition).

We used Bayesian Regression models fit in R (2) using the package `brms` (3) for all analyses except the cognitive models, which were implemented in the probabilistic programming language `webppl` (4). For regression models, we used the default priors built in to `brms`. The dependent variable in all regression models was imprecision, that is, the absolute distance between the true location of the balloon (x-coordinate of its center) and the location where the participant touched the screen. We used a Log-normal distribution to model the data because the natural lower bound for imprecision is zero and the data was right skewed with a long tail. Numeric predictors that entered the models were scaled to have a mean of zero and a standard deviation of 1. For each model, we collected 6000 samples from four chains, removing the first 2000 for burn-in. All models had converging chains (Rhat values < 1.01). Details specific to each analysis can be found below. The analysis code can be found in the online repository associated with the study (<https://github.com/ccp-eva/gafo-cc-analysis>).

We pre-registered an analysis plan at <https://osf.io/tdsvc>. The analyses reported below follow the same logic as the pre-registered analyses but they differ substantially in detail. The main difference lies in the random effects structure we used in the models. In the pre-registration, we did not include random slopes for target centrality (i.e. the distance of the location where the balloon landed from the center of the screen), neither within subject nor within cultural setting. Instead, we included random slopes for trial within subject. We decided to change this and remove random slopes for trial but include them for target centrality. The reasons were as follows: trial effects in the sense of learning across trials were unlikely because participants did not

receive differential feedback. Furthermore, in multiple studies with the same task since the registration we never found any trial effects (1, 5). We therefore removed trial from the models completely. On the other hand, we included random slopes for target centrality to be able to look at cross-cultural variation. The cognitive model was not mentioned in the pre-registration because it is a more recent development (see 5).

## Cross-cultural variation

As a first step, we investigated cross-cultural variation in performance. As stated in the pre-registration, this can be problematic when including random intercepts for participant and cultural setting at the same time. Participants are fully nested within cultural setting. If there was an effect of cultural setting, we would expect participant random intercepts to cluster by cultural setting. This clustering would appear whether or not cultural setting would be included in the model as a random effect or not – the only difference would be if the participant random intercepts are estimated as a deviation from a grand intercept or a culture-specific one. Standard metrics such as WAIC or LOO would penalize the model with additional intercept for cultural setting for having additional parameters that do not help to improve predictive accuracy.

To get around this problem, we used a cross-validation procedure (see e.g., 6). For each cultural setting, we randomly sampled a data set that was 5/6 the size of the full data set (training data). Then, we fit the model to this training data and used the estimated model parameters to predict the remaining 1/6 of the data (testing data). We then compared the model predictions from the different models by computing the mean difference between the true and predicted imprecision, over all trials in the testing data set. This approach gets around the problem mentioned above because the model predicts a new data set for which the individual random intercepts are unknown. Clustering by culture could therefore only be predicted by a model that included culture as a predictor. We repeated the cross-validation procedure 100 times and counted which model performed best most often.

We compared the following models (`brms` notation):

`null`:

- `imprecision ~ age + target_centrality + (target_centrality | participant)`

`culture`:

- `imprecision ~ age + target_centrality + (target_centrality | participant) + (target_centrality | culture)`

`culture_age`:

- `imprecision ~ age + target_centrality + (target_centrality | participant) + (age + target_centrality | culture)`

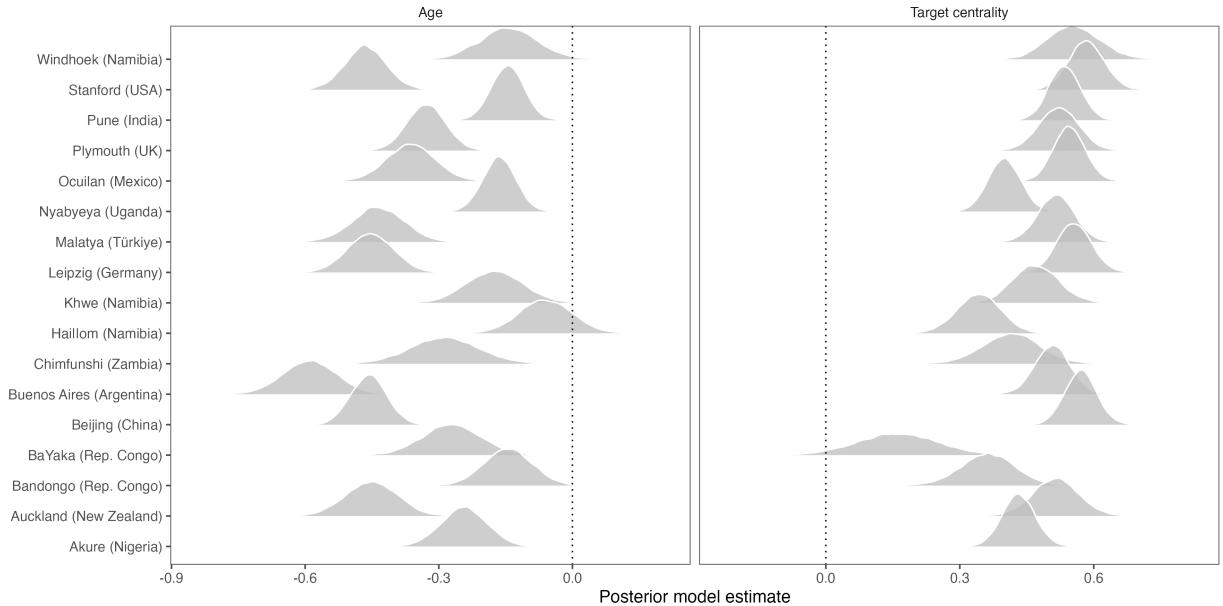
We pre-registered the inclusion of additional models which did not include age as a predictor. To reduce computational demands and given that we did not implement this approach to determine the effect of age, we decided to leave these models out so that all models included age as a predictor. The main questions were, therefore, whether there were systematic absolute (model `culture`) or also developmental (model `culture_age`) differences between cultural settings.

The results showed that the `culture_age` model made, by far, the best predictions and outperformed the `culture` model in 98% and the `null` model in 100% of cases. Furthermore, the `culture` model outperformed the `null` model in 73% of cases. This suggests that there were substantial absolute and developmental differences between cultural settings (see Figure 6A).

## Processing signatures

The second analysis focused on signatures in the data that suggest that children in all cultural settings use similar cognitive processes to infer the location of the balloon. The first – somewhat weaker – signature was simply an increase in performance with age. The second – stronger – signature was a strong effect of target centrality. That is, the further away from the center the balloon lands, the more imprecise should participants be. This second signature is derived from the cognitive model introduced in (5). It predicts that trials in which the agent looks further away from the center (i.e., to the left or right side of the screen) result in higher levels of imprecision compared to trials in which the agent looks closer to the middle.

The cognitive model implemented gaze following as a social form of vector following, whereby participants estimate a gaze vector that connects the center of the agent's eye and the center of the pupil. The model's prediction about a centrality effect is best understood by considering a similar phenomenon: pointing a torch light to a flat surface. The width of the light beam represents each individual's level of uncertainty in vector estimation and is represented in the model as a Normal distribution around the true gaze vector with a participant specific standard deviation. On each trial, the model assumes that the participant samples a vector from this distribution to infer the location of the balloon. The smaller the standard deviation – the narrower the light beam –, the more precise on average the participant is. Now, when the torch is directed straight down, the light beam is concentrated in a relatively small area. When the torch is rotated to the side, the light from one half of the cone must travel further than the light from the other half to reach the surface. As a consequence, the light is spread over a wider area. This is true no matter how wide the cone (how large the standard deviation) is. A formal definition of the model can be found below.

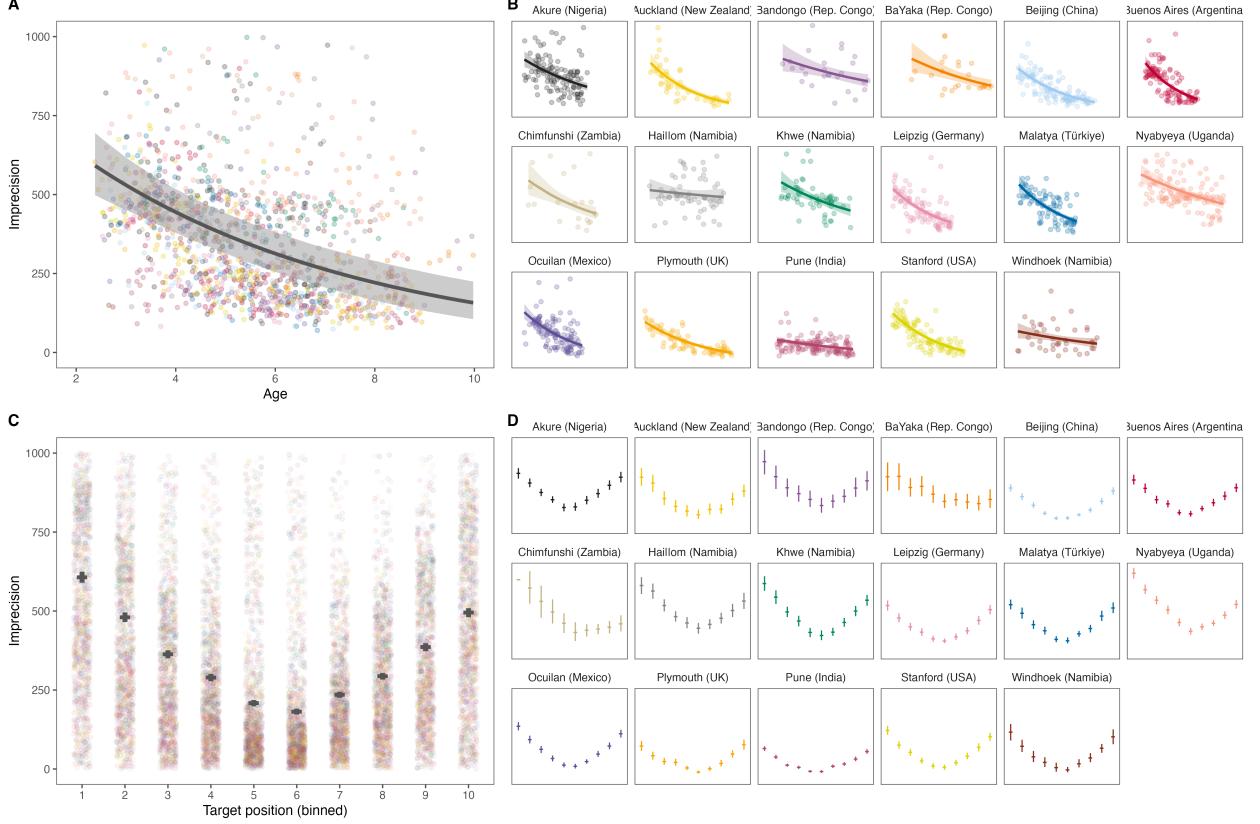


Supplementary Figure 5: Posterior distributions of model estimates for the predictor variables by cultural setting.

To test these predictions, we inspected the parameter estimates for age and target centrality in the “winning” `culture_age` model described in the previous sections. We found strong main effects of age ( $\beta = -0.3$ , SE = 0.05, 95% CrI = -0.4 - -0.21) and target centrality ( $\beta = 0.47$ , SE = 0.03, 95% CrI = 0.4 - 0.54). Figure 5 visualizes the posterior distributions for each cultural setting and shows that – despite variation in strength – there was a substantial effect of age and target centrality in all cultural settings.

Another way to look at these signatures is to visualize the group-level developmental trajectories and the aggregated performance at different areas of the screen. Figure 6A shows that children got more precise with age in all cultural settings. Figure 6B shows the u-shaped pattern predicted by the cognitive model:

the closer the balloon lands to the center of the screen (bins 5 and 6) the more precise children are in all cultural settings.



Supplementary Figure 6: A) Developmental trajectory across and B) by community. The developmental trajectories are predicted based on a model of the data aggregated for each participant. C) Performance by screen section across and D) by community. Each bin covers 1/10th of the screen. Points show means, and error bars 95% confidence intervals for the data within that bin aggregated across participants. Transparent dots in A) and C) show aggregated data for each individual.

## Cognitive model

The u-shaped pattern reported above may also arise if participants did not process the agent's gaze at all but only selected the middle of the screen or selected random locations. When only selecting the middle, the further away the balloon lands from the center, the further away it is from the center and the participant's click. When randomly selecting locations, the maximal imprecision is smaller when the target lands in the center (max: half screen width) compared to when it lands on the edge (max: full screen width). As a consequence, both alternative accounts would result in a u-shaped pattern and a strong effect of target centrality. They would not, however, predict a developmental improvement in performance. Nevertheless, we wanted to quantify the evidence in favor of the vector-based gaze estimation model compared to these alternative center bias and random guessing models.

The vector-based gaze estimation model has been described in detail in (5). In brief, the it inversely models the process generating clicks based on observed eye movements. Formally, the model is defined as:

$$P(\theta|x_c, \alpha_l, \alpha_r) \propto P(x_c|\alpha_l, \alpha_r, \theta)P(\theta) \quad (1)$$

Here,  $\theta$  represents an individual's cognitive ability to locate the focus of the agent's attention,  $x_c$  represents the clicked coordinate, and  $\alpha_l$  and  $\alpha_r$  correspond to the left and right pupil angles (each defined as the angle between a line connecting the center of the eye to the pupil and a line extended vertically downward from the center of the eye).

The basic assumption in this model is that participants click on the screen location where they think the agent is looking. The true eye angles ( $\alpha_l$  and  $\alpha_r$ ) are not directly observable and are estimated with noise, yielding  $\hat{\alpha}_l$  and  $\hat{\alpha}_r$ .

Each click  $x_c$  implies a “matched pair” of estimated pupil angles  $\hat{\alpha}_l$  and  $\hat{\alpha}_r$ , with the constraint that the lines extended along those two angles meet at the precise location of where the target is believed to be. As a consequence, we can rewrite the likelihood function of the model as:

$$P(x_c|\alpha_l, \alpha_r, \theta) \propto P(\hat{\alpha}_l, \hat{\alpha}_r|\alpha_l, \alpha_r, \theta)P(x_c) \quad (2)$$

$P(x_c)$  is a prior over potential target locations. Because the target was last visible in the screen and because the agent was located in the center, we assumed that participants have an a priori expectation that the target will land close to the middle. We estimated the strength of this center bias (i.e., the standard deviation of a Normal distribution around the screen center) based on the data:  $P(x_c) \sim \mathcal{N}(960, \sigma^p)$ .

The primary inferential task for participants is therefore to estimate the pupil angles ( $\hat{\alpha}_l$  and  $\hat{\alpha}_r$ ), i.e., to sample from the term  $P(\hat{\alpha}_l, \hat{\alpha}_r|\alpha_l, \alpha_r, \theta)$ . Here, we assumed that the pair of estimated pupil angles were sampled from a probability distribution which is the product of two Normal distributions of equal variance,  $\sigma_v$ , centered on the true pupil angles:

$$P(\hat{\alpha}_l, \hat{\alpha}_r|\alpha_l, \alpha_r, \theta) \propto \phi(\hat{\alpha}_l; \alpha_l, \sigma_v)\phi(\hat{\alpha}_r; \alpha_r, \sigma_v), \quad (3)$$

Here,  $\sigma_v$  plays a crucial role in determining the accuracy with which participants estimate pupil angles. Smaller values of  $\sigma_v$  result in a narrow distribution around the pupil angle, making clicks far away from the target less likely. Conversely, larger values for  $\sigma_v$  lead to a wider distribution, making clicks far away from the target more likely. To circle back to the analogy introduced above,  $\sigma_v$  corresponds to the width of the light beam. Thus, the goal of the model was to estimate participant-specific values for  $\sigma_v$ :  $\sigma_{v_i}$ . These participant-specific values were sampled from a Normal distribution centered around the value we expected for a child given their age ( $age_i$ ):  $\sigma_{v_i} \sim e^{\mathcal{N}(\sigma_{v_{age}}, \sigma^{\sigma_{v_{age}}})}$ . (Values were exponentiated to always be positive).  $\sigma_{v_{age}}$ , in turn, was defined via a simple regression model:  $\sigma_{v_{age}} = \beta_0^{\sigma_{v_{age}}} + age_i \cdot \beta_1^{\sigma_{v_{age}}}$ . Where  $\beta_0^{\sigma_{v_{age}}}$  and  $\beta_1^{\sigma_{v_{age}}}$  represent the population-level intercept and slope that together describe a curve that represents the average developmental pattern.

To summarize, the model assumes that participant's clicks are generated by a process that relies on noisy estimates of the agent's gaze direction. The precision, with which the gaze direction is estimated, varies between participants and increases with development.

The two alternative models assume that participants ignore the agent's gaze completely, instead they are assumed to follow simple heuristics. According to the center bias model, they always try to click in the center of the screen:  $P(x_c) \sim \mathcal{N}(960, 160)$ . (960 is the x-coordinate of the center and 160 is the width of the balloon). According to the random guessing model, they randomly click coordinates on the screen:  $P(x_c) \sim \mathcal{U}(0, 1920)$ .

All models were run separately for each cultural setting. The code to run the models can be found in the associated online repository. We also refer to this source for information on the prior distributions for all model parameters.

We compared models based on the marginal likelihood of the data for each model, which represents the likelihood of the data while averaging over the prior distribution on parameters. The pair-wise ratio of marginal likelihoods for two models is known as the Bayes Factor. Bayes Factors are a quantitative measure of the predictive quality of a model, taking into account the possible values of the model parameters weighted by their prior probabilities. The incorporation of the prior distribution over parameters in the averaging

Supplementary Table 2: Log Bayes Factors in favor of the gaze model compared to two alternative models.

Community	$\log(\text{BF}_{\text{gaze,center}})$	$\log(\text{BF}_{\text{gaze,guess}})$
Buenos Aires (Argentina)	2702.50	457.30
Auckland (New Zealand)	1169.31	274.69
Bandongo (Rep. Congo)	1357.89	68.69
BaYaka (Rep. Congo)	1988.20	84.36
Chimfunshi (Zambia)	1301.64	53.42
Beijing (China)	2241.90	497.07
Hai  om (Namibia)	2453.12	60.53
Pune (India)	4449.60	1419.74
Khwe (Namibia)	1131.30	217.61
Leipzig (Germany)	1981.50	519.27
Ocuilan (Mexico)	2248.02	723.07
Akure (Nigeria)	3691.15	312.01
Plymouth (UK)	2200.25	899.59
Stanford (USA)	2052.36	761.82
Malatya (Türkiye)	1876.08	332.46
Nyabyeya (Uganda)	4718.17	141.55
Windhoek (Namibia)	825.53	315.11

process implicitly considers model complexity: models with more parameters typically exhibit broader prior distributions over parameter values and broader prior distribution can attenuate the potential gains in predictive accuracy that a model with more parameters might otherwise achieve (7).

Table 2 shows the Bayes Factors in favor of the vector-based gaze estimation model for each cultural setting. The evidence in favor of the gaze model compared to the two alternative models was clear (all  $\text{BF} > 1\,000\,000\,000\,000$ ). This result rules out that the u-shaped pattern in the data was the result of participants always clicking the center instead of following gaze.

## Experiential predictors

The final analysis focused on whether we could predict performance in the task by aspects of everyday experience. For the ease of model fitting, we aggregated the data for each participant so that models predicted the average imprecision across trials (5 showed that the performance mean is nearly perfectly correlated with  $\sigma_v$ . When re-running the winning model on the trial-by-trial data, the results were qualitatively and quantitatively identical.). The aspects we could focus on were limited to the questions we asked in the questionnaire. That is, we analysed the effects of exposure to technology and household composition.

We asked about children’s exposure to screens as well as touchscreens. These two variables were largely redundant (see Figure 1B) and so we included only one of them in the model. We chose the availability of a touchscreen as a predictor because the task itself was presented on a touchscreen. We expected (and pre-registered) that children with exposure to touchscreens would perform better.

For household composition, we asked for the total number of people in the household, the number of children and the number of younger children. We standardized each predictor *within* each culture before fitting the models. Thus, the interpretation of the coefficient is the gain in precision for living e.g., in a larger household relative to other children from the same cultural settings.

We compared models in a Bayesian model comparison. Models were compared based on the difference in expected log pointwise predictive density (ELPD) computed via the widely applicable information criterion (WAIC) and the standard error of that difference (SE). As pre-registered, we fit a separate model for each aspect of household composition. We compared the following models.

Supplementary Table 3: Log Bayes Factors in favor of the gaze model compared to two alternative models.

Model	diff <sub>WAIC</sub>	diff <sub>SE</sub>	WAIC	SE	Weight
touchscreen	0.00	0.00	16935.74	71.16	0.43
younger children	-0.27	1.02	16936.27	71.17	0.26
household	-0.76	0.51	16937.26	71.10	0.11
touchscreen (by culture)	-0.99	0.56	16937.73	71.12	0.00
children	-1.13	0.37	16938.00	71.16	0.00
null	-4.32	3.63	16944.38	70.97	0.20

null:

- `mean_imprecision ~ age + (age | culture)`

touchscreen:

- `mean_imprecision ~ touchscreen + age + (age | culture)`

household:

- `mean_imprecision ~ household + touchscreen + age + (age | culture)`

children:

- `mean_imprecision ~ children + touchscreen + age + (age | culture)`

younger\_children:

- `mean_imprecision ~ younger_children + touchscreen + age + (age | culture)`

Table 3 shows that the model predicting average imprecision by the availability of touchscreens performed best and better than any of the models including a predictor referring to household composition. However, the difference between the models was very small (ELPD < 1, see Table 3), suggesting that they are largely equivalent, and, for the sake of consistency, we therefore inspected the posterior estimates for household composition predictors nevertheless.

To test whether there was variation across cultural settings in the importance of the availability of touchscreens, we added a model to the comparison that allowed this predictors to vary by cultural setting:

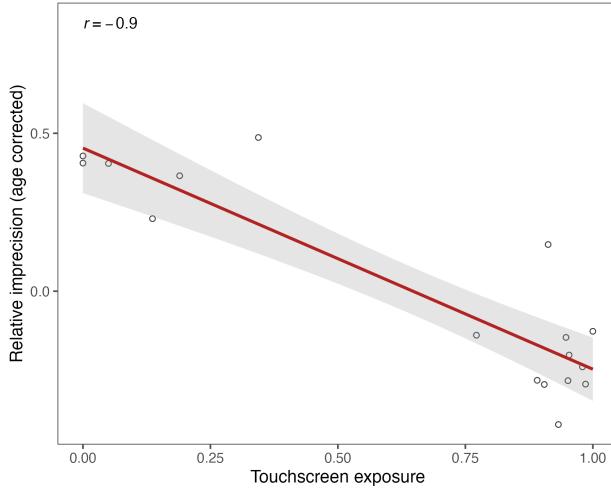
touchscreen (by culture):

- `mean_imprecision ~ touchscreen + age + (touchscreen + age | culture)`

Table 3 shows that this model preformed relatively poor, suggesting that there was little variation across cultural settings in how the availability of touchscreens influenced performance. When inspecting the estimates within the winning model, we saw that children with exposure to touchscreens performed better compared to children without exposure ( $\beta = -0.14$ , SE = 0.04, 95% CrI = -0.21 - -0.07). Figure 7 shows that there was a very strong correlation between touchscreen availability and performance on a cultural setting-level as well. To account for age differences between settings in this analysis, we used random intercept estimates for each setting from a model predicting performance by age (the null model mentioned above). Thus, the

values on the y-axis in Figure 7 represent the deviation from the grand intercept for each setting for age = 0 (i.e., the mean given the centering procedure we applied before fitting the model).

When inspecting the posterior estimates for the different predictors referring to household composition, the overall pattern was consistent with the interpretation that social interactions, in particular with older children and adults, support the development of gaze following. However, all estimates were very small and not reliably different from zero. We think the reason for this lack of a strong association is a lack of resolution: household composition is very far removed from the factors that previous work has suggested to be related to the development of gaze following in younger children, such as attachment quality or the importance of gaze in early communicative interactions (8–10). We hope that future work can increase the resolution with which everyday experiences in children from diverse cultural settings are recorded to compare the drivers behind development as we observe it.



Supplementary Figure 7: Correlation between performance in the gaze-following task and the exposure to touchscreens on a cultural setting-level. Realtime imprecision accounts for differences in age between settings in that it corresponds to the random intercept estimate for each setting in a model predicting performance by age.

## Appendix

### Voice-over script

#### Welcome (before the start of the task)

Hello! Great that you're here. We'll now play a balloon game. Can you see the children in the picture over there? We want to play together with the children using the balloon. We'll now talk you through exactly what will happen.

#### Fam 1

Look, a girl/boy is standing in the window. And can you see the balloon over there? The balloon always falls down and lands on the ground. And you have to find it! The girl/boy helps you and always looks at the balloon.

[balloon falls down]

Where is the balloon? Touch the balloon!

## **Fam 2**

Perfect, that was great! Now, we'll continue playing. Can you see the girl/boy and the balloon again? The balloon will fall down again. This time, it will fall behind a hedge. And you have to find it! The girl/boy helps you and looks at the balloon.

[balloon falls down]

Where is the balloon? On the hedge, touch where the balloon is.

## **Test**

Nice, good job! Now, we'll continue playing. There is the balloon, the girl/boy and the hedge. The hedge is growing a bit now.

The balloon is behind the hedge now. You can't see it - but the girl/boy can! The balloon falls to the ground and you have to find it. Remember - the girl/boy always looks at the balloon!

## **Goodbye (after the last test trial)**

The children are super happy after playing. Thanks a lot for your help! See you soon and goodbye!

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