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RESEARCH

Finger Fluting in Prehistoric Caves: A Critical Analysis of the Evidence for Children, Sexing and Tracing of Individuals

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Abstract

Finger flutings are channels drawn in soft sediments covering walls, floors and ceilings of some limestone caves in Europe and Australia and in some cases date as far back as 50,000 years ago. Initial research focused on why they were made, but more recently, as part of a growing interest in the individual in the past, researchers began asking questions about who made them. This shift in direction has led to claims that by measuring the width of flutings made with the three middle fingers of either hand, archaeologists can infer the ordinal age, sex and individuality of the 'fluter'. These claims rest on a single dataset created in 2006. In this paper, we undertake the first critical analysis of that dataset and its concomitant methodologies. We argue that sample size, uneven distribution of sex and age within the sample, non-standardised medium, human variability, the lack of comparability between an experimental context and real cave environments and assumptions about demographic modelling effectively negate all previous claims. To sum, we find no substantial evidence for the claims that an age, sex and individual tracing can be revealed by measuring finger flutings as described by Sharpe and Van Gelder (Antiquity 80: 937-947, 2006a; Cambridge Archaeological Journal 16: 281–95, 2006b; Rock Art Research 23: 179–98, 2006c). As a case study, we discuss Koonalda Cave in southern Australia. Koonalda has the largest and most intact display of finger flutings in the world and is also part of a cultural landscape maintained and curated by Mirning people.

Keywords Cave Art · Palaeolithic · Finger Flutings · Children · Koonalda Cave

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Introduction

Finger flutings (i.e. channels drawn by people on soft surfaces in limestone caves) have been recorded in Europe for well over 100 years particularly in France and Spain. Though no finger flutings have been directly dated themselves, in Europe, they are associated with art dating to the Late Pleistocene in caves such as El Castillo (ca. 40,800 BP), Chauvet (ca. 36,000 BP) and Altamira (ca. 18,500 BP), as well as younger caves of the Magdalenian (ca. 18,000–12,000 BP) such as Las Chimeneas, Rouffignac and Tuc d'Audoubert. Finger flutings have also been recorded in a few locations in southern Australia, particularly at Koonalda Cave (ca. 30,000 BP). Whilst all of the previous examples of finger flutings (or digital tracings) are associated with Homo sapiens, more recently, they have been documented in association with Neanderthals at the French site La Roche Cotard (57,000 BP) (Marquet *et al*., 2023).

Although some finger flutings depict figurative images of animals and others depict non-figurative signs, they appear to be mostly non-representational lines (Van Gelder and Nowell, 2020). Finger flutings have been variously interpreted as doodling (Breuil, 1912) or images of serpents (Nougier & Robert, 1958; Barriere 1982) or water (Marshack, 1977), the residue of surface preparation for making art (Lorblanchet, 1992) and evidence of the moment when a shaman touches the 'skin' of the otherworld (Lewis-Williams, 2002; see also Baird 2015; Van Gelder & Nowell, 2021). The notion of a shamanic context was irrelevant to Australia and the possibility of finger flutings as a mnemonic device was instead explored (Gallus, 1968a, 1968b, 1977). For the next 30 years or so, here and elsewhere, research on finger flutings drew an interpretative context from questions around purpose and technique.

A major shift in the focus on 'why' finger flutings were made to 'who' made them took place when evidence was provided by Sharpe & Van Gelder (2006a) that children were responsible for many of the flutings in key Palaeolithic caves of southwestern France. The finding that children are 'fluters' has since become widely accepted, and more recently, a similar claim has been made for the flutings in Koonalda Cave, southern Australia (Van Gelder, 2015b). Koonalda has long been recognised as having the largest and most intact display of finger flutings anywhere in the world (Mulvaney, 1975).

The evidence for children, as young as 2 years old, as fluters is drawn from a dataset provided in 2006 (Sharpe & Van Gelder, 2006a). The same data was also used to claim that the sex of the fluter could be identified and individuals and their movements could be traced throughout a cave (Van Gelder, 2012a, 2012b, 2015a, 2016a, 2016b; Van Gelder & Sharpe, 2009). The single most important method arising from the 2006 dataset is the use of a threshold to differentiate finger flutings made by children from those made by adolescents and adults. A statistical analysis of this resulting method and its applications was undertaken by Stapert (2007), but Stapert did not critique the 2006 dataset.

In this paper, we provide the only critical analysis of the data to be undertaken and, as reported here, fail to find evidence for claims that an age category, sex of individual fluters and movement in a cave can be derived from ancient finger flutings by using the dataset and resulting threshold provided by Sharpe & Van Gelder (2006a, 2006b, 2006c).

By way of conclusion, we argue that a meaningful attribution of finger flutings relies on objectivity, precision and a much broader context from which to interpret. The combined application of digital technology and a deeper exploration of the whole site as a social, cultural and creative space has the potential to provide a reliable understanding of finger flutings (and other forms of engraving). It is also important to note that a site such as Koonalda Cave is kept culturally alive by Mirning people, who continue to shape their land. We use this site as a case study to look more deeply into the attributions applied to finger flutings in Koonalda and more widely in Europe.

Koonalda Cave

Location and Description

Koonalda Cave is a deep cave within the boundary of the Nullarbor National Park and approximately 1200 km west of Adelaide, South Australia (Fig. 1).

Koonalda Cave was visited by Indigenous people to mark the walls and extract flint across more than 30,000 years (Walshe, 2017). This time span includes the periods before, during and after the last glacial maximum—an epoch of hyper aridity. Despite these inhospitable conditions for humans, Australian Indigenous people maintained cultural and spiritual connection with the cave and the surrounding region.

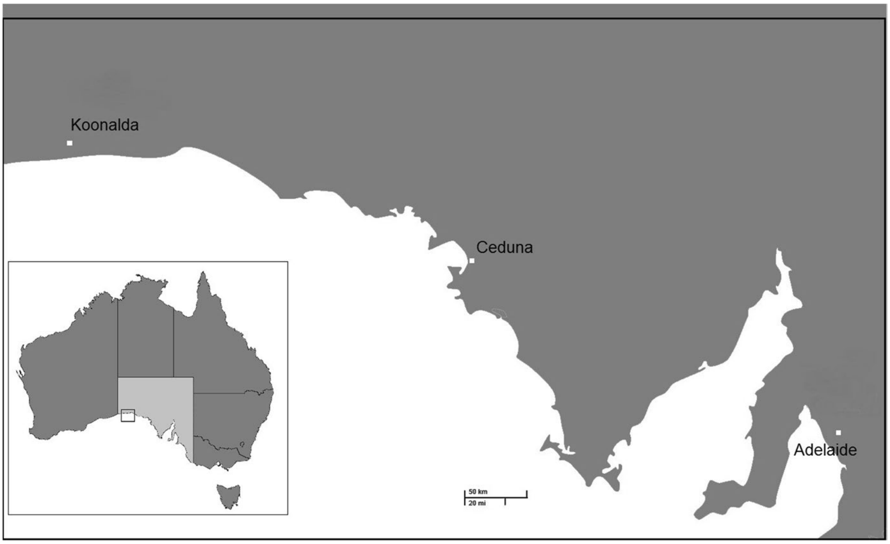

Fig. 1 Koonalda Cave, South Australia

Koonalda cave stands out from Palaeolithic caves globally, for its expansive and intact display of finger flutings on softer surfaces and incisions made on harder surfaces. In the 1960s, the announcement of the discovery of a gallery with an extraordinary display of finger flutings brought international attention to Koonalda, and eventually, Australian National Heritage status was awarded in 2014. Koonalda is also known for its subterranean waters, and from 1897 to 1957, sporadic visits were made by European explorers and adventurers keen to sample from, or boat on its lakes and streams some 80 m below the surface. The engravings, however, went unnoticed by those European visitors, and it was not until 1957 following speleological interest that possible cultural markings were reported (Gallus, 1968a, 1968c). This led to intense archaeological investigation and extensive recording of the engravings, between ca. 1966 and 1976 (Edwards & Maynard, 1968; Maynard & Edwards, 1971; Sharpe, 1973a, 1973b, 1977; Sharpe & Sharpe, 1976; Wright, 1971).

Finger Flutings and Incisions

The main chamber of Koonalda Cave is some 60–80 m below ground and was the focus for excavation activity between 1957 and 1978 (Gallus, 1968a, 1968b, 1968c, 1971; Wright, 1971). Thousands of pieces of flint that had naturally spalled from flint bands exposed as nodules high up on the walls formed the bulk of excavated material (Wright, 1971). Charcoal from the archaeological trenches yielded a range of dates from ca. 31,000 to 10,000 years old (Gallus, 1968c, 1971; Wright, 1971). However, the charcoal sequence was discontinuous, and controversy over the antiquity of Koonalda was never fully resolved. A more conservative chronological range has been long accepted, being ca. 22,000 to 10,000 years ago (Flood, 1997; Mulvaney, 1975; Mulvaney & Kamminga, 1999; Wright, 1971). More recent sampling and reanalysis of existing dates indicates a more likely range of at least 30,000 to 5,000 years ago (Walshe, 2017).

The finger flutings are concentrated in the 'art chamber' which is to the northwest of the main chamber. These two chambers are merely an extension of each other, and at some point, people were able to walk along a relatively flat floor from one to the other. Following one or more internal structural adjustments, a massive pile of rubble that once made up the roof of the chamber now interrupts the northwest passage and divides the art chamber from the main chamber (Fig. 2).

This pile known as the 'ramparts' rises some 20 m above the floor of the main chamber (Zlot & Bosse, 2014) and must be scaled in order to reach the art chamber. Incisions are also found on the cave walls, commencing above the ramparts and down into the art chamber.

The northwest passage terminates in the 'squeeze' which as its name suggests is a narrow and short tunnel, accessible only by those who are equally narrow. The squeeze opens into an alcove which overlooks a deep lake at the end of the north passage (Fig. 2). In this way, the two passages connect, albeit with a height difference of some 40 m. The walls and ceiling of the squeeze and alcove are marked with incisions along with an extensive coverage of modern graffiti.

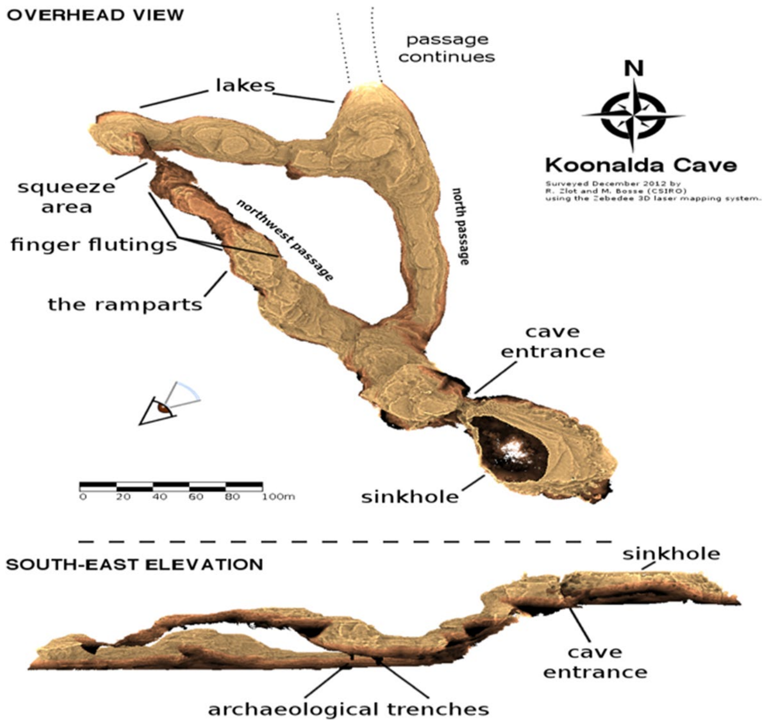

Fig. 2 Overhead view of Koonalda Cave and southeast elevation

Graffiti, dating from ca.1904, is also visible in the art chamber but does not obscure the bulk of the finger fluting panels. It is interesting that Europeans failed to recognise Indigenous cultural marks in the cave but did not hesitate to leave their own marks.

Engravings are a form of marking made by the fingers or an abrading implement, such as a sharp bone or stone (Maynard, 1977; McDonald & Clayton, 2016). In step with European terminology, Koonalda's engravings on softer surfaces were described as 'meandering grooves made by fingers in soft limestone' (Mulvaney, 1975: 156). The walls of the passage above the ramparts and into the art chamber are covered in 'montmilch' or 'moonmilk', formed by carbonate precipitation. Although a relatively soft precipitate compared to clay, it is able to retain structure when touched. Holding the fingers relatively close together and sweeping them across the surface results in a stream of flutes (Edwards & Maynard, 1968; Maynard & Edwards, 1971). This type of mark (Fig. 3) has become commonly known as finger flutings (Nowell & Van Gelder, 2020) or digital tracings (Marquet *et al.*, 2023). Other engraving types have been made by cutting into (incising) harder surfaces such as walls without precipitate and on boulders. Finger flutings and incisions co-occur where an accessible section of cave wall is only partially composed of precipitate. Koonalda has an unusual expanse of precipitate with some 350 m of wall surface covered with finger flutings (Maynard & Edwards, 1971). Incisions

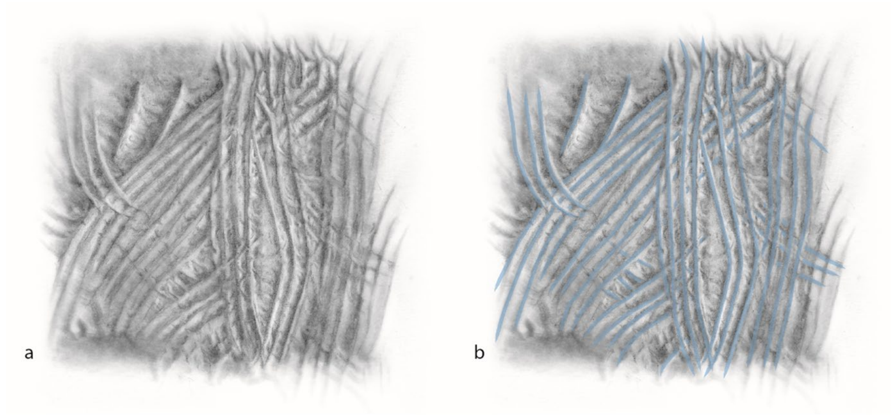

Fig. 3 Illustration of a section of digital tracings in Koonalda Cave **a** showing direction of finger movements and **b** finger movements highlighted (artist: Kathryn Killackey)

have also been made on the many boulders between the ramparts and the art chamber (Sharpe, 1973a, 1973b, 1977; Sharpe & Sharpe, 1976).

Gallus (1977) commented on the absence of figurative art in Koonalda Cave when compared to European cave art. He also noted that in Europe, often finger flutings and figurative forms would merge, leading him to speculate on a fundamental difference in creative expression between hunter-gatherers of the northern and southern hemispheres. Ritualistic, shamanic and totemic themes in the sense of empathic hunting had preoccupied European research, but Gallus (1977) saw no equivalent for this in Australia. Instead, his interest lays in marks as a form of proto language, and this aspect was pursued rigorously by archaeologist and art historian Christine Sharpe (1973a, 1973b, 1977), Sharpe & Sharpe, 1976). Other research also disassociates the engravings in Koonalda from a magical or religious origin or, alternatively, presents them as a simple response to a soft surface and instead considered the finger flutings as being on a spectrum of non-art to art (Edwards & Maynard, 1968; Maynard & Edwards, 1971:79-80).

Influenced by Marshack's (1972), Marshack, 1977) symbolic theories, C. Sharpe concentrated on the incised boulders to investigate a possible proto language before concluding that it was impossible to find meaning in the incisions (Sharpe, 1973a, 1973b, 1977; Sharpe & Sharpe, 1976). C. Sharpe became far more interested in 'what the artists are saying to us' and explored the 'maturity, proficiency and even values' of the artists (Sharpe, 1973a, 1973b, 1977; Sharpe & Sharpe, 1976:130).

The notion of 'proficiency' (or technique) began to be studied systematically by setting up a series of replicative experiments using different mediums such as paint, plaster or clay on which finger flutings could be made (Sharpe & Fawbert, 1995; K. Sharpe *et al.*, 1998, 2002). These experiments also explored the notion of 'maturity' by looking at finger flutings as a possible mnemonic device used by children. The idea that children might be making marks as a mnemonic device was certainly novel, but the suggestion of children being involved in cave art was not without precedent. Child-sized handprints have been recorded in caves in Australia and Europe (Bednarik, 1986a; Cane & Gara, 1989), and more recently, powerful oral testimonies of creating cave art as a child have come from Western Arnhem Land, Australia (Goldhahn *et al.*, 2020). Bednarik (1986b) sought direct evidence for children making finger flutings in caves by comparing the width of a modern one finger flute made by a child with the width of a prehistoric one finger flute. His results were preliminary but raised the possibility of children making finger flutings in caves (Mulvaney & Kamminga, 1999:365).

By the late 1990s, the number of European caves recorded with finger flutings was expanding and the need for consistent terminology was emphasised (Bednarik, 1986b; K. Sharpe *et al.*, 1998, 2002). Interest in children as possible creators of finger flutings was also burgeoning, but data offering a threshold for attributing flutes to children took a further 20 years after Bednarik's preliminary effort.

Evidence for Children as Fluters

In 2006, results were presented from experimental trials whereby participants were asked to create finger flutings on a clay surface (K. Sharpe & Van Gelder, 2006a). This dataset shifted the interpretative context for finger flutings from 'why' they were made to 'who' created them (Sharpe & Van Gelder, 2005, 2006a). This pursuit of 'who' led to evidence for children as the main creators of much of the finger flutings in Europe. Extrapolating further from their 2006 data, the authors also made claims for attributing fluters' sex (including children) and identifying individuals (Sharpe & Van Gelder, 2006a, 2007a; Sharpe & Van Gelder, 2009; Sharpe & Van Gelder, 2010; Van Gelder, 2012a, 2012b, 2015a).

Attributing finger flutings to individual children and identifying the sex of individuals, who made finger flutings in key European sites has drawn considerable public attention (*e.g.* https://www.cam.ac.uk/research/news/prehistoric-pre-school). In Australia, evidence for children in Koonalda Cave has brought affirmation to those who regard it as a 'community' site and a challenge for those who regard it as restricted to men only. Given the high degree of public interest in Palaeolithic children and Koonalda's cultural significance and international standing, it is surprising that the source data has not been previously analysed with respect to characteristics of the creators. The first step is to look more closely at the experiments behind the dataset used by Sharpe and Van Gelder (2006a).

Critical Analysis

Initial experimental creation of finger flutings commenced in the early to mid-1990s with results made available thereafter (K. Sharpe *et al.*, 1998, 2002). An important finding from these trials was the observed variation in width along a flute due to the uneven application of pressure by the fingers. Equally important, it was found that variation could be minimised by using only the three central fingers (between thumb and smallest finger) held close together, to create a fluting stream. The type of medium (plaster of Paris, acrylic paints or clay) was also found to influence both the width and variation in width within and among fluting tracks. These findings assisted Sharpe & Van Gelder (2006a) to set up two later trials with somewhat more clearly defined parameters, i.e. a three finger fluting stream (3FF from hereon) in a clay medium. A smaller trial involved two participants each creating a 3FF stream, ten times, and a larger trial involved 135 participants each creating one, 3FF stream (Sharpe & Van Gelder, 2006a).

Smaller Trial

The smaller trial involved one adult female and one adult male (ages unspecified) each making a 3FF ten times, each time using a fresh tray filled with clay. The consistency of the clay was not specified and seemingly without controls. In one set of comparisons, the width of each 3FF was measured at the narrowest point below the top of the stream. It was found that width varied by 8 mm for the male and by 3 mm for the female (Sharpe & Van Gelder, 2006a:945, Table 4).

Width was also measured at 5-cm intervals down the 3FF, which each measured about 20 cm in length. Variation in the width of these interval measurements gave a SD of 0.5 mm which was judged to be insignificant by the original authors. This trial also concluded that handedness and sex were insignificant sources of variation, though these were not formally assessed. These claims may be reasonably questioned (Stapert, 2007) but instead were used to further build the conditions for the trial involving a larger cohort of participants.

The composition of the clay in different trays was not gauged for firmness or consistency, and it is unknown how standard the matrices were per participant and per trial, apart from being sufficiently soft for the purpose of creating a 3FF. What bearing this may have on results remains untested.

Larger Cross-Sectional Trial

Sharpe & Van Gelder (2006a) enlisted 135 participants aged between 2 and 55 years old to each make a 3FF in a tray of clay, though only four females and ten males were older than 15 years of age. One 3FF width was then measured at one location to the nearest millimetre below the commencement of the stream and 'at the narrowest point' and matched to the participant's nominal age in years. Sharpe & Van Gelder (2006a) created three age-based categories: child, adolescent and adult. The 2006 dataset is here reconfigured from the original and presented in Table 1.

From this data, Sharpe and Van Gelder (2006a) arrived at a threshold of 30 mm or less for identifying a 3FF created by a child 5 years old or younger. The 3FF width distinguishing a child from an adolescent or adult has been revised in later publications whereby the threshold is 33 mm (Van Gelder, 2015a, 2015b), 34 mm (Van Gelder, 2012b) or 35 mm (Sharpe & Van Gelder, 2009:277). In these cases, a child is defined as aged 7 years or younger. Generally, Sharpe and Van Gelder and later Van Gelder have applied the 30–33-mm threshold in Europe and Koonalda Cave to distinguish a child under 7 years of age. The definition of a child has since become somewhat circular whereby 'an individual whose three middle fingers make a mark of 33 mm or less' is a child (Van Gelder, 2015a:120).

Table 1 For modern participants, the *N*, mean[1] and standard deviation[2] of the narrowest widths (in mm) of F2-F4 close together for each 1-year age group separately be gender[3] (Sharpe & Van Gelder, 2006a, 2006b, 2006c)

Age	Sex	*N*	Mean	SD	Age	Sex	*N*	Mean	SD
2	F	1	22.00		2	M	1	26.00	
5	F	12	28.17	4.63	5	M	22	32.50	3.52
6	F	7	35.14	1.77	6	M	7	35.71	1.60
7	F	0			7	M	1	32.00	
9	F	7	37.86	1.57	9	M	7	41.57	2.88
10	F	4	38.50	3.11	10	M	4	41.25	3.40
11	F	2	36.00	1.41	11	M	0		
12	F	8	39.38	5.21	12	M	0		
13	F	3	41.67	9.45	13	M	0		
14	F	12	37.83	3.54	14	M	10	43.70	4.74
15	F	8	37.75	2.66	15	M	5	41.80	5.12
16	F	0			16	M	1	34.00	
17	F	0			17	M	1	46.00	
18	F	0			18	M	1	49.00	
26	F	1	41.00		27	M	1	42.00	
44	F	1	40.00		33	M	1	41.00	
48	F	1	42.00		35	M	1	46.00	
55	F	1	45.00		36	M	1	49.00	
					46	M	1	45.00	
					48	M	1	39.00	
					52	M	1	42.00	

[1]Mean values for widths are shown in each year of age when at least one of the sexes has one or more values

[2]The standard deviations are for widths for a given age and sex where there is more than one individual

[3]The subtotals are 68 females and 67 males. The original study identified gender, though it is sex that is being identified here in practical terms

Table 1 presents the *N*, mean and SD for nominal age and sex. It indicates a near equal total number of females and males, but distribution by age is very inconsistent. Adults are poorly represented, and only two children are aged less than 5 years old. The largest *n* values are found in the 5-year-old age group with 38 participants. In stark contrast, there are only 11 adults aged 26–55 years old. Thirteen age groups are represented by just one participant (and therefore one sex) and 31 age groups have no representation. Most of the data refers to age groups 5–15 years old although with no or very poor representation of at least one sex for ages 7, 8, 11, 12 and 13 years.

Sharpe & Van Gelder (2006a:944) claim that individuals 'of teenage years, or even earlier' have finger widths equivalent to adult size. In other words, they suggest that children older than 13 years old most likely have adult-sized finger widths. The composition of their dataset, however, is insufficient to resolve this claim, and their surrounding considerations ignore this fundamental limitation. The limited age-specific sub-sample sizes and use of the ordinal groupings do not permit consideration of a plausible range of 3FF widths if drawn from the populations involved. Note that whilst the minimum sex-specific 3FF widths are found among the 2-year-olds as anticipated, the maximum width (51 mm) is found in a 12-year-old female and a 14-year-old male. This is surprising and emphasises that whilst younger age groups sample sizes are too small to effectively estimate age and sex-specific variance, the extremely small sample of adolescents and adults results in young adolescents having the widest 3FF widths due to sampling error (Sharpe & Van Gelder, 2006a, 2006b, 2006c).

The authors limited age-specific sub-sample sizes, and use of ordinal age groupings does not permit consideration of the rapid but variable growth rates among adolescents and preadolescent participants who make up the large majority of this dataset.

Finger Fluting Widths: In Situ Measurements

According to Sharpe and Van Gelder, a child is someone who makes a 3FF of 33 mm width (Sharpe & Van Gelder, 2006a; Van Gelder, 2015a). This is not in keeping with standard methods for scoring biometric traits to categorise a child, adolescent or adult (Nowell, 2021). It also results in an 'ipso facto' situation whereby all children produce 3FF less than or equal to 33 mm; therefore, any 3FF measuring equal to or less than 33 mm was produced by a child. Two participants, one aged 14 and one 13 in the 2006 trial, both produced a 3FF of 31 mm. Participants aged 13 and 14 years old may or may not have been children—biologically and/or culturally. As discussed earlier, 13-year-old females and 15-year-old males were found to have the highest SD of any age group, and this most likely reflects differential growth rates—i.e. the onset of puberty. Regardless, Sharpe & Van Gelder (2006a, 2006b) and Van Gelder (2015a, 2015b) have identified children (and their sex) from finger flutings in caves of southwestern France and northern Spain and in Koonalda Cave by using the threshold of 33 mm. For this reason, precision is critical but the capacity for precision when measuring finger flutings in caves has received surprisingly little scrutiny.

One potentially serious limitation is how Sharpe & Van Gelder (2006a) measured 3FF widths in cave settings by holding non-digital callipers 'as close as possible' to a fluting stream whilst avoiding direct contact. Not all fluting streams are at a convenient height or angle, as is apparent from photographic images provided across various publications (Sharpe & Van Gelder, 2006a, 2006b, 2006c; Van Gelder, 2012a, 2012b; Van Gelder, 2015a, 2015b; Van Gelder, 2016a, 2016b; Van Gelder & Sharpe, 2009). The changing nature of positioning callipers close to but not touching a fluting stream is made apparent by noting the difficulty in positioning a photographic scale. Additionally, the level of accuracy in measuring width at the narrowest point, somewhere 'just below the top', is subject to substantial observer error. The potential for observer error in finding the 'narrowest point' along a meandering mark was recognised and was offset by using the same observer in each measuring situation (Cooney, 2013; Sharpe & Van Gelder, 2006a; Van Gelder, 2012a). Van Gelder (2012a:1209) put the difference in repeat measurements at ± 1 mm, but according to Cooney (2013:164-5), repeat measurements differed by up to 3 mm for width. Relying on only one millimetre to separate a child from an adolescent or adult, is fraught by the imprecision of the dataset and by the method for measuring in cave settings. The smaller trials (discussed above) found 3 mm and 8 mm variations within an ~20 cm fluting unit, further compromising the reliability of a 30–33-mm threshold. Rather than offsetting observer error by incorporating randomised trials, using the same observer merely ensures that the same or a very similar measurement will be gained (Spiegelhalter, 2020). Lastly, variation in firmness and sediment type of each cave wall is not addressed by Sharpe and Van Gelder (2006a, 2006b, 2006c). Just as clay trials offer different consistencies, so do cave walls.

In Koonalda Cave, Van Gelder applied the same methodology for measuring the width of 3FFs in the art chamber. Again, there were no randomised trials, but a 'margin of error' was here set at 2 mm (Van Gelder, 2015b:155). Given that previous repeat measurements have demonstrated an error closer to 3 mm at the upper end, it is not obvious why a 2-mm margin of error was applied here. Van Gelder presents 3FF width measurements of 30 mm, 31 mm, 32 mm, and 33 mm for panel C (Van Gelder, 2015b:158, Figure 4). The published image does not include a scale, but taking the measurements as given, it does not avoid the fact that a deviation of 2 or 3 to 8 mm (as demonstrated in the clay trials) pushes the threshold well into the adult category.

Inferring Sex from Finger Fluting Units

The 2006 data for 3FF widths were tabulated according to nominal age and were not separated according to sex (Sharpe & Van Gelder, 2006a:943). Here are these data reconfigured and presented in Fig. 4. Both the substantial overlap in 3FF widths and the uneven distribution of participants by age are evident here.

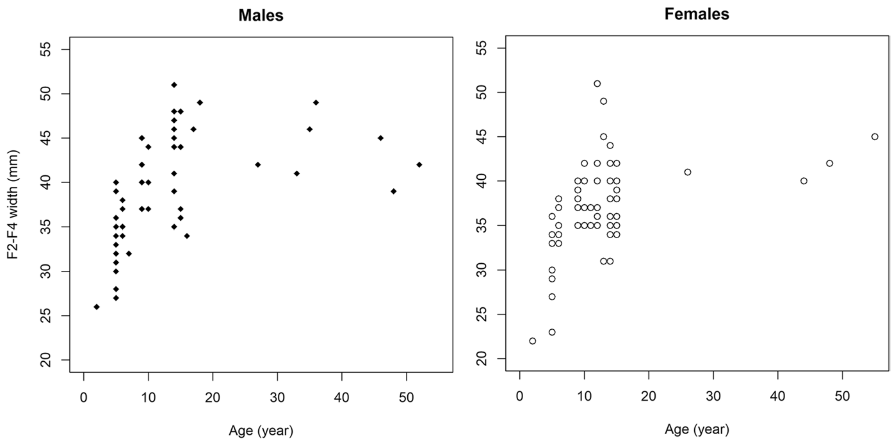

Fig. 4 Overlap in measured F2–F4 finger widths among individual males and females by year of age (Sharpe & Van Gelder, 2006a, 2006b, 2006c; total of 135 participants, 67 males and 68 females)

After the original experimental flutings indicated that the sex of a participant could not be discerned, it was thought that hand size may prove to be a more reliable indicator of sex, particularly when all fingers were kept tight together (Sharpe *et al.*, 2002:110). Transferring this notion of 'tightly held' to 3FFs and drawing on bioanthropological research by Peters *et al.* (2002), Sharpe and Van Gelder (2005, 2006a) presented a methodology for sexing finger flutings.

Peters and colleagues enlisted 502 participants (100 males and 402 females) to explore a long-standing question on sexual dimorphism in relation to finger tips. A participant's hand was photocopied with the palm down and fingers splayed. Wrist flexion was monitored in order to avoid distortion of finger length measurements, which had been found to be a significant source of error in earlier experiments. Fingers were identified as 2D–4D, with the middle finger as 3D. From the photocopy, the relative heights for 2D:3D and 4D:3D were calculated. To ensure consistency and improve accuracy, a horizontal line was first drawn along the tip of 3D and from this line, a measure was taken down to the tip of 2D or 4D. This measurement is the gap between 2D and 3D and 3D and 4D. The gaps were presented as a ratio—2D:4D. For the 502 participants, it was found that the ratio (2D:4D) for males is 0.92–0.98 mm and for females is 0.92–1.00 mm (Peters *et al.*, 2002:215). That is, 2D and 4D in females tend to be of even height relative to the middle finger, whereas in males, 2D is noticeably shorter than 4D relative to the middle finger. Peters *et al.* (2002) note that similar findings have been found in other countries.

The imbalance in number of male vs female participants in the study by Peters *et al.* (2002) was based on the recognition that far more disagreement rested on female digit tip and length patterns than for males. Their results indicated sex differences in tip and length patterns for digits; however and importantly, they remained cautious when it came to speaking of 'male' and 'female' attributes.

> At the very least, such general statements ignore the very considerable overlap in finger length and tip-extent patterns for males and females, and **create the impression of a dichotomy that is not present in the data**. (Peters *et al.*, 2002:216 emphasis added)

Peters *et al.* (2002) raise two important caveats. First, where wrist flexion cannot be controlled for, the reliability of results is questionable for relative tip height (2D:4D). Second and of particular relevance here, caution needs to be applied when using the data to determine sex.

The methodology applied by Van Gelder and Sharpe (2009) to sex finger flutings in Rouffignac is confusing in its description, but they arrive at a 2D:4D ratio as developed by Peters *et al.* (2002). The first step is to identify a 'four- or five-fingered unit' where 'the profile' has not been distorted (Van Gelder & Sharpe, 2009:326). Distortion here relates to the angle of the fluting hand to the wall, presumably in acknowledgement of the issues around wrist flexion as described by Peters *et al.* (2002). The next step is to measure 'the relative height of F2 to F4 against F3' (Van Gelder & Sharpe, 2009:326) where 'F' is equivalent to 'D' in Peters *et al.* (2002).

In taking measurements, Van Gelder and Sharpe (2009) ignore the many physiological differences between a participant who is standing with arm held at an approximate right angle to the body whilst positioning their hand, palm down onto a horizontal glass surface (photocopier) and a participant facing a wall with arm at an unknown angle to the body and palm at unknown angle to wrist before the fingers (with palm not making contact) move down the wall, applying variations in pressure for an unknown length. Treating both contexts as equivalent, Van Gelder and Sharpe (2009) measure the relative heights of 'fingertops' (finger tips in Peters *et al*. (2002)) for 4FF in Rouffignac Cave (France) and assign sex to particular fluting streams according to the 2D:4D ratio.

Images of the 4FFs selected for measuring are presented in Van Gelder and Sharpe (2009:327-331, Figs. 2–8) without a scale making it difficult to estimate the degree of accuracy. What is clear is that the boundary of each finger top (tip) is imprecise; some flutes are more angular than fluid and additional distortion (volume) is caused by presenting a 3D image as a 2D image. Perhaps it would be clearer if Van Gelder and Sharpe (2009) had provided graphics to illustrate how they measured these imprecise boundaries. Further, it is long recognised that the flutings tend to widen over time due to cave conditions (Maynard & Edwards, 1971). The ratio derived by Peters *et al*. (2002) relies on millimeter graduations. As also discussed by Peters *et al*. (2002), there is substantial overlap in the ratio for males and females. The methodology applied by Van Gelder and Sharpe (2009) appears to overlook these caveats, leaving only compromised evidence when assigning sex to individual cave artists.

More recent bioanthropological and medical research has upheld the statement by Peters *et al*. (2002) concerning a falsely perceived dichotomy in the 2D:4D ratio (Richards *et al*., 2020; Zheng & Cohn, 2011). Hand size data has been used to sex hand stencils in caves (Snow, 2006, 2013) who argued that sexual dimorphism was less apparent in Upper Palaeolithic populations but other research by, for example, Galeta *et al*. (2014) and Nelson *et al*. (2017) confirms that although male hands tend to be larger than female hands in every studied population, there remains a significant degree of overlap. Variability also manifests in the curvature of an individual's fingers, and this will distort the relative length differences between fingers (Nelson *et al*., 2017). Hand morphology is far from consistent and yet size data is expected to be an exact match, thus following a normative cline, when applied to past populations. Research by Snow (2006, 2013) remains singular in finding a high degree of reliability for assigning sex to Upper Palaeolithic hand stencils. The key point is that each region or locale requires its own unique dataset (Snow, 2013).

Identifying the Individual (Child or Adult)

The final claim by Sharpe and Van Gelder in their foundational paper (2006a) and later reiterated by Van Gelder, 2012a, Van Gelder, 2012b, Van Gelder, 2015a, 2015b, Van Gelder, 2016a, 2016b) is the identification of individual fluters in caves via specific 3FF widths. In this way, an individual is assigned a unique 3FF width that can be used to trace their movement throughout a cave. Although not all finger fluting streams are measured in each site, it is assumed that individuals cannot share a specific 3FF width. Given that the data behind this claim rests on assumptions drawn from a limited (135) participant set, which did in fact demonstrate overlap in width ranges, this claim is more than surprising. As discussed earlier, there are additional problems of imprecision and observer error when measuring width. As with the threshold of 30 or 33 mm used to differentiate a child (5 years old or younger or 7 years old or younger) from an adult, the difference is in the range of 1 mm and so it is with tracing individuals. Sharpe *et al*. (1998, 2002) had earlier concluded that due to variable pressure from fingers, the same participant does not replicate identical flutings across repetitive trials regardless of controls for medium and technique. Having explored the elements of technique such as spacing, depth and cross-section of flutings all were found to fail in providing a means of distinguishing individuals (Sharpe *et al*., 2002:110). Sharpe *et al*. (2002:110) categorically state that this also applies 'in particular to its *breadth* (sic).' Here the term 'breadth' refers to the width of a 3FF.

Observed variability when measuring in situ flutings was not discussed nor controlled for when measuring 3FF units in key European sites (Sharpe & Van Gelder, 2006a, 2009; Van Gelder, 2015a). Instead, it is boldly claimed that individual children (younger than 5 years old or 7 years old) and 'non-children' (adolescents and adults) can be traced throughout major European art sites on the basis of each having a unique 3FF, acting as a type of 'biomarker' (Cooney, 2013; Van Gelder, 2015a, 2015b).

Discussion

Research on finger flutings took a very different path with the shift from 'why' to 'who', as described by Van Gelder (2015a). The seeds for this were sown early by C. Sharpe who emphasised artistic proficiency and thus, developmental maturity, over meaning (Sharpe, 1973a, 1973b, 1977). These steps were important for shifting the focus away from a narrow view of caves as principally male spaces for ritualistic purposes as presented by, for example, Breuil and Berger-Kirchener (1961).

By applying uncritiqued interpretations developed in a European context to an Australian one homogenizers fluters and finger flutings across large spans of time and hemispheres. For Koonalda Cave, this has grave consequences whereby culture, language and belief systems unique to its locale and its people are ignored in the pursuit to find 'who' was behind all of this. The emphasis on children further narrows the objectives by becoming preoccupied with small children making marks on a wall. There already exists a vast body of evidence for Australian Aboriginal children under 5 years of age undertaking a wide range of activities around food gathering and preparing (Tindale, 1974). Much of this is learned through imitation (direct observation) as children are never separate from adults. Green (2019) directly observed and illustrated a 14-month-old girl imitating her grandmother in making sand drawings. Whilst the grandmother used a stick to make marks, her infant granddaughter used her finger to copy the same marks (Green, 2019:47).

Children as imitators of adult activity rather than being recipients of linguistic instruction is not considered by Sharpe and Van Gelder (2006a) who stated that children aged 2 and 3 years had difficulty following instruction. For this reason, only two children aged under 5 were included in the study. If very young children cannot follow instruction, then surely more caution needs to be applied when assigning prehistoric finger flutings to children under 5 years of age. However, it would also be useful to have more details about the process for enlisting children under 5 years old to make finger marks in clay. As it stands, there is no information on how many children participated initially but failed to provide useful data.

In Australia, Aboriginal children routinely helped women to dig up vegetable foods by using a short wooden digging stick (Tindale, 1974:94) or by simply pulling up vegetables by hand. In 1963, Pitjantjatjara children of central Australia were photographed grinding kangaroo meat, bone and cartilage with heavy pounding stones (Tindale, 1974: colour plate 40). Such specialised and repetitive activities as these may result in the shape of the fingers and hand tissue deviating from the norm. If comparison is to be made with modern counterparts, a means of measuring adipose and other relevant aspects is needed. As pointed out by Nelson *et al.* (2017), the issue of sorting children and fully grown adolescents from adults continues to be inadequately addressed by hand size data.

The 'Arunta' (also Aranda) people of Central Australia were the focus of extensive anthropological and linguistic study by Spencer and Gillen (1927) across some 5 years. During this time, measurements of adult hand spans were taken. To the surprise of Spencer and Gillen (1927:35), 'hands are decidedly small' when compared to European hand spans. Men were found to average 16.8 cm and women 15.6 cm with the smallest span being only 15.3 cm. Compared to modern hand spans, a span of 16.8 cm is equivalent to a 9–10-year-old boy and a 10–11-year-old girl and a span of 15.6 cm is equivalent to a girl aged less than 8 years old (Statistical Society of Canada, 2003-2023). A study of Australian pianists hand spans found an average of 22.6 cm (19.7 to 27.4 cm) for adult males and 20.1 cm (16.3–24.1) for adult females (Boyle, 2015). These are larger on average (and using only minimum measurements) than the average Arunta male and female as measured circa 1900. The same study measured 49 children and teenagers aged 6–17 years old. The range was wide, at 14.7 to 23.4 cm and found that:

> there is significant overlap between the spans of adult women and those of young children (under 12 years)….a significant proportion of women (almost one third) have "child-sized" hands. (Boyle, 2015, https://paskpiano.org/pianists-hand-spans-australian-study/)

Okumura and Araujo (2019) argue that the reliability of using modern datasets to analyse past populations has been inadequately explored and as such is unconvincing. Sharpe and Van Gelder (2006a:941) refer to anatomical studies of Cro-Magnon to argue for an 'anatomically similar size to modern people'. Although no longer in use, the term Cro-Magnon refers to early modern humans. Whilst early modern humans share genetic traits with us, they most certainly lived very different lifestyles and data arguing for anatomical comparability was not provided by Sharpe and Van Gelder, nor is it found in the two publications (Delporte, 2004; Stringer, 1992) referenced by these authors. The question of comparability between modern and Palaeolithic children was pursued by Cooney (2013) who examined available skeletal data for 82 individuals from 37 Palaeolithic sites across Europe and western Siberia. Of these 82 individuals, Cooney generates a sub-set of five children (categorised by

Cooney as ‘non-adult’) aged less than or equal to 10 years old (Cooney, 2013:88). The associated sites for this sub-set are located in France, Italy, Portugal and Russia and dated between 13,000 and 30,000 years old, thus ranging from early to Late Upper Palaeolithic. Cooney (2013) estimated each child’s stature from femoral length. All five measurements were found to fall within the range for modern mean heights, suggesting to her that comparability was reliable. On this basis, Cooney postulated that hand sizes would also be comparable, thus supporting Sharpe and Van Gelder (2006a) in stating that modern hand size datasets are applicable to Palaeolithic populations.

Of the five children in Cooney’s sample, it is worth noting that two infants (aged 1–3 years old) from Grotte des Enfants, Italy, were known to have suffered from periostitis and rachitic lesions, which causes deformity of the long bones. The 3-year-old from Lagar Velho, Portugal, was suspected to be the result of interbreeding between a Neanderthal and a modern human—which is not to suggest that a child born with Neanderthal and modern human traits is incapable of producing marks (Marquet *et al*., 2023) but the comparative dimension of such a child is untested. Lastly, height of a 3-year-old from Le Figuier, France, was estimated from humeral length in the absence of other long bones, and Cooney’s estimate of height for this infant differed from earlier estimates by 10 cm (Cooney, 2013:90). Regardless of these exceptional specimens, Cooney remained confident that her height estimates for the sub-set of children, from Early to Late Palaeolithic burials can be matched to regression lines for modern European populations.

Much genetic, molecular genetics and palaeontological research has investigated the effect on body shape and size in the transition from hunter-gatherer to agriculturalist. By comparing Upper Palaeolithic and Neolithic populations for body size as well as body shape, Piontek and Vancata (2012) found significant differences in body size, body shape, limb proportions and sexual dimorphism. More recent genetic and skeletal height research by Cox *et al*. (2019) lends broad support to this finding. Cox *et al*. (2019) observed a general downward trend in height between the Early Upper Palaeolithic and Mesolithic, followed by little change thereafter except for a slight increase in the Bronze Age. When looking at standing height as a measure of two components (leg length and sitting height), Cox *et al*. (2019) found a marked difference in change over time for leg length but unremarkable change over the same time (Early Upper Palaeolithic to Neolithic) for sitting height. It has not yet been reported if these differential changes over time (body shape; body size; limb proportions) affect hand size, but it would be unusual for the upper limbs to remain unchanged regardless of changes to the lower limbs and overall body morphology.

Australian Indigenous people did not pursue a vigorous transition from hunter-gatherer to agriculturalist, leaving models for Neolithic populations largely redundant. It is ‘the role of developmental plasticity in response to changes in the environment’ (Cox *et al*., 2019) that holds greater resonance with Australian Indigenous populations.

Looking at the data for El Castillo, Las Chimeneas, Gargas, Rouffignac and Koonalda Cave, there is no 3FF width that does not overlap with another width when applying the range of 8 mm for an individual creating a fluting unit and the 2 mm or 3 mm range to accommodate variation in recording in situ flutings. As it stands, there is no reliable evidence for 3FF width to be used as a marker to identify children or individual children or non-children (adults) in caves, nor individuals to be tracked. The earliest research in this arena identified limitations and argued for caution—all of which have been dismissed over time.

Conclusion

Identification of children in Koonalda Cave, southern Australia, and in a range of key Palaeolithic caves in Europe, as well attributions of sex and individuation to finger flutings in the latter sites, was based on data published in 2006 by Sharpe and Van Gelder. Unlike Stapert (2007) who focused on the application rather than the dataset, our critical analysis of the data makes clear that it is inadequate for the claims made. The threshold used to identify children in caves is unreliable, as are the methods for identifying sex and tracing individuals. Critical analysis of the method for measuring fluting streams (3FF and 4FF) has revealed unavoidable imprecision when measuring and later comparing finger fluting streams. As it stands, there is no direct evidence for children making finger flutings in ancient caves, as claimed by Sharpe and Van Gelder (2006a, 2006b), Cooney (2013), and Van Gelder (2015a, 2015b). There is no reliable method for identifying an individual in a cave, nor for attributing sex to finger flutings as claimed by others (Cooney, 2013; Van Gelder, 2012a; Van Gelder, 2012b; Van Gelder, 2015a, 2015b; Van Gelder, 2016a, 2016b; Van Gelder & Sharpe, 2009). The only reliable evidence for children leaving marks in caves is via handprint records and site-verified oral testimonies.

Reliable biometric data are required in order to demographically categorise finger flutings. The uncertainties displayed in the data could be resolved with more thorough data on hand dimensions among a larger more representative sample of individuals across a wide range of ages. Additionally a better understanding of the role of variation in each fluting substrate on fluting dimensions is also pertinent to the interpretative context but is yet to be investigated.

Digital techniques applied to hand stencils in caves (Nelson *et al.*, 2017; Sanfilippo *et al.*, 2013) have established useful guidelines for applying similar techniques to finger flutings. The field of geometric morphometric analysis may well enable sorting of finger flutings into age-related categories and has already proven its value in comparing actual and experimental markings on cave walls (Marquet *et al.*, 2023). However, an initial step demands that reliable comparative data are gathered by enlisting a large number of participants and adequate age distribution, to undertake trials. It is imperative that there is reliability when comparing data gathered from contemporary populations with populations of the past. There is also a further question within this—compatibility of data between hemispheres. The presence of children in Koonalda Cave was determined from limited data derived from modern northern hemisphere populations. This homogenising of biological, cultural and social attributes across time and space, in order to generate a 'one size fits all' method, demands deeper investigation. It is as unlikely that finger flutings in Australian caves share a conceptual origin with those in caves across Europe as it is that biologically, Pleistocene and Holocene populations are globally a direct match.

Indigenous figurative art in Australia presents a range of native animals, and figurative art in Europe presents its own coterie of local fauna. Apart from all being animals, there is no commonality between the two continents—as pointed out by Gallus some 55 years ago (Gallus, 1968a, 1968b, 1968c, Gallus, 1977). Universality of form should not be mistaken for universality of purpose. Research into finger flutings has drifted away from both cultural and archaeological contexts. Each site has its own unique characteristics and each site has its own unique archaeological context. These aspects have been largely forgotten by more recent research which has narrowed its objectives onto 'the artist' resulting in claims that a few children wandered at large in dark underground spaces. Palaeolithic children are a much under-researched area (Nowell, 2021) and any effort is to be welcomed, but it remains the fact that all of this is of little service in understanding complex sites, such as Koonalda Cave. Alongside newer fields of interest such as geometric morphometrics and other digital applications, there is a need to again approach marks in caves from the context of Indigenous knowledge, anthropology, archaeology and linguistics.

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Declarations

Competing Interests The authors declare no competing interests.

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