Hands on Research: The Application of the 2D:4D Ratio to Children's Hand Stencils

by

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B.A. University of Victoria, 2010

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Supervisory Committee

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ABSTRACT

Handprints and hand stencils are a ubiquitous element of rock art. For archaeologists, they represent a window onto the lives and communities of practice of prehistoric peoples. They are a means of recognizing the individual in the archaeological record and their contribution to the production of rock art. Children represent an understudied archaeological demographic despite comprising 50% of many prehistoric populations. In this thesis, I investigate the applicability of the 2D:4D ratio for sexing children's hand stencils in a modern context. Based on a sample of 318 living children between the ages of 5 and 16 years old, I analyzed the degree of variance between the ratio derived from the soft-tissue measurements, and the ratio derived from a hand stencil created by the same child. The results of this research support my prediction that the 2D: 4D ratio cannot be used reliably to sex children's hand stencils archaeologically.

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Chapter 1: Introduction

Framing the Research: Handprints in Rock Art

Contemporary artists such as Pablo Picasso, Max Ernst, Salvador Dali and Jackson Pollock used hand imagery in their artwork to create a link between the prehistoric past and the modern artist (Powell, 1997). For these artists, hand imagery was a connection that linked the past with the present (Powell, 1997). The representation of the human hand is a prolific element of world rock art. Handprints are at times, the most common element to be found in rock art globally, sometimes numbering in the hundreds at one site. While the hands often occur in isolation or in small clusters on the walls and ceilings of caves and rocks shelters, other times they occur in larger groupings that hint at their meaning. For instance at the 35,000 year old site of Chauvet (France), handprints were placed in such a way as to create a bison. Scientists noticed that some of these handprints were distinguishable by a crooked "pinky" finger. They concluded that not only was this bison created by several different people but that the patterning of the placement of the individual handprints suggested that it was created as part of a dance or ritual (Clottes 2003). In Borneo, 12,000 year old handprints are connected by a painted leafy vine suggesting a "tree of life." Each of these prints is "tattooed" with a unique pattern of dots and geometric shapes (Chazine 2008). The repetition of the same hand throughout a cave and perhaps especially where the hand stencils are located, might even tell us something about the personality of the rock art artists. For example, where hand stencils appear on stalagtites above a 19 meter shaft at Cosquer cave in France, one might argue that the rock art artists had to have been very brave, or fearless (Clottes, 2008).

Hand imagery is unique in that, unlike parietal art, the rock art artists left behind clues to their identity with every handprint that they made. Archaeologists can discern the approximate height of the individual from how high their hand stencil is found on the wall; the width of the digits and the size of the overall hand gives an indication of age and techniques like the 2D:4D ratio may make it possible to discover if both males and females were actively producing rock art. The small size of many of these hand stencils is indication that leaving a mark in the world was not the sole purview of adults, children too left behind traces of their presence. Currently, handprints provide the most conclusive means of determining the sex of prehistoric artists (Nelson et al. 2006). According to biological research, a finger ratio (2D:4D) is pre-determined in the fetal stage through exposure to oestrogen and testosterone (Koehler et al. 2004). This finger ratio refers to the difference between the length of the second digit or 'index finger', and the fourth digit or the 'ring finger.' Typically males have a longer ring finger in relation to their index finger while females demonstrate the opposite (Neave et al. 2003).

In brief, there are three types of hand imagery in rock art; positive handprints, negative hand stencils, and stylized hands. Positive handprints are made by dipping the hand into pigment and then placing the hand against a flat surface. What remains is a positive impression of the pressure points of the hand. The 'completeness' of the print is largely dependent on how firmly the hand was pressed against the surface. Negative hand stencils are created when a hand is placed against a flat surface and pigment is blown around the hand rather than placed directly on it. When the hand is removed from the surface, a negative outline of the hand remains. Stylized handprints are hand images that have been drawn or modified with decorations or which have been exaggerated until they no longer resemble the anatomical hand. At rock art sites in France, negative hand stencils far outnumber positive handprints (Von Petzinger, 2009). In Montana, USA, positive handprints outnumber negative hand stencils (Greer & Greer, 1999). There appears to be very little consistency in terms of how many hand stencils are found in a cave or at a rockshelter, where they are placed, colour choice and their dating, even if the rock art sites are close-by (Leroi-Gourhan, 1982). Yet regardless of these inconsistencies, handprints remain the most common element of rock art worldwide (Anati, 1994; Bahn, 1998; Greer & Greer, 1999; Nelson et al., 2006; Snow, 2006).

Figure 1: Cave of the Hands, Patagonia
http://www.cbc.ca/news/technology/story/2012/06/14/cave-paintings-europe.html

Figure 2: El Castillo, Spain
http://www.cbc.ca/news/technology/story/2012/06/14/cave-paintings-europe.html

Figure 3: Red Hands Cave, Australia
http://www.australiaforeveryone.com/au/places_sydney_absites.htm

Figure 4: Gua Tewet, Borneo
http://ngm.nationalgeographic.com/ngm/0508/feature2/gallery5.html

Studying handprints in rock art is a powerful means of returning identity to these anonymous Ice Age artists. It also offers researchers a window onto ephemeral practices that otherwise leave no trace. Recent handprint studies have demonstrated the potential to ascertain whether males and females both participated in the production of the rock art of the Upper Palaeolithic (Chazine & Noury, 2006; Conkey & Gero, 1997; Conkey, 2007; Greer & Greer, 1999; Sharpe & Van Gelder, 2004; 2006b; 2006c; 2009; Snow, 2006; White, 2003) We know from the small hand stencils, finger flutings and footprints, that children were involved in the production of rock art, deep within the caves (Bednarik, 2008; Clottes, 2008; Guthrie, 2005; Sharpe & Van Gelder, 2006). Yet few studies have been conducted on these relatively rare examples of children's art. An informed, scientific analysis of these hand stencils has the potential to reveal if both male and female children were not just present, but *active participants* in the production of the rock art. One scientific means of approaching this analysis is with the use of the 2D:4D ratio (Manning, 1998).

Research Question

Underlying the current research applying the 2D:4D ratio to archaeological hand stencils is the assumption that hand stencils accurately reflect the anatomical hands that produced them. This assumption is at the heart of my thesis research, as it should be for anyone pursuing these kinds of studies. If the hand stencil *is* an accurate reflection of the anatomical hand, then we can assume that any 2D:4D ratio analyses derived from hand stencils to be accurate and the sex that the ratio is used to determine conforms to the typical male or female ratio. If the hand stencil does not accurately reflect the anatomical hand, then any calculations obtained from the hand stencil would be inaccurate and would likely lead to a misclassification of sex. Therefore, I ask the following research question as the foundation of my thesis research:

Can the 2D:4D ratio be used to determine sex from children's hand stencils in a modern context?

My experimental study will compare the anatomical 2D:4D ratios of living individuals against the 2D:4D ratios calculated from the hand stencils that these same individuals produce. As the research of the past decade has focused primarily on adult hand stencils with the exception of children's finger flutings, the 2D:4D analysis which I am proposing will be pursued using local children from the Victoria area. This analysis will therefore amend the assumption underlying all current and ongoing research using the 2D:4D ratio and will also shed light on the potential use of the ratio where children's hand stencils are concerned. To answer my research question, I have broken it down into the four following sub-questions:

1. Is the hand stencil is an accurate reflection of the anatomical hand?

2. Does age effect the amount of error present in the 2D:4D ratios of children and to what degree?

3. Does sex effect the 2D:4D ratios of children and to what degree?

4. Does the 2D:4D ratio ‘fix’ into place sooner for females than for males, based on the quicker osteological growth and development of their hands (Scheuer & Black, 2000)?

Ultimately, the answer to each of these questions, which in turn answers my research question, will determine the viability of using the 2D:4D ratio to determine sex from children’s hand stencils archaeologically.

Thesis Outline

Early interpretations of parietal art, which included hand stencils, reflected a bias in the discipline of archaeology (Canby, 1961; Prideaux, 1973, Nelson et al., 2006). It was commonplace to assume that the art of the Upper Palaeolithic was the result of men and small boys only and that the art was most likely produced while in a shamanistic trance (Canby, 1961; Lewis-Williams, 2002; Nelson et al., 2006; Prideaux, 1973). Fortunately opinions on who produced the rock art of the Palaeolithic are shifting and it has become commonplace to assume that both men and women were active participants (White, 2003). In Chapter 2, I focus briefly on the origins and the perpetuation of the androcentric bias in archaeology as it underlies the bias against children in the archaeological record. As Bednarik (2008) has mentioned, the idea that at least a portion of the overall corpus of rock art as yet discovered may have been made by adolescents and children, has not been a popular theoretical perspective. In this chapter I explore the reasons behind the disregard for children in the archaeological record and I discuss how current research is seeking to amend the shortfall. While research on the archaeological contributions of children are still not as common as they should be, I briefly discuss some theoretical interpretations of children's hand stencils as well as Gargas and Cosquer caves in France.

Because hands account for 25% of the distinct bones in an adult hominin skeleton (Tocheri et al., 2008), this chapter also includes sections devoted to an understanding of the biology of the hand from the evolution of its morphology, to its current osteology, and finally to an understanding of the influence of fetal hormones on its growth and development. Examining the morphological evolution of the human hand and its association with the development of tool use and manufacture is critical to understanding how rock art was produced. Delving into the osteology of the modern human hand and in particular, the growth and development of the hand in utero through adolescence, sheds light on the complex nature of its structure and function. Because fetal hormones, most notably fetal estrogen and fetal testosterone are responsible for the development of sex related differences in the urinogenital system, as well as the digits of the hand, this is an integral area of my research (Austin et al., 2002; Lutchmaya et al., 2004; Manning et al., 1998; 2001; 2001; 2004). Armed with this background information, I am better able to examine the hand stencils from my sample and to make informed determinations regarding the sex of the individual artists, and the viability of using the 2D:4D ratio in an archaeological setting.

Chapter 3 is my methods chapter which introduces not only my own experimental study, but includes a discussion of the studies which are the foundation for my research. I divide these studies into two sections. First, I look at the clinical research into the 2D:4D ratio and then I overview of the archaeological applications of the ratio to date. These clinical studies are important, particularly Manning et al.'s 1998 publication, for a few reasons. Firstly, because these key studies are the cornerstone of all research involving the 2D:4D ratio, they are repeatedly cited and referenced in the studies that succeed it. Secondly, and most relevantly to my research methods, these studies introduce a methodology for 2D:4D research-a method which has become standard practice for both clinical studies as well as the archaeological studies. Finally, these clinical experiments are of note because they establish an age range at which the 2D:4D ratio is commonly expressed in children. As I explain in chapter 3, these studies are the reason that my sample included children between the ages of 5 and 16.

The archaeological studies I discuss in this chapter are relevant as they situate my research within the larger body of 2D:4D ratio studies which have involved the direct application of this technique. Applying the 2D:4D ratio to the representation of the human hand is not as straightforward as clinical studies involving the anatomical hand. The ratio must be modified in circumstances involving finger flutings in particular. The development of a method for using the 2D:4D ratio on positive handprints, negative hand stencils and finger flutings as well as the necessary modifications to that method and the science behind it are described herein. These two sections form an important introduction to my own method which is derived from that used in the clinical studies where anatomical measurements were possible, and from the archaeological method, where the measurements of the negative hand stencils I collected from my sample are involved. My method includes information regarding sample collection, ethics approval, details recorded from the participants, the measurements, and a discussion of the statistical tests used to examine the data.

In Chapter 4, I present my results and my analysis. Included in this is a brief discussion of the relevance of each sub-question as to how they each contribute to answering my overall research question. In this chapter, I move through each sub-question presenting the results of the statistical analyses and I briefly summarize the results. These results are then discussed in full in Chapter 5, my discussion chapter. Just as in my results and analysis, I structure this discussion by sub-question and attempt to interpret the results not only in terms of my own research question, but also to make more general conclusions about the potential use and the limitations of applying the ratio to archaeological examples of children's hand stencils in the future. This last chapter provides a synopsis of the conclusions that I have drawn, critically analyses the outcome and any short-fallings of my research and discusses the possibilities of future research on this topic.

Chapter 2: Theoretical Background

Introduction

This chapter is intended to provide a theoretical framework for my research into the use of the 2D:4D ratio on children's hand stencils. Until now, each experimental application of the 2D:4D ratio archaeologically, with the exception of the research by Sharpe and Van Gelder on finger flutings, has involved adult sized hands only. However, ignoring the presence of children's hand stencils excludes a significant demographic of the Palaeolithic population. If we are attempting to envision the lifeways of Palaeolithic peoples by analysing the rock art they left behind, the contribution of children cannot be ignored. Children in the past likely formed an integral weave in the fabric of Palaeolithic culture. While my research focuses on a modern sample of children, it is hoped that this experiment will make it possible to examine archaeological examples of children's hand stencils with an eye to exploring the lifeways of ancient children. The primary theoretical context of my research is the archaeology of children. In this chapter, I present several reasons why this bias against children has left significant holes in our understanding of the past and the lifeways of Palaeolithic peoples.

The information we have learned from archaeological hand stencils so far, particularly that both men and women participated in their production, has been a considerable leap forward in overcoming the bias in the discipline however, children of the past remain on the periphery. One way forward may be to carry out the same level of analysis on children's hand stencils that has been done for adults. First however, it is important that we do so with a knowledge and an understanding of how the 2D:4D ratio works and the potential limitations associated with it. To accomplish this, I have done a brief study of the morphological history of the human hand and research to date on this topic. The facts which I believe are the most relevant to the production of rock art including the specific grips that are required to make pigments and to hold tubing while creating a hand stencil are discussed.

While morphology of the human hand is important and therefore should be discussed as one aspect of the background research of this topic, the osteology of the human hand particularly as it relates to growth and development, are even more relevant. This is because the growth of the human hand and the contribution of the associated hormones directly pertain to the 2D:4D ratio. While I do discuss the relationship between fetal and child development and the expression of the 2D:4D ratio in Chapter 3, the theoretical discussion I employ in this chapter relates only to the differential growth of the hand by sex and the stages at which significant features develop osteologically in utero and postnatal.

Finally, I conclude with an examination of the key hormones which are expressed by the 2D:4D ratio and which cause it to be sexually dimorphic. This exploration of the genetic and hormonal relationship of the 2D:4D ratio to growth and development is integral to our understanding of the ratio and more importantly, to its use as a tool for determining sex in both the modern context of my sample as well as future archaeological work. Moreover, this part of the theoretical background discussed in this chapter includes an examination of the medical use for the ratio and how the 2D:4D ratio has been used to diagnose illnesses and disabilities in children as well as later in life. These considerations must be taken into account by archaeologists pursuing 2D:4D ratio research; we must always remember that the ratio is first and foremost a medical means of diagnosing abnormality based on the sexual dimorphism expressed in the ratio.

These topics, a review of the archaeology of children, the modern and ancient use of hand imagery, the morphological and osteological development of the human hand and medical application of the 2D:4D ratio based off of an understanding of the hormones and the genetics at play, form the basis for the theoretical framework of my research. These topics, explored in this chapter, should be the foundation of any research involving the 2D:4D ratio and its use archaeologically. If we do not understand what we are using, then we cannot understand the results that we are acquiring.

The Archaeology of Children

> "abbé Breuil was convinced that making art was a religious activity, so rock art had to have been done by priests and shamans, who would have been male only, because in his experience, only men were priests. Leroi-Gourhan, Guthrie, Onians, and others thought art was made by hunters, and in their understanding of world ethnography, only men were hunters. Many believed that caves were too deep, dark, and difficult to get into, and so would have been too frightening for women" (Russel 1991 in Hays-Gilpin 2004: 90).

The early interpretation of parietal art, which included hand stencils, reflected a bias in the discipline of archaeology. It was commonplace to assume that art was the result of men and small boys only, shamanistic practices, and trance (Canby, 1961; Lewis-Williams, 2002; Nelson et al., 2006; Prideaux, 1973). The development of an anthropology of gender came from the realization that the exclusion of women from theory, ethnography and archaeology resulted in fundamentally flawed research (Hirschfeld, 2002). Over the past several decades, feminist anthropology has overturned this phallocentric perspective and women and their contributions to past and present societies now forms a large part of anthropological research. As a result, the current interpretation recognizes that Palaeolithic rock art was created by males and females of all different ages (Chazine & Noury, 2006; Conkey & Gero, 1997; Conkey, 2007; Greer & Greer, 1999; Sharpe & Van Gelder, 2004; 2006b; 2006c; 2009; Snow, 2006; White, 2003). However despite this paradigm shift, popular artist reconstructions of Palaeolithic lifeways, particularly those found in museum dioramas, continue to portray rock art artists as male only (Moser, 1998; Sharpe & Van Gelder, 2009). While public perception of Palaeolithic lifeways may need time to reflect on the current research, archaeologists still have a long way to go towards correcting the exclusion of children from the archaeological record (Hirschfeld, 2002). As children are often associated with women and the domestic sphere and dependent infants even more so, it is likely that the exclusion of children from anthropological inquiry is directly related to the gender bias (Gottlieb, 2000; Hirschfeld, 2002). Ironically while children are often identified in association with women, the reality is that children are more often found to be the primary caregivers of younger siblings than the adults (Kamp, 2001). While our concept of gender is culturally constructed, 'childhood' is a universal experience (Hirschfeld, 2002).

Biologically, children exist within a childhood stage, often from birth until adolescence. The stage or stages of childhood vary cross-culturally within history, in terms of age, and socioeconomic class (Bugarin, 2006). For example, within Western society, childhood is a medical gradation which marks the stages of a child's life from infancy until young adulthood, wherein a final transition is made to adulthood (Kamp, 2001). The period of childhood is structured around play and the socialization which may come from play, as well as education, in which a child learns what is required for it to become a successful, productive member of Western society. In other cultures, children may contribute economically to their society by participating in the subsistence strategies of the group. This participation could involve herding domesticated animals, collecting water and or firewood (Kamp, 2001). Among the Ngoni people of Zambia for example, young boys are socialized into adulthood by preparing for war, learning of their environment, and making their own weapons and tools (Bugarin, 2006). Likewise, young girls of the Maasai participate in the activity of adult women by gathering wild berries, fruits and nuts (Bugarin, 2006). Despite our knowledge of these practices, and the fact that children frequently make up the largest demographic portion of any human group, children remain on the periphery of ongoing anthropological research (Baxter, 2006; Hirschfeld, 2002). Yet children in antiquity, similar to adults, were active agents in the creation of an archaeological record. This record may be most visible to bioarchaeologists working directly with skeletal materials as it is with skeletal analysis that it is possible to recognize 'subadults' within the archaeological record and to further identify the health and diet of children in antiquity, as well as evidence suggesting child abuse, infanticide, child sacrifice and participation in such violent activities as warfare (Perry, 2006; Schwartzman, 2006). By analysing the physical evidence of children and childhood as well as the material culture which can be attributed to children, we form the basis for an archaeology of children (Bugarin, 2006).

Aside from the gender bias, one of the most likely reasons that children have been excluded from anthropological inquiry stems from the idea that children and their activities on the landscape negatively impact the archaeological context, acting as a distorting element in an archaeological distribution (Hammond & Hammond, 1981). For example, Wilk and Schiffer's (1979) research on children's play and the use of vacant lots suggested that the activities of children and their use of discarded objects as playthings may affect the distribution of materials throughout the landscape of the vacant lot. Further experimentation by Hammond and Hammond (1981) corroborated Wilk and Schiffer's (1979) research indicating that children's activities at a site and their use of artifacts as playthings alters the primary context of site materials. Hammond and Hammond (1981) further imply that the incongruities of artifact collections within a site often attributed to unknown ritual activity may in fact be the result of the distortions of child's play. However, viewing children's activities on the landscape as merely a distortion of adult activity erases children as active participants within the social group. Theoretically, the socialization of children by adults suggests that rather than a distortion, children should produce a patterned distribution of artifacts that can be analyzed. These artifact distributions should reflect the cultural norms, beliefs and practices of the society (Baxter, 2006). If archaeologists do not take into account the reality of children and children's activities on the landscape, the potential is there to unintentionally eliminate their presence from the archaeological record in lieu of adult assemblages (Bugarin, 2006).

Another reason children have been neglected from anthropological inquiry is due to the prejudicial interpretation that the contribution children make to cultural reproduction, is less than the contribution of adults (Hirschfeld, 2002). In this view, children are distinct, unequal being compared to adults and subject to cultural ineptitude, whereas adults are considered masters of the culture as a whole. According to Socialization theory, a child's cultural competency within a given society is due in large part to the intervention of adults. Discussions of children acquiring culture can therefore be construed as discussions of how adults formulate children's activities in order to develop children into models of cultural proficiency within a society. This view undoubtedly stems from a lack of understanding of how children's culture directly impacts adult culture, as well as the contribution that children make to the development of their own cultural competency. While its true that children live within the given cultural context of adults, arguably they also exist within their own cultural context; that of children. Children do not set out to become proficient adults; their goal is to be proficient children. In this way, children cannot be said to be inept members of an adult society, since they are already adept members of their own society, which includes a culture of its own. Assuming that children only learn and are socialized through mimicry of adult behaviour reflects a normative view wherein children and their behaviours are only important research components in relation to their adult counterparts (Hirschfeld, 2002).

A child's cultural world is composed of a number of factors, including the child's connection to the environment, to adults, and to other children (Schwartzman, 2006). How the environment is divided and structured is culturally specific. Not being familiar with the structure of a landscape can cause disorientation and feelings of unease. Environmental divisions may reflect different categories of age, gender and class or further, task oriented locations within a culture. Where children are allowed to make use of the environment is often dictated through parental consent, a process which may influence a child's perception of its environment and where within the landscape a child's activities will take place. Children's use of space cannot be called random, since it is so dictated by both parental consent and cultural ideals. Rather, a child's use of space is patterned within the cultural landscape (Baxter, 2006). Archaeologically, children and their cultural domain can only be accessed if it is acknowledged that children have agency. This agency can be expressed by children through technology, as a process of socialization, which leaves behind archaeologically visible remnants (Smith, 2006).

For example, excavations of prehistoric mounds associated with the Pueblo Indians of the American Southwest have revealed small figurines made of adobe clay, molded into the shape of humans and domestic animals (Fewkes, 1923). One interpretation is that they are fetish figurines while another, based on the work of ethnologists studying the Navaho, is that the figurines are the result of children's play. While the figurines bear a striking resemblance to the fetish figurines made by adults for ceremonial purposes, analysis of some of the figurines show that tools were not used in their manufacture and that they are too small to have been made by adult fingers. This suggests that at least some of the figurines are not fetish related at all, but children's toys, made by children, and taken out of context (Fewkes, 1923).

In 2006, Patricia E. Smith identified juvenile pottery craftsmanship among the Huron of Southern Ontario, Canada, between 1400 and 1650 AD. Juvenile pots are frequently identified by their small size, rudimentary form and simple motifs. Smith's interpretation is that the small size of the pots could reflect the amount of clay provided to children for practice. The rudimentary form of the pots refers to her observation that while the pots are consistently even, they lack the proper curvature of adult craftsmanship. The motif's on the juvenile pots do not have as much depth of impression and the spacing between design elements is less systematic than adult pottery, possibly reflecting the development of children's motor skills. The most important element of Smith's analysis was recognizing that while children were copying adult designs, they were also given the liberty of being creative. Juvenile pots often exhibit geometric patterns that are rarely seen on adult pottery, suggesting that children were given the opportunity to experiment, while the overall consistency of the pottery production demonstrates a structured learning system (Smith, 2006). By participating in their own learning, Huron children demonstrate agency within the archaeological record.

Finally, Robert W. Park's (2006) work with the Inuit, descendants of the Thule in the Canadian Arctic has direct implications for identifying children in the archaeological record. According to Park's research, Thule children made and used a variety of miniature implements such as spinning tops, wooden balls, playhouses which left visible traces on the landscape in terms of pebble foundations, dolls with deerskin clothes that taught young girls how to sew, hunting tools as well as "toys, sledges, kayaks, umiaks, cooking pots, snow knives and sleeping platform mattresses" (Park, 2006: 57). As it is well-documented that the Inuit consider children to be small adults, it follows that the manufacture and use of miniature objects by and for children was a means by which children of the Thule could practice adult tasks. Park's (2006) research is significant because it demonstrates the socialization process that children undergo as they approach adulthood.

As the above examples demonstrate, children's play can provide valuable insight into the cognitive, cultural and social development of a child (Hirschfeld, 2002). Play can be taken as an opportunity for a children to experience cooperation and competition with other children; games may teach social and physical strategies that children may need to be successful members of their society as adults (Kamp, 2001a). In addition, children's play that focuses on craft production may begin as play but develop into the economic production of that craft by early adulthood (Kamp, 2001b). As the above examples indicate, aspects of children's play, their relation to the landscape and the participation in the economics of a culture all leave tangible traces of their presence within the archaeological record. It is important that children; their health, their activities, and their economic roles be recognized by anthropologists. Fundamentally, understanding children and childhood cross-culturally and in antiquity can only improve our understanding of culture. Ignoring the archaeological evidence for children disregards a significant portion of prehistoric populations and generates faulty research (Kamp, 2001).

Children presently and in antiquity have often been economic contributors to their own households and communities. Evidence of children in the archaeological record can be elucidated from the presence of playthings, craft production and children's presence on the landscape. It must be acknowledged that children have agency within a society and are therefore important to be studied as active cultural participants. Following on the heels of an archaeology of gender, an archaeology of children which recognizes childhood agency, economy and culture is critical to the field of anthropology. As a significant portion of past and present societies, the presence of children on the landscape has direct implications for the culture of any society and they must be recognized for their contribution to the archaeological record. Since the acquirement of culture and cultural skills is a lengthy process which begins and progresses throughout childhood, children are therefore responsible for the greatest amount of cultural learning within any given society and as such, are most definitely worth our attention (Hirschfeld, 2002). Incorporation of children and childhood into the study of archaeology provides a well-rounded description of culture and acknowledges that overall society is multi-faceted and made up of more than an adult population.

Archaeological Hand Stencils: A Global Perspective

> "Handprints/stencils are an astoundingly enduring and widespread image class and are among the most frequent motifs on every continent. They occur in Africa, the Americas, Asia, Australia and Europe. Their meaning, however, remains recondite (Ouzman, 1998: 36).

Most, if not all publications on the subject of archaeological handprints begin with a sentence or two regarding the ubiquity of hand imagery in world rock art. This is both because the practice of representing the human hand is geographically widespread and because it has a long history, beginning in the Palaeolithic. Hand stencils in France and Spain may be the earliest in the world - being primarily Gravettian in age (Pike et al., 2012). For some time now, the hand stencils at Gargas and Cosquer caves in France have been thought to be the oldest in the world (Clottes et al., 1992; Pike et al., 2012; Snow, 2006). However Uranium dates from the site of El Castillo in Spain may upend this long held belief proving that hand stencils that could date as far back as 37.3 ka, or into the Aurignacien (Pike et al., 2012). If this date holds up under further testing, it would indicate that hand imagery is among the most ancient of rock art motifs in Europe (Pike et al., 2012). Regardless, the meaning behind the creation of hand stencils around the world most likely differs in different places, at different times (Dobrez, 2013). That being said, "the act of leaving a recognizable trace of one's hand on a surface by direct contact [must ultimately] facilitate an investment of cultural meaning" (Dobrez, 2013: 6). Which is to say that while the meaning behind hand stencils undoubtedly varies by geographical location as well as by time period, the act of creating a hand stencil is meaningful in and of itself. As Dobrez points out,

> "the capacity of the hand, either as direct instrument in the case of finger flutings, stencils and prints, or for the manipulation and manufacture of tools, is understood in rock art studies, but only a small number of rock art researchers focus on its role in cognitive evolution. Indeed, the hand in all its aspects is inescapably chief protagonist in any story of rock art (Dobrez, 2013: 3).

The ubiquity that is so often mentioned of hand stencils in world rock art is perhaps what draws our attention. Sometimes hand stencils are merely one element of the rock art at a site, appearing as either an isolated hand stencil or only one of a handful. For example, at Feather Cave in New Mexico, there are only 3 white hand stencils and at U-Bar Cave, also in New Mexico, there is only a single positive handprints, as well as some black fingerlines (Greer & Greer, 1997). At other sites, handprints and hand stencils number in the hundreds. In Borneo, for example, the site of Gua Ham contains at least 375 hand stencils in association with other common motifs (Chazine, 2005). Hand stencils are recognized as a pervasive motif in Australian rock art where, at the site of Carnavron Gorge for example, they number in the thousands (Gunn, 2006). Similarly, hundreds of hand stencils decorate Cueva de las Manos in Argentina and the well-known cave site of Gargas, France, has over 250 hands, many of which are noted for being 'mutilated' (Barrière, 1975; Gradi et al., 1976; Leroi-Gourhan, 1986). There are many theories behind the 'mutilated' hands of Gargas including ritual and illness among others, as well as the possibility that the digits are not missing but are rather bent (Leroi-Gourhan, 1986). So called mutilated hands are not limited to Gargas or even to France, they are also found in other parts of the world such as in Australia, Argentina and New Mexico (Walsh, 1979; Wellmann, K.F, 1972).

Occasionally, hand stencils superimpose other images, such as in the rock art of Montana, and in other instances, they surround figurative images such as at Pech-Merle (Greer & Greer, 1999; Leroi-Gourhan, 1982). They have been found to decorate open bluff sites, caves and rock shelters and some have even been found on stalagtites hanging from the ceiling (Clottes, 2008; Greer & Greer, 1999). In Finland, where there are few instances of hand images, there are some that have been exaggerated to represent paw-prints (Lahelma, 2005). Handprints and hand stencils have been documented in some of the Fijian islands, in New Caledonia, Melanesia, at numerous sites in South Africa, in several countries of North Africa including Algeria, Libya, Nubia, Egypt, and Morocco (Achrati, 2003; Berrocal & Millerstrom, 2013 Manhire et al., 1983; Manhire, 1998; Sand et al, 2006). They have been discovered in Yemen, in Saudi Arabia, in several U.S. states, at Lac la Croix in Western Ontario, and all over Europe (Achrati, 2003; Clottes, 2008; Creese, 2011; Greer & Greer, 1997, 1999; Wellmann, 1972). In 1993, a few rare examples of black and red handprints and hand stencils were even recorded in Western Inner Mongolia (Taçon et al., 2010).

Despite the prevalence of hand imagery in rock art, these images are frequently ignored in favour of the 'more elaborate' figurative images they are often found in association with (Chazine, 2005). In Australia, the presence of hand imagery at a site is often given a mere mention in the literature in favour of the figurative images, and if any detail of the hand imagery is given, it is usually to do with the size of the hand stencils, particularly if they are either very large, or very small (Gunn, 2006). There are few visual records and even fewer detailed studies of the number of hand stencils found at individual sites, whether the hands are either right or left, their locations and their arrangements (Gunn, 2006). This lack of detailed documentation is not unusual, nor is it relegated merely to Australia. Where children's hand stencils are concerned, there is even less supporting documentation to their whereabouts and even fewer analyses. Despite these shortcomings, whether hand stencils appear in isolation or in large clusters, their presence at rock art sites around the world suggests that they likely served different functions and that their meaning is deeply contextual (Chazine, 2005). Even if we cannot decipher their meaning, given that hand imagery is such a pervasive motif in world rock art, it is worth our time as researchers to pursue a more thorough documentation and inventory of the hand stencils at rock art sites, such as has been done in France.

Case Study and Interpretation: Gargas and Cosquer Caves

In France alone, there are twenty-eight rock art sites containing representations of the human hand (Von Petzinger, 2009).

Table 1: Rock Art Sites Containing Hand Imagery in France (Von Petzinger, 2009)

Region	Cave Sites
Ardèche	Chauvet
Ariège	Bédeilhac, Les Trois Frères, Le Portel
Bouches-du-Rhône	Cosquer
Charente	Vilhonneur
Corrèze	Le Moulin-de-Laguenay
Dordogne	Grotte d'Antoine, Roc de Vézac, Font-de-Gaume, Abri du Poisson, Les Combarelles I, Labattut, Le Bison, Bernifal
Gard	La Baume-Latrone, Grotte Bayol
Hautes-Pyrénées	Tibiran, Gargas
Lot	Pech-Merle, Le Bourgnetou, Cantal, Les Fieux, Roucadour, Les Merveilles
Mayenne	Margot
Pyrénées-Atlantique	Erberua
Yonne	Grande Grotte d'Arcy-sur-Cure

Only ten of these twenty-eight sites have positive handprints and in only five of the ten cases are positive handprints the only representation of hands in the caves. Gargas has the most numerous amount of negative hand stencils of any cave, containing at least 250 hands, followed by Cosquer with 65 hands. These two caves are unusual and stand out for the sheer number of hands comprised within. Beyond these, it becomes common for caves to consist of thirteen hands and under, with six caves having just one single hand (Von Petzinger, 2009). No relationship in terms of style or placement can be discerned between handprints at even nearby caves like Gargas and Tibiran, nor are there numbers consistent from cave to cave either (Leroi-Gourhan, 1982). Even the distribution of the hands within caves appears to be random; they are found at the entrance to Bernifal, they surround the dappled-horse at Pech-Merle and are in the middle of the animal paintings at Roucadour (Leroi-Gourhan, 1982). Most notably, Gargas and Cosquer are the only caves to contain hand stencils made by children (Von Petzinger, 2009). This particular aspect of these two caves is what makes them significant to the discussion.

Gargas cave is located near Aventignan in the Hautes-Pyrénées of France (Barrière, 1975; Wildgoose et al., 1982). The cave was discovered in 1870 by Dr. F. Garrigou and the art was subsequently investigated by Breuil in 1907, in conjunction with Cartailhac and Neuville in 1911 and 1912. These early investigations revealed the long human history associated with Gargas, dating from the Mousterien through the Châtelperronnian, Aurignacian and Périgordian (Barrière, 1975). In 1965, Leroi-Gourhan noted the lack of 'organic' link between the many hands at Gargas and the figurative art. This made it extremely difficult to stylistically date the hand stencils, and to guarantee that the stencils were made at the same time as the rest of the art in the cave (Leroi-Gourhan, 1965). In 1992, a small sample from Gargas was dated to 26 860 +/- 460 using Accelerator Mass Spectrometry (AMS).

Cosquer cave was first discovered and was subsequently named after Henri Cosquer, a deep-sea diver who first visited the cave in the 1980's, but did not find the art until 1991 (Clottes, 2008). The entrance to Cosquer is presently under thirty-seven meters of water and nearly four-fifths of the entire cave is now flooded. Entering the cave is dangerous, even for experienced divers. During the Gravettian when the cave was in use, the sea level was one hundred and fifteen meters lower than it is at present, and the coastline was still several kilometres away. The art at Cosquer is preserved in two upper chambers of the cave that are only partially above sea level. Radiocarbon dates from charcoal and a hand stencil revealed two periods of use; first during the Gravettian between 28 000 and 25 000 years ago, and the second around 19 000 years ago. All of the hand stencils found at Cosquer date to the earlier period, and are considered to be characteristic of the Gravettian (Clottes, 2008).

The hand stencils at Cosquer are unique in that they appear on more than just the cave walls, but also decorate stalagtites (Clottes, 2008). These stalagtites hang just above a nineteen meter shaft, presently filled with seawater. Clottes argues that the presence of the hand stencils in such a precarious spot suggests that it was actively sought out by the people who made them, despite the obvious dangers. These hand stencils are also interesting for the markings, a number of them are decorated with red or black dots and other marks. Hand stencils also appear on a sloping wall, partially submerged. These hand stencils overlay a series of engravings suggesting that they predate the hand stencils. Yet on another wall, the opposite holds true and the hand stencils have been covered by engravings. These two instances suggest that hand stencils at Cosquer were an ongoing tradition during the two periods of frequentation (Clottes, 2008).

Beyond being contemporaneous, the dates for Gargas and Cosquer also make these hand stencils the oldest known examples in world rock art (Clottes et al., 1992; Snow, 2006). These dates, the discovery of similar examples of ‘mutilated’ hands, and the presence of children’s hand stencils among them suggests a continuity between these two caves (Barrière, 1975; Bednarik, 2008; Breuil & Cartailhac, 1907; Cartailhac, 1907; Clottes et al., 1992; Clottes, 2008; Hooper, 1980; Leroi-Gourhan, 1967; Rouillon, 2006; Roveland, 2000; Snow, 2006; Wildgoose et al., 1982).

The children's hand stencils appear to range in age, from infancy to adolescence, judging from the size of the hand stencils alone (Barrière, 1975; Clottes et al., 2005; Leroi-Gourhan, 1967; Pigeaud, 2009; Roveland, 2000; Sharpe & Van Gelder, 2006). Certainly in the case of the infant's stencil, an adult or an older child would have been required to place the baby's hand on the wall in order to produce the hand stencil. Roveland (2000) argues that if this is the case, we must view these images of children's hands as the *representation* of children and not as the *products* of children. However in 1967, Leroi-Gourhan proposed that there might have been a ritualized reason for the presence of children in these caves. While the resulting contributions of children to the rock art have been noted, no researcher has attempted to determine sex from the children's hand stencils using the same approach applied to adult hand stencils: the 2D:4D ratio.

This is perhaps because the idea that at least a portion of the overall corpus of rock art as yet discovered may have been made by adolescents and children, has not been a popular theoretical perspective (Bednarik, 2008). Despite this, we know that children were present in the caves as children's footprints have been found at Pech-Merle, Tuc D'audoubert, Chauvet and Niaux (Bednarik, 2008; Sharpe & Van Gelder, 2006). Often, the children's footprints far outnumber those of adults. Sharpe and Van Gelder (2006) claim that the footprints are sufficient evidence to 'provisionally' assume children were responsible for the majority of the rock art in Europe. By contrast, Bednarik (2008) argues that even the child sized hand stencils and finger flutings found in the caves are not sufficient evidence of children *producing* rock art as in many cases, they occur at too high an elevation on the cave wall for a child to have made them without the aid of an adult, holding the child aloft or directing their hand (Sharpe & Van Gelder, 2006). In other words, handprints and footprints only prove that children were present in the caves.

According to Jean Clottes (2008), children may have accompanied practiced shamans into the caves and participated in shamanistic rituals that may have incorporated rock art. According to Clottes, this theory could account for some of the cruder drawings found in caves. Inexperienced participants, such as children, could have been responsible for their production, while the more practiced pieces could have been the result of experienced shamans. Clottes suggests that negative hand stencils may also have been part of ritual. The act of creating a hand stencil involves producing a negative impression of the hand which as Clottes explains, blends into the rock, taking on the same colour, either red or black. In this way, Clottes weaves a narrative around a hand disappearing into the rock, into the ‘world of the spirits,’ allowing the individual to gain their power. Clottes believes that this shamanistic interpretation would make the presence of hand stencils made by young children perfectly understandable (Clottes, 2008).

Dale Guthrie (2005) takes a different approach, proposing that there was nothing religious or ceremonial whatsoever about the production of rock art. Rather, according to his argument, the large corpus of rock art was the result of testosterone-fueled adolescent boys. Guthrie suggests that at least half the population of the Paleolithic were children of various ages. A specific segment of that overall population would have been adolescent boys. Like Clottes, Guthrie believes that the cruder rock art of the Palaeolithic was the result of children, whereas the finer images were created by adults. To bolster his position, Guthrie points to the presence of numerous handprints, hand stencils and finger flutings made by children. In addition, Guthrie claims that the dark and sometimes dangerous recesses of the caves may have been a draw for adolescent males. Lastly, according to Guthrie, the 'sexual images' of the Palaeolithic, those of naked women, erections and vulvae, can be taken as further proof that a large portion of the rock art was created by hormone driven adolescent boys (Guthrie, 2005). Although for the most part, the significance and the frequency of images in parietal art that could be construed as 'vulvas' have been greatly exaggerated (Bahn & Vertut, 1997; Bahn, 2011). Moreover, the presence or absence of spirituality in the production of rock art is not scientifically testable (Bednarik, 2008; Jonaitis, 2007). What's more, using the behavioural patterns of contemporary adolescent boys to serve as a model for the Palaeolithic as Guthrie does, is highly problematic. As Jonaitis (2007: 4) argues, "just because the majority of graffiti artists today are adolescent boys does not mean that the cave artist was of that age, indulging in the same fun and relatively unserious activity."

What we can say is that studies investigating the presence of children's footprints in addition to the more deliberate creation of hand stencils and finger flutings are an overall contribution to the archaeology of children. Recognizing the contribution of child sized hand stencils amidst the adult sized ones and the remarkable art within the caves is at least a step forward in acknowledging the presence of children within the archaeological record. Proceeding with an analysis of archaeological examples of children's hand stencils, particularly in regards to our ability to potentially determine sex from them would be a leap forward for both the archaeology of gender, and the archaeology of children. Children were clearly there in the caves during the Palaeolithic and their presence has left tangible evidence on the landscape. For whatever their purpose, whether it be mimicry of adult behaviour, socialization into ritual and tradition or merely play, it is clear that children had agency, which their hand stencils express. Further analysis of their hand stencils, not only in terms of the sex of the child artist, but their skill in production, whether the same child made multiple hand stencils, their use of materials, the locations within the cave that their hand stencils are found, the height at which they were created - all of these elements provide us with valuable insight into the cognitive, cultural and social development of children during the Palaeolithic. Regardless of whether the children's hand stencils are *representations* of children or the *productions* of children, recognizing the presence of children and their active participation in Palaeolithic lifeways through their hand stencils is an important way forward for the archaeology of children and for a well-rounded, unbiased field of anthropology. An anthropology that does not ignore the evidence of children in the archaeological record as a distortion, but embraces that children are and were a significant part of the demographic and an integral part of the cultural framework of the past, as they are now.

Conclusion

In sum, the purpose of this chapter was to examine the theoretical underpinning of my research and how, with a concise discussion of the archaeology of children, my research contributes to our understanding and our overcoming the bias against children in the archaeological literature. In exploring the ancient use of hand imagery in this chapter, I hoped to frame my research and to demonstrate the long history of representing the human hand, as well as to discuss the idea behind meaning making. As I mentioned earlier, where archaeological hand stencils are concerned, we must be cautious about creating narratives. The meanings behind the use of modern hand imagery are as varied as hand stencil production was likely to be during the Palaeolithic. Techniques like the 2D:4D ratio may allow archaeologists to determine the sex of the rock art artists and along with other methods of ascertaining height and age, this is one way of recognizing individual rock art artists and their contribution to Palaeolithic lifeways. Where children's hand stencils are concerned, analysis is one way of perceiving what it meant to be a child during the Palaeolithic. Building on this necessary background research, I will further explore prominent research into the expression of the 2D:4D ratio in extant children around the world as well as the archaeological application of the ratio to positive handprints, negative hand stencils and finger flutings to date in the following chapter.

Chapter 3: Method

Introduction

Before introducing a selection of the clinical studies on the 2D:4D ratio which have been conducted to date and before providing a synopsis of the archaeological work that has applied the ratio to hand imagery in this chapter, I first begin with an overview of the osteology of the modern human hand and a discussion of the hormones specifically associated with the expression of the 2D:4D ratio. A fundamental understanding of the osteology of the human hand, particularly as it relates to growth and development, for any studies involving the application of the ratio to archaeological hand stencils, is particularly relevant. The growth pattern of the human hand and the associated hormones are directly related to the expression of 'typical' and 'atypical' 2D:4D ratios. These topics are always briefly mentioned in the introductions of the clinical studies on the 2D:4D ratio as abnormality of the ratio and the link to mental and physical pathologies can be traced back to anomalies during fetal development. Moreover, these topics are important because they highlight the fact that in clinical studies, the sexual dimorphism of the 2D:4D ratio is secondary to the research associating atypical ratios with mental and physical abnormalities. However, the sexual dimorphism of the ratio is exactly what interests archaeologists studying hand stencils in rock art settings around the world. Being able to determine if both males and females participated in the production of hand stencils throughout the Palaeolithic has obvious implications for the Archaeology of Gender and for correcting long-held biases within the discipline.

The clinical studies I address in this chapter were selected for several reasons. In a practical sense, these clinical studies were the first to approach the topic of the 2D:4D ratio and to begin exploring its association with a variety of medical phenomenon. Second, these studies introduce a method for examining the 2D:4D ratios of living people which has become the standard for these types of studies and which has also served as the method for 2D:4D ratio analyses in various archaeological contexts. Third, these clinical studies address the topic of children and the expression of the 2D:4D ratio from fetal development through childhood and into adolescence. This is particularly relevant to the topic of my thesis and it is the results discussed in these clinical studies which has formed the basis for my own recruitment practices, and the method which I employed.

Following this discussion, I examine the few attempts at archaeological applications of the 2D:4D ratio to determine sex from handprints, hand stencils and finger flutings. There have not been many attempts to use the 2D:4D ratio in this capacity though interest in the technique and the potential information that can be ascertained regarding lifeways and the production of rock art during the Upper Palaeolithic is strong among archaeologists in the field. Certainly one of the major issues with applying the ratio archaeologically has been the need to modify the method of analysis used in these clinical studies, particularly with finger flutings but also with negative hand stencils. In this chapter, I discuss how the method has been modified and the statistical reliability of using the ratio, particularly as my own method of data collection and analysis have been greatly impacted by both these clinical studies as well as the archaeological ones. Finally, my research question, the details of my recruitment practice, data collection and the method I used for my analysis are discussed in detail.

Osteology

Hands account for 25% of the distinct bones in an adult homonin skeleton (Tocheri et al., 2008). A modern human adult hand is composed of twenty-seven bones-eight carpals, five metacarpals and fourteen phalanges total (Scheuer & Black, 2000). The scaphoid and the lunate carpals articulate with the radius of the upper limb to create the radiocarpal joint. The trapezium, trapezoid, capitate and the hamate articulate directly with the metacapals. The proximal and distal rows of carpals further articulate with one another at the transverse midcarpal joints, and are tightly linked to one another through the interosseous ligaments. The metacarpals are numbered laterally from one to five and are considered long bones because they each possess a tubular shaft with a proximal base and a distal head (Scheuer & Black, 2000). The first metacarpal, the thumb, has a characteristic saddle-shaped base and because it does not articulate intermetacarpally, it is therefore the most free-ranging. It is also the most sexually dimorphic of all of the metacarpals, due to its association with 'gripping'. The second metacarpal is vital to the integrity of the hand and to making the power and the precision grips. The third metacarpal is often called the axis as it tends to be the most stable portion of the hand. The fourth metacarpal is typically the most slender of all the metacarpals with the fifth being generally more robust (Scheuer & Black, 2000).

As mentioned, the in-utero growth and development of the hand tends to be quicker for males than it is for females (Scheuer & Black, 2000). At 33 days in-utero, the hand plate is the earliest recognizable element of the human hand. By day 38, digital rays, which are thickenings in the digital plate through which small projections signal future digit development begin to project through the crescentic flange. The interdigital notches which separate the fingers commonly develop between day 38 and day 44. Chondrification of the carpals begins by day 48, and is followed by chondrification of the metacarpals, the proximal, middle and distal phalanges. The tactile pads of the digits develop around day 52 and between days 48-56, interzones begin to appear. The ossification of the hand does not follow a pattern like the rest of the skeleton with the exception of the foot. There are 48 centres of ossification in the hand, some of which ossify in the early fetal stages and some after birth (Scheuer & Black, 2000).

At birth, the nineteen primary ossification centres of the long bones of the hand have developed (Scheuer & Black, 2000). With ossification, the speed at which the hand grows and develops becomes quicker for females than for males at an increasing rate. The carpal bones typically ossify between two and four months for females, and three and five months for males. At this age, the difference between male and female growth rates are only one to two months. Following this, the epiphyses for the bases and heads of the proximal, middle and distal phalanges as well as the metacarpals begin to develop as early as ten months. They continue to develop through the second year for females and the third year for males. Ossification centres begin to appear in females for the lunate at three years, the trapezium at four years, and the trapezoid and scaphoid at five years. For males, the ossification centres for each of these carpals appear one year after those of females, on average. At eight years old in females, the ossification centre for the pisiform develops and the triquetral becomes visible in dry bone whereas these developments are echoed in males two years later at ten. Between nine and eleven, the trapezium, trapezoid, lunate and scaphoid also become recognizable in dry bone and the pisiform at twelve, as the hook of hamate fuses. The osseous development of the hand is complete for females at fourteen and a half and a full two years later for males at sixteen and a half, marking the end of adolescence (Scheuer & Black, 2000).

The osteological development of the human hand and the differential rates of growth and development reveal an early pattern of sexual dimorphism. Because the 2D:4D ratio is also sexually dimorphic, this begs the question whether the differential growth rate of the hand could be linked to the 2D:4D ratio setting into place earlier for females than it does for males. Understanding the underlying osteology of the modern human hand and the pattern of its growth and development sheds light on the complex nature of its structure and function. The next step as it applies to the study of rock art, is to improve our ability to determine the sex of individual rock art artists through the images of the hands they left behind. The 2D:4D ratio is at present, our best technique for doing so. However, prior to applying the ratio to archaeological materials, we must first begin with an understanding of the modern human hand and how fetal hormones affect its growth and development.

The 2D:4D Ratio

As previously mentioned, the 2D:4D ratio is a widely used technique for the analysis of pathologies in premature, newborn babies and young children (Manning et al.,1998; 2001; 2001; 2002; 2003; 2004; McFadden et al., 2002). For example, high levels of fetal testosterone may compromise the development of the left cerebral hemisphere and create problems with language and lead to autism (Austin et al., 2002). Alternatively, high levels of fetal testosterone may help to facilitate the development of the right cerebral hemisphere, leading to advanced musical, spatial and mathematical talents (Austin et al., 2002). The 2D:4D ratio has been correlated with left hand preference and with visuo-spatial perception (Manning et al., 2000; 2001; Williams et al., 2003). Males with a low 2D:4D ratio positively correlate with low birth weight and with low head circumference (Lutchmaya et al., 2004; Manning et al., 2004; Ronalds et al., 2002;

Williams et al., 2003). There is equally a significant relationship between the hand, the 2D:4D ratio, fetal growth, and pathologies such as congenital adrenal hyperplasia, developmental psychopathology, autism, Asperger's syndrome and Down's Syndrome (Austin et al., 2002; Brown et al., 2002; Buck et al., 2003; Lutchmaya et al., 2004; Manning et al., 2001; 2004; Ronalds et al., 2003). In adults, the ratio may be related to myocardial infraction in men and breast cancer in women (Lutchmaya et al., 2004).

The aspect of the ratio which is most relevant to archaeologists is the fact that it differs between males and females with males typically having a lower ratio than females (Austin et al., 2002; Lutchmaya et al., 2004; Manning et al., 1998; 2000; 2001; 2002; 2003; 2004). The sexual dimorphism of the ratio is thought to be due to its positive correlation with fetal estrogen and negative correlation with fetal testosterone (Austin et al., 2002; Lutchmaya et al., 2004; Manning et al., 1998; 2001; 2001; 2004). There is evidence to suggest that the sex difference in the ratio may develop alongside the urinogenital system (Manning et al., 1998). In vertebrates, the development of the urinogenital system and the appendicular skeleton are both controlled by *Hox* genes. Hox gene mutations are related to sterility, and the malformation of fingers. Such mutations are evidence that the production of sex steroids by the fetal gonads, the fetal testes and ovaries and the hormones that they produce are responsible for both the development of the fingers and the fetal reproductive system (Austin et al., 2002; Kondo et al., 1999; Lutchmaya et al., 2004; Manning et al., 1998; 2004; Williams et al., 2003). Testosterone begins to be produced at approximately 8 weeks of gestation as the Leydig cells in the testes of male fetuses begin to differentiate (Manning et al., 1998). Testosterone is a critical element to the development of the digits and by extension, the 2D:4D ratio. When there is a high concentration of testosterone, a low 2D:4D ratio occurs indicating that there was high prenatal testicular activity and therefore, such a ratio is typical of males. The association between the 2D:4D ratio, testosterone concentrations, sperm numbers and possibly even sperm function in adulthood could be a predictor of male fertility (Manning et al., 1998).

Literature Review & Critique

Manning et al.'s 1998 publication titled 'the Ratio of 2nd to 4th Digit Length: a Predictor of Sperm Numbers and Levels of Testosterone, Luteinizing Hormone and Oestrogen,' engendered great interest in the potential of the 2D:4D ratio to detect medical abnormality. By early 2009, more than three hundred publications on the ratio had appeared (Voracek & Loibl, 2009). A brief search for the 2D:4D ratio in Google Scholar will pull up thousands of results that are linked to current and ongoing research on the subject. The publications are varied as are the uses for the 2D:4D ratio as, among other things, an indicator of sex, class and ethnicity. The 2D:4D ratio has also been proven to correlate with sex hormones while other studies substantiate a heritability or predisposition to diseases, including some infectious diseases, as well as an individuals susceptibility to behavioural disorders. Additional research connects the ratio and personality, physical ability-particularly excellence in sports, while other research recognizes the ratio as an index for homosexuality and for sexual attractiveness.

Voracek and Loibl's (2009) review of many of these publications made it clear that while the topics addressed on this subject are varied, the research itself has been conducted by a limited number of people, institutions and countries, and that there is limited range in the journals that the publications appear in. For example, Manning appears as a coauthor in a significant amount of the publications related to the ratio. Moreover, despite the 2D:4D ratio being an anthropometric trait, the majority of the research to date has been conducted by psychologists rather than anthropologists, undoubtedly stemming from the fact that Manning is himself a psychologist (Voracek & Loibl, 2009). Finally and surprisingly, the bulk of the research on the 2D:4D ratio has not been published in major psychological journals but rather more broadly in journals of the behavioural sciences, biomedical, social sciences and neurosciences. In reality, the numerous publications on the 2D:4D ratio are the result of meta-analysis, the comparing and contrasting of results from different studies in an effort to identify patterns and interesting relationships between the results. This publication and citation bias has resulted in only a handful of original studies upon which all other research is based (Voracek & Loibl, 2009).

Clinical Studies

As the first of its kind and therefore as the precursor to all further research, Manning et al.'s (1998) publication stands as the defining research on the 2D:4D ratio. It is the method of measuring digits and calculating the ratio described in this paper that is the foundation for the method used in other studies of its kind and which has been copied and improvised upon to be of use in determining sex from archaeological hand stencils. The importance of this early publication on the 2D:4D ratio and the method behind the data collection and analysis cannot therefore be understated. This paper is always cited in subsequent research and has reached such widespread appeal that the 2D:4D ratio is now alternatively referred to as the 'Manning Ratio.' In short, Manning et al.'s (1998) publication involved two studies which suggested, based on "the differentiation of the urinogenital system and the appendicular skeleton in vertebrates, [which is] under the control of *Hox* genes, [that] the common control of the digit and gonad differentiation raises the possibility that patterns of digit formation [might] relate to spermatogenesis and hormonal concentrations” (Manning et al., 1998: 3000). In other words, the results of the 2D:4D analysis indicated that the digit ratio was sexually dimorphic in both the left and right hands. The mean ratio for males was 0.98 suggesting that on average, males had a longer 4D while the females from this sample had digits which were equal in length, with a mean ratio of 1.00. This study involved a total sample of 800 subjects, 400 male and 400 female that ranged in age from two years to twenty-five years of age. The school-aged subjects were all recruited from preschool, primary, and secondary schools in Merseyside near Liverpool, UK while the rest of the subjects were recruited from the Liverpool University. Digit lengths were recorded on the ventral surface of the hands of each subject from measurements taken from the basal (palmar-proximal) crease to the tip of the 2nd and 4th digits using vernier callipers set to 0.05 mm. This method of measurement has become standard practice for all studies involving the 2D:4D ratio. The most relevant aspect of this study in terms of my research were the results that indicated that the sexual dimorphism of the ratio was present from at least two years of age on and that 2D:4D is most likely established in utero. These results were demonstrated through data analysis using a series of parametric tests including unpaired t-tests, simple linear and multiple regression analysis and ANOVA (Manning et al., 1998). While the exact statistical methods used varies per study of the 2D:4D ratio, the statistical analyses performed in this first preliminary study are frequently repeated.

Manning et al’s (1998) assertion that the 2D:4D ratio develops in utero was questioned in 2006 by Malas et al. To test this theory, Malas et al. (2006) conducted an experiment on cross-sectional measurements of the 2D:4D ratio in 161 aborted fetuses between the ages of ten and forty weeks. The 2D:4D ratio was measured from the midpoint of the metacarpophalangeal joint (the basal or palmar-proximal crease) to the tip of the digit for each fetus and Malas et al. (2006) were able to determine that the 2D:4D ratio did not change significantly for either male or females ($p>0.05$) throughout the gestational period. A longer second digit was more typical of the female fetuses though the difference between 2D and 4D was not significant for either sex ($p>0.05$). These results were established using a series of non-parametric tests and an ANOVA, similar to Manning et al's (1998) statistical analysis. Malas et al.'s (2006) study confirmed that the sex difference in the ratio is present in utero as Manning et al. (1998) postulated, but that while the ratio does increase during prenatal development, it does more so immediately after birth. Based on the results of their study, Malas et al. (2006) concluded that the ratio was more likely to become significantly sexually dimorphic in later childhood.

A similar conclusion had been drawn from the results of an earlier study by Williams et al. (2003) which involved Scottish children between the ages of 2 and 5. The study recruited 196 participants, 108 male and 88 female from local nurseries subject to parental (and ethics) approval. As the primary focus of this study was to determine if a link could be found between abnormal 2D:4D ratios in children and developmental psychopathology, parents of the participating children were asked to complete questionnaires relating to social difficulties and social cognition. The 2D:4D ratios of the participants were derived from scanned images of the hands. Digit length was measured from the palmar proximal crease to the finger tip along the midpoint with vernier callipers. Standard statistical tests were conducted on the data including single factor and repeated measures ANOVA. The predominant result of the analysis indicated a correlation between social difficulty, or what was termed 'male-like' behaviours including increased aggression with lower 2D:4D ratios (below 1.00) in female participants particularly.

There was also a less prominent intercorrelation between high 2D:4D ratios (above 1.00) and emotional issues or what was considered ‘female-like’ behaviours with the male participants. These results suggest that sex hormones may be acting on the brain early on during development however Williams et al., (2003) suggest that further work needs to be done on these results to establish to what extent the digit ratio can be used as an indicator for mental health issues across a full lifespan. While there may be a causal link between increased aggression and/or emotional stability and sex hormones, I find it problematic to associate these descriptions with either ‘male’ or ‘female’ behaviours as this seems laden with cultural bias. That being said, this study is important to the subject of my thesis research for the additional relationship that was discovered between the 2D:4D ratios of the participants and age which had not previously been identified. The male participants of the sample had smaller mean 2D:4D ratios (left and right: 0.95) than the female participants (left and right: 0.96) of the sample. The 2D:4D ratios of the participants demonstrated a slight increase with age at a rate of 0.0084/year for the left hand and 0.012/year for the right. While this relationship between 2D:4D and age was determined to be weak, the results did suggest that the ratio does not fix into place until middle childhood (Williams et al., 2003).

In 2004, Manning et al. investigated sex and ‘ethnic differences’ in the 2D:4D ratios of 798 children from various biological populations. These included 90 Berber children from Morocco, 438 Uygur children, 118 Han children from the North West province of China and 152 Jamaican children. All of the children were between the ages of five and fourteen. The palmar surface of the right hand of each participant was photocopied and verified for any injury to the 2nd or 4th digits as well to establish that the palmar proximal creases were clearly visible in each sample. Digit measurements were taken in standard format from the palmar proximal crease to the finger tip along the midpoint. Among the results of these statistical analyses, it was established that the 2D:4D ratios were significantly lower in males than in females of Uygur, Han and Jamaican origins. Moreover there were significant differences in the ratio between populations; the Han population had the highest mean 2D:4D ratio, followed by the Berbers and the Uygurs. The lowest mean ratios was found in the Jamaican sample however, all ‘ethnic’ variations in the 2D:4D ratios were independent of sex, indicating that the sexual dimorphism of the 2D:4D ratio is not related to ethnicity. Overall this study determined that the 2D:4D ratio is present in children between the ages of five and fourteen and therefore that the sexual dimorphism of the ratio is firmly established by middle childhood and that it is widespread in populations around the world (Manning et al., 2004).

These studies, as some of the first and the most prominent research to date on the 2D:4D ratio and in particular, the expression of sexual dimorphism in children’s hands share a methodology with little variation. All of these studies involve both parental and ethics approval and acquiring a sample from schools, including preschool and university. The method behind the data collection is also very similar and frequently involves digital scans or photocopies as well as anatomical measurements, where they were possible. The exact method of measurement is consistent from one study to another with measurements taken from the palmar proximal crease to the fingertip along the midpoint with a set of vernier callipers. The statistics involved used to analyze the data included an analysis of variance, and regression and t-tests primarily. While these studies have established the method by which all future studies involving the 2D:4D ratio have been conducted, even to some extent archaeological ones, the most important aspect of these studies for the purpose of my thesis research has been the determination of an age range at which it can be expected that the sexual dimorphism of the 2D:4D ratio be consistently expressed. It is reviewing these studies in particular that led to my interest in pursuing a 2D:4D analysis of children's hand stencils with the desire to ascertain whether an archaeological application might be possible. In addition, the method discussed in these studies has formed the basis for my own data collection and analysis, as it has for the following archaeological attempts to use the ratio.

Archaeological Applications

The first mention of the 2D:4D ratio by archaeologists in a paper by John and Mavis Greer in 1999. Their research focused on 708 rock art sites in Montana which contained positive hand prints (Greer & Greer, 1999). While handprints account for only 10% of the overall corpus of rock art in Montana, they are pervasive in that they appear at so many sites. As of yet, 413 handprints have been documented at rock art sites on the plains, in the mountains and the foothills, on boulders, sandstone bluffs, limestone outcroppings as well as in caves and rockshelters throughout the state. While they are not a dominant motif in the local rock art, they are particularly notable for the fact that, in an unusual twist, positive handprints far outnumber other representations of the human hand. For example, 358 of the known 413 hands are positive, while 47 are stylized and only 5 are negative hand stencils. The Greers' primary research took place at 15 sites in the Smith River Drainage area of central Montana where 122 handprints have been discovered, 84% of which were positive handprints (Greer & Greer, 1999).

In 1999, the 2D:4D ratio was relatively unknown and research into various applications of the ratio were still in the early stages. While the Greers were aware of Manning et al.'s (1998) research on the 2D:4D ratio, they made a conscious decision not to use it in their study of the positive handprints based on their unfamiliarity with its error margin (Greer & Greer, 1999). Rather, the Greers used other means, such as the measurement of the size of the hands to determine if the positive handprints were made by adults or children and the placement of the hands in relation to other forms of rock art to determine patterns that might indicate sex. Handprints were measured from the base of the palm to the top of the fingertips and as they all fell within a 15-20 cm range, they were determined to be adult sized. The Greers acknowledged that this method of measurement was imprecise and that both adults and older juveniles could have handprints that measured within this range. However it was unlikely that a child under the age of 12 would have large enough hands to affect their analysis and while children's handprints have been documented at other sites in Montana, such as Avalanche Gulch Mouth Shelter and Fish Creek Pictographs, none were present in the Greers' overall sample (Greer & Greer, 1999).

According to the Greers' research, the meaning behind handprints in Montana varies based on the context in which they are found and in particular their relationship to other geometric and figurative art (Greer & Greer, 1999). Handprints that are associated with ceremonial functions such as shamanistic rituals, vision quests and fertility rites are most often found at open bluff marker sites. Another type of meaning is attributed to 'marker' sites where the hands serve as announcements to passersby relaying information about trail routes, specific hunting grounds or even tribal identities. Interestingly, stylized hands appear in greater numbers at 'ceremonial' locations whereas positive handprints are more commonly associated with marker sites. Based on their observations, the Greers suggested that it might be possible to determine sex from handprints by analyzing their placement in relation to other figures. For example, the Greers concluded that the handprints at the site of Whitetail Bear were female based on their size and their shape but also due to their placement-the handprints overlaid the figurative images of a large bear and a big horn sheep-in this case, placement which could be indicative of female fertility rites (Greer & Greer, 1999).

While the Greers' method of analysis in 1999 may not have been as 'scientific' as the more recent hand stencil analyses which have involved the use of the 2D:4D ratio, their observations on the size of the handprints in relation to age estimation and the sex of the rock art artists in relation to the function and the placement of the handprints are not without merit. Beyond the importance of the Greers' general handprint observations, their research is of note because it was the first archaeological reference to the potential use of the 2D:4D ratio for handprint analysis. At the time, the research on the 2D:4D ratio was very fresh and the potential as well as the complications associated with its use were still too undocumented, factors which undoubtedly influenced the Greers decision not to pursue it. It is likely that even if they had, the Greers would have encountered a fundamental issue with attempting to use the 2D:4D ratio to analyze positive handprints in that positive handprints tend not to reflect the entirety of the hand of the rock art artist. Rather, positive handprints retain the imprint of the pressure points of the hand which means that the handprint is frequently missing segments. From personal observation and experimentation with positive handprints, I have noticed that while the tops of the fingertips may not be present due to the amount of pressure applied at this region, most often the segment that is missing is the palmar proximal crease of the fourth digit. Since 2D:4D ratio measurements are taken from the palmar proximal crease to the fingertip along the midline, this creates an obvious issue for analysis. While it may still be possible to extrapolate the data, the chance of error undoubtedly increases exponentially.

The first noted study on the use of the 2D:4D ratio archaeologically was published by Chazine and Noury in 2006. Their research focused on a particular panel of negative hand stencils at the site of Gua Masri II in East Kalimantan, Borneo, Indonesia (Chazine & Noury, 2006). The cave itself was first discovered and studied in 1999 and contains approximately 140 negative hand stencils (Chazine, 1999 a; Chazine & Fage, 1999 b,c; Chazine & Noury, 2006). The particular panel which served as the experimental wall for the first application of the 2D:4D ratio was notable for the fact that it contained 34 of the total negative hand stencils in the cave. Chazine and Noury (2006) used special software designed specifically for their analysis of the hand stencils which they called the 'Kalimain.' It allowed them to capture the size and the morphology of each hand stencil as well as to calculate the 2D:4D ratios. Using the Kalimain software, Chazine and Noury attributed 16 hand stencils to male rock art artists and 14 to female rock art artists while 3 hand stencils were indeterminate and 1 was not included in the analysis due to the absence of all fingers. However because two of the in-doubt hand stencils had ratios close to the 1.00 midpoint (0,998 and 0,985), they were declared female, bringing the count of female hands to 16, while the third in-doubt hand stencil had a ratio of 0,977, and so was declared male, bringing the male count to 17 (Chazine & Noury, 2006).

Beyond sex, the Kalimain program was supposedly able to discern another feature of the hand stencils; whether or not they were made by the same individual (Chazine & Noury, 2006). According to Chazine and Noury's explanation, the software was able to do this based on a comparison of the 2D:4D ratios in each of the 34 hand stencils. The results as they were reported indicated that six people made two copies of their hand in three different sections of the same panel. Similarly to the Greers (1999), Chazine and Noury posited that there was a deliberate placement and organization to the negative hand stencils on the panel which was indicative of sex. For example, according to Chazine and Noury's analysis, 'female' hands appeared in a circular pattern on the panel, whereas 'male' hands appeared in succession to one another, following a hierarchy. However, Chazine and Noury (2006) noted that since the software program was unable to assign a chronological order to the hand stencils, further analysis of the hand stencils would need to be done before such conclusions could be drawn.

While the analysis of the hand stencils was conducted scientifically and the results made readily accessible to archaeologists interested in these studies, there is an absence of transparency in Chazine and Noury's explanation of the Kalimain software. The parameters were not detailed in the article though the limited explanation given infers that some form of digital imaging was used (Chazine & Noury, 2006). It is not even made clear how the Kalimain program calculates the 2D:4D ratios from the hand stencils or where the reference points on the hand stencils are taken from (Chazine & Noury, 2006; Nelson et al., 2006). While software like the Kalimain program may be the way forward for studies involving negative hand stencils and the 2D:4D ratio, if for the reason alone that there is an increased likelihood of reducing human error during calculation, a more detailed explanation of how the software was developed, how it works and its limitations must first be considered. It is exciting to think that a program like the Kalimain being readily available for use in archaeological studies of negative hand stencils could lead to similar discoveries regarding deliberate modes of organization, how they might relate to a sexual division and/or cohesion as well as other historical and social interpretations of the rock art but it is imperative that such technology first be widely understood. Chazine and Noury's (2006) lack of transparency in regards to their specially developed software program and their seeming unwillingness to clarify or to make the software available to other researchers is problematic. The scientific method Chazine and Noury (2006) used for their analyses should be consistent and repeatable-since the Kalimain program has not been explained or its limitations explored, the results of their analysis on the hand stencils at Gua Masri II are ambiguous.

The same cannot be said for the technique employed by Sharpe and Van Gelder in numerous publications on a variation of the 2D:4D ratio used to analyze a series of children's finger flutings on the Desbordes Panel in Chamber A1 of Rouffignac cave, France (2004; 2006a; 2006b; 2006c; 2009). Finger flutings, like hand stencils, are common at archaeological sites worldwide and are found, for example, in Australia, New Guinea, and Southwest Europe. They appear across a large time span and many of the flutings likely date to the Upper Palaeolithic. The flutings at Rouffignac have been dated to between 13-14 000 years old, but Sharpe and Van Gelder (2009) believe that the flutings could be as old as 27, 000 BP. If they were, it would make the finger flutings contemporaneous with the hand stencils from Gargas and Cosquer. Sharpe and Van Gelder's (2006a) approach to sexing the finger flutings was inspired by Marshack's (1972) forensic analysis of incised lines. Marshack's approach included the use of magnification to examine the junctions and cross-sections of the lines. This was important as differences between cross-sections could have implied the use of different fingers, a different person, or possibly different dates for the flutings. Most importantly, Marshack's forensic approach involved examining the incised lines first, before delving into questions of meaning (Marshack, 1972; Sharpe & Van Gelder, 2006a). To that end, Sharpe and Van Gelder's (2006a;

2009; 2014) forensic analysis involves studying the width of the three fingers, the 2D, 3D and 4D, for each fluting and the tops of the fingers as well as the location, depth, and the height of each fluting to determine such data as the age, the sex and the height of the fluter. The temporal sequence of the flutings is established by noting direction and overlays (Marshack, 1977; Sharpe & Van Gelder 2006a; Van Gelder, 2014).

The 2D:4D ratio cannot be used as is for finger flutings, as the ratio requires measurements of the entire length of the second and fourth digits, from palmar proximal crease to fingertip (Sharpe & Van Gelder, 2009). These variables are not measurable in flutings, as only the tips of the fingers are used to create lines. Building on the work of Peters et al. (2002) and Manning et al. (1998), Sharpe and Van Gelder (2006a; 2009) measured the lengths of the second finger (2F), third finger (3F) and fourth finger (4F) of each fluting and compared the extension of each fingertip relative to each other. Similar to the results of the 2D:4D ratio, the 2F does not extend as far as the 4F for males with a ratio under 1.00, while the reverse is true for females with a ratio above 1.00. In terms of age, the results of their analysis indicated that a number of the finger flutings had been produced by children, many of whom were likely held aloft by adults or by older children during their production (Sharpe & Van Gelder, 2006a). These children were likely between the ages of two and five (Sharpe & Van Gelder, 2006c). Instances of children's flutings occur elsewhere then Alcove I in Rouffignac cave; Chambers E and G both contain the work of children. In Van Gelder's (2014) most recent publication, she references her study of 12 caves in France and Spain identified four caves with evidence of children's flutings and eight without. This indicates that finger fluting is not the sole activity of either children or adults, both were practicing this form of rock art, sometimes, together (Van Gelder, 2014). Van Gelder

(2014) has even suggested that finger flutings might be a form of protowriting as yet unrecognized as such. While this is a very exciting possibility, what we can say for sure at this point is that the flutings themselves are a clear example of children being involved in the production of rock art. It suggests that the interpretation of finger flutings as male symbols, possibly as part of puberty rituals are unsubstantiated. Rather than a ceremonious function, these children's flutings could represent the possibility of play and exploration (Sharpe & Van Gelder, 2006c).

However like the 2D:4D ratio, Sharpe & Van Gelder (2009) recognize that this method is not accurate 100% of the time. In 1999, Sharpe and Lacombe developed a general nomenclature for finger flutings for all researchers. This nomenclature divided finger flutings into categories such as 'units,' 'clusters,' and 'panels.' Differences were noted between whether the fluter used one or more fingers to flute a unit, and whether the fluter remained standing still or continued to move during production. Based on this, flutings were further subdivided into four categories; 'kirian,' 'evelynian,' 'rugolean,' and 'mirian.' All of these categories refer to whether the fluter was standing still or in motion, and how many fingers were involved in the overall production. The presence of the nail, how much pressure is applied to each finger and the material can all affect the outcome of the finger fluting (Sharpe & Van Gelder, 2006a). If the width of finger flutings is increased based on the amount of pressure applied, the potential to miscalculate the age of the individual might also increase. The possibility that the finger flutings were created while the fluter was in motion adds another potential variable as movement during production would likely affect the angle of the wrist. A hand that is not kept perfectly straight with the second, third and fourth digits together can cause the second digit to sometimes appear longer than the fourth digit and vice versa, based on the angle of the wrist during motion (Peters et al., 2002). As this is a core issue in the method of measurement for positive handprints and negative hand stencils, it is unsurprising that it could also be a factor when analysing finger flutings.

The interesting results of Snow's 2006 should influence further analysis of archaeological hand stencils. Specifically, Snow (2006) performed two levels of analysis using a modern sample of 111 subjects. Each subject provided four scans of his or her left and right hands with fingers spread or closed though only the scans of the hands with fingers spread ended up being used for the analysis as hand stencils are all invariably created with fingers spread themselves. Snow collected a series of five measurements for each hand, the lengths of what he labeled D2, D3, D4 and D5, more commonly known as 2D, 3D, 4D and 5D, and the overall length of the entire hand. Snow determined that absolute length predicted the correct sex of the subject of his modern sample 77% of the time with left hands, and 81% of the time with right hands. With left and right hands combined to make a sample of 222, the results were correct 79% of the time with only 21 of 114 female samples misclassified as male and 26 of 108 male samples misclassified as female! As Snow explains, the absolute length of each subject's hands could only have been made by adult individuals. However he cautions that this method would not be able to discriminate between female hands and subadult male hands (Snow, 2006).

Snow's (2006) second set of analysis of the same sample of hands using the 2D:4D ratio adjusted for this. This analysis used both the 2D:4D ratio as well as measurements of the index finger and the little finger, 2D:5D. However, the results of this secondary analysis were not as conclusive as the first set. The ratio accurately predicted sex only 59% of the time and 51 of the 114 female hands were classified as male while 39 of the 108 male hands were classified as female. Snow concluded that while the results were statistically significant, neither of these ratios are consistent or conclusive enough to be used archaeologically to analyze a single handprint or more. Used in conjunction with the relative length of the digits and the overall hand length (analysis 1) would increase the reliability. Based on his calculations, Snow (2006) suggested that we should only expect to accurately identify the sex of the individual rock art artist 80% of the time.

While Snow's (2006) study of modern hands was exemplary, his archaeological sample included only six negative hand stencils from four caves in France; Les Combarelles, Font-de-Gaume, Abri du Poisson and Pech-Merle. Arguably, six negative hand stencils was too small of a sample size to reveal anything conclusively about the use of the 2D:4D ratio archaeologically. Fortunately, this was a core issue that Snow attempted to address in his more recent publication. In this study, Snow digitally photographed and analyzed 32 negative hand stencils from Abri du Poisson, Bernifal, El Castillo, Font-de-Gaume, Gargas, Les Combarelles and Pech-Merle (Snow, 2013). While 32 archaeological hand stencils is certainly better than a sample of 6, it is still a small sample to be working with. Snow admits that a large sample of archaeological hand stencils which meet the requirements for pursuing a 2D:4D ratio analysis is difficult to acquire whether by absence of complete digits or by permission to enter and photograph the caves and that this was a factor influencing the number of hand stencils collected for this study. However Snow (2013) asserts that 32 hand stencils is enough of a sample with which to perform an analysis and to make generalizations about the sex of rock art artists.

Snow's (2013) analysis involved two steps which were first tested on a modern sample collected from 222 students at Penn State University. The procedure Snow employed involved taking digital images of the students hands both splayed and closed. Measurements of the hand scans were taken from the midpoint of the crease at the palm of the hand to the tip of the 3D to determine overall hand length. The remaining measurements were taken from the base of the palmar proximal crease to the tips of digits 2 through 5 along the midpoint. Just as with negative hand stencils, the palmar proximal creases of the digits is not apparent in digital hand scans and so this marker point was established by drawing the crease in reference to the wedge points on either side of the digits. Step 1 of Snow's approach involved measuring the length of digits 2 through 5 as well as overall hand length. According to the predictive discriminant function employed in this technique, step 1 mainly distinguishes adult male hands out of the sample. Using this technique alone, Snow cautions, is likely to misclassify adolescent male hands as female hands based on size alone. Step 2 of Snow's analysis involved employing 2D:4D but also the 2D:5D which resulted in correctly classifying male/female hands 60% of the time. However, Snow argues that neither a Step 1 or a Step 2 analysis on there own produced robust enough results. Instead, Snow advocates that we should be using both techniques especially where ambiguous hands are concerned (Snow, 2013).

To that end, Snow (2013) attempted this two step analysis on the 32 digitally photographed negative hand stencils collected for this study. With the Step 1 analysis, Snow discerned that 10% of the hand stencils were made by adult males. The Step 2 analysis indicated that five of the hand stencils had most likely been produced by subadult males while 24 of the remaining hand stencils were attributed to females. Moreover, Snow explains that his most recent analysis reconfirms the assertions that he made in his 2006 publication regarding the sex of the rock art artists who produced the 6 hand stencils he measured from photographs at the time. Based on the results of this two step approach which indicates that 75% of the archaeological hand stencils analyzed were produced by female rock art artists, Snow asserts that it is possible that females were far more active in producing rock art, possibly even dominating the production, than previously thought. While this is an interesting claim in and of itself, especially given the considerable male bias in rock art analyses discussed in Chapter 2, perhaps the most interesting feature of Snow's results is a secondary finding that the digit ratios taken from the archaeological sample appear to show a wider gap between males and females. With less overlap between the sexes, this could imply that hands were more sexually dimorphic during the Upper Palaeolithic (Snow, 2013). This finding is important as it suggests that 2D:4D ratio analyses conducted on archaeological hand stencils is more accurate in sex determination than the ratio is proving to be in modern samples, particularly in North America.

Overall, Snow's (2006; 2013) statistical analyses of using the 2D:4D ratio to accurately determine sex from archaeological hand stencils has bridged the gap between the more clinical studies and applications of the ratio by Manning and others and its potential archaeological applications better than most. Snow's modern samples and the techniques he has employed to try to better the probability of accurately determining sex from hand imagery has been a benefit to the community of archaeologists studying this facet of rock art. While it may be possible to differentiate between male and female hands in living populations by size alone as male hands tend to be larger globally, the considerable overlap between males at the lower end of the scale and females at the high end make size-sex estimations unreliable (Snow, 2006). Snow's (2013) two step analysis method bears further scrutiny for several reasons, not the least of which because this process appears to differentiate between subadult male and female hands with greater reliability but most significantly because it seems to increase the probability of correct sex-estimation in both a modern and an archaeological context. Since it is not possible to identify sex from children's hand stencils by size alone, a study involving this two step procedure and children's hand stencils will hopefully be the next undertaken by Snow (Nelson et al., 2006; Snow, 2006; 2013). Despite the fact that a 2D:4D analysis and Snow's 2 step procedure are not without the potential for error and they do not completely eliminate the possibility of sex misclassification, we continue to pursue studies involving the ratio because the success rate is high enough that it has the capacity to inform on trends in larger populations, such as the inference of female dominance in rock art hand stencilling (Snow, 2006; 2013).

Research Questions

According to Snow (2006), we can increase the accuracy of the ratio at determining sex by increasing the number of archaeological hand stencils examined. That being said, techniques like the 2D:4D ratio should be used with caution, and with a full understanding of their limitations. It is critical when pursuing these kinds of studies that we keep in mind that the 2D: 4D ratio is, at its core, a medical means of recognizing abnormality and that the sexual dimorphism revealed by the ratio is a secondary characteristic of its function. Nevertheless, because of the sexual dimorphism of the digit ratio, it has become *the* method of determining sex from archaeological handprints, hand stencils and finger flutings. With the exception of finger flutings, archaeological research involving the 2D:4D ratio has focused on adult sized hand stencils despite the additional presence of children's hand stencils in the caves.

Beyond this underrepresentation of children within the archaeological literature, it is my opinion that these archaeological studies of the application of the 2D:4D ratio to hand stencils have missed a pivotal step. While Snow's (2006; 2013) research has involved a modern sample and testing variations of the 2D:4D ratio before an archaeological application, there has yet to have been a study which has involved analyzing the anatomical 2D:4D ratios of living peoples and comparing them against the 2D:4D ratios that the same individuals produce in a hand stencil. Underlying this oversight is an assumption that negative hand stencils are accurate representations of the anatomical hands that created them. Following this is a second assumption, that because the hand stencil *is* the hand that made it, that the 2D:4D ratio is therefore an accurate tool for determining sex in an archaeological context. These assumptions form the basis for my thesis research and the following research question:

Can the 2D:4D ratio be used to determine sex from children's hand stencils in a modern context?

Answering this research question will provide us with insight into the future possibility of using the 2D:4D ratio as a technique with which to determine sex from children's hand stencils in an archaeological context.

Recruiting the Participants

In order to create a statistically viable experiment, this research required a large number of participants. To that end, I began this research by recruiting a large sample of children from summer camp and local schools. Science Venture Summer Camp is an annual non-profit organization at the University of Victoria which focuses on hands-on science, engineering and technological learning opportunities for children and youth. Campers at Science Venture were as young as five and as old as eleven. The remaining participants were recruited from Glenlyon Norfolk Middle and High Schools in Victoria. The middle and high school students were all between the ages of eleven and sixteen. The age range selected for in this experiment was deliberate. Based on the study by Malas et al. (2006), I selected five as the youngest acceptable age for this experiment to cover the earliest range of 'middle-childhood.' I selected sixteen as the oldest acceptable age for this experiment on children's hand stencils because as Scheuer and Black (2000) explained, hands are osteologically adult-sized for females by fourteen and a half and for males by sixteen and a half. This age range had an additional benefit in that it included pubescence which allowed me to address whether or not the hormonal advent of puberty had any affect on the 2D:4D ratios in my sample. A total of 436 children participated in this research, two hundred and twenty-four were male and two hundred and twelve were female.

This research was subject to the approval of the Human Research Ethics Board and participation was contingent on both written parental consent (Appendix C), child verbal consent as well as a 'child information sheet' (Appendix D) which explained the experiment to the children in accessible language. Parents were notified of the logistics of the experiment, they were advised that there were no risks to their child associated with this research beyond that which their child might experience with any arts and crafts related activity, and parents were assured that this would be a fun and unique learning opportunity for their children. Parents signed agreeing to the activity their children would be participating in, and provided me with the permission to use their child's anatomical measurements and his or her hand stencil for my thesis as well as for future research. The child's information sheet broke down the same information given to the parents into more accessible language and emphasized that it was the child's decision to participate, that they could withdraw their participation at any time, and that there would be no consequences to them for having done so. Before any anatomical measurements were taken, each child was asked for his or her verbal consent. This entailed an understanding of the experiment they were participating in, how the measurements I was collecting were going to be used, and assured them of their anonymity within the scope of the project. This information was disseminated to them in a brief presentation on Paleolithic art, children's contribution to the production and discussion of this art, and the coordination of the experiment which was to follow. I once again stressed that participation was voluntary, that there would be no consequences of choosing not to participate, and that even if their parents had given them permission, the final decision was theirs to make. Children whose parents did not give their permission but whose children did want to participate were allowed to do so to avoid excluding them from their peer activity but their information was not recorded thereby fulfilling the terms of my ethics approval.

Data Collection: Anatomical Measurements

Anatomically, 2D:4D measurements are consistently measured from the base of the palmar proximal crease to the fingertip without compressing the finger pad of the second and fourth digits respectively. For the purpose of this research, I took anatomical measurements following these directives from both the left and right hands of each participant using digital vernier calipers set to 0.01 mm. To maintain consistency, I always measured the second digit first, followed by the fourth digit. Each participant's measurements were recorded in a spreadsheet at the time of measurement along with their name, age and sex. While the experiment was meant to be anonymous, names were recorded on the spreadsheet initially for a couple of reasons. Firstly because a portion of my sample base was young enough to have difficulty remembering a number assigned to them rather than their own name. Secondly because it made it much easier to correlate the hand stencil sample provided by each participant to their parental consent form, and to their anatomical measurements recorded on the spreadsheet. Names were later stricken from the database and each participant was reassigned a sample number correlating all of their collected data, thereby guaranteeing each participant the anonymity approved by the Human Research Ethics Board.

Data Collection: Creating a Hand Stencil

(Figure 5: Example BloPen© used for creating a negative hand stencil in a modern context)

Creating a hand stencil in a modern context is significantly different from that of an archaeological context. However, my purpose in creating this experiment was not to recreate either the materials or the setting one might expect from a cave thirty thousand years ago. Rather, my purpose in setting up this modern version of hand stencilling was to produce a 'clinical' setting for the participants which would not hamper their effectiveness at creating a hand stencil through such extraneous variables as cave topography and charcoal manipulation. The 'clinical' setting included basic white printing paper, a flat wall surface and a BloPen (c). BloPens are non-toxic, water-soluble airbrush markers. Each pen comes with an individual applicator and they are easy to use, and easy to sanitize. Each pen was dismantled between use and the applicator portion which came into contact with the child's mouth was thoroughly washed in biodegradable dish soap before the pen was reassembled for use by another participant. Participants were instructed to write their first and last name on their paper so that I would be able to match their samples to their parental consent form. Participants were not instructed which hand to use, but they were given extra guidance on how to use the pens if needed.

(Figure 6: Creating a Negative Hand Stencil)

Data Collection: Hand Stencil Measurements

2D and 4D measurements are much more difficult to take from a hand stencil than from an anatomical hand as the palmar proximal crease is not present in a hand stencil. However as the palmar proximal crease is an essential point for measuring the 2D and 4D, it was necessary to ‘create’ it for each hand stencil. In order to do this, I assessed the location of the ‘wedge’ between the third and fifth fingers and drew a line connecting the two across the fourth digit, thereby creating the 4D palmar proximal crease. A wedge constitutes the space between digits where the pigment has been blown to accentuate the fingers of the hand. In creating the palmar proximal crease, I had to assess where the wedges were between the fingers, which did not necessarily correspond with the lowest point of pigmentation on the paper. Instead, I had to examine the pattern of spray each participant produced while using the BloPens. In many cases, the wedges were visible with a clear delineation of the lowest point of the wedge which in life, would have corresponded well with the anatomical hand. However in cases where I did not

(Figure 7: Measuring a Negative Hand Stencil) feel that the wedge was in the correct spot as in life, or it was evident that the participant had not blown pigment far enough down between the fingers so that the wedge reflected his or her anatomical hand, their sample was discounted, and marked as immeasurable in the spreadsheet. To create the 2D palmar proximal crease for the second digit, I drew a line from the wedge between the second and third digit, straight across the second digit, since the wedge created by the angle of the thumb cannot be used to create a crease that would be relevant to the second digit. The uppermost point of measurement in a hand stencil is the centre point of the tip of the second and fourth digits. Using a ruler and a fine-point mechanical pencil, I drew a line from the centre of the palmar proximal crease vertically to the top of the centre point of the finger tip. As in the anatomical measurements, I measured the second digit first, followed by the fourth, using vernier calipers set to 0.01 mm. All measurements were recorded in the spreadsheet for analysis.

Creating the Database

After collecting all of the data from the participants and recording the information into a basic spreadsheet, I proceeded to make a formal database which would make the information easily accessible and manipulable for the statistics that I would later run. To create this database, I used the program Numbers, which is the Mac equivalent of Microsoft Excel. The final sample reflected in the database is an accurate count of all participants who provided written parental consent, verbal consent, anatomical measurements of their hands and a hand stencil for analysis. All participants who met this criteria were assigned a number in numerical order and their individual names were removed from the database to guarantee their anonymity, as per my ethics requirements.

Appendix A and B contain each participant's personally identifiable information. These categories include:

Sex

As this study focuses on sex determination from children's hand stencils, having a reference to each participants sex was integral to the research and to future analysis.

Age

I recorded each participant's age for the purpose of examining whether age was a factor in a child's ability to produce a hand stencil and to what degree. This ties in to children's cognitive and motor skill development and was therefore an important category of which to keep a record. Furthermore, as my age-range crosses puberty, I retained this category in order to determine whether the children's 2D:4D ratios became 'typical' at a specific age, and if that age was also sexually dimorphic.

Sample Number

Sample Numbers refer to individual participants within the entirety of the sample. The numbers are numerical and can be traced back to a specific participant by name however, the numbers were given to each participant to guarantee their anonymity within the study.

Table 1 also includes the following categories:

Left Hand Anatomical 2D/Right Hand Anatomical 2D

These two categories contain each participant's measurements of the length of their second digits, in millimetres.

Left Hand Anatomical 4D/Right Hand Anatomical 4D

These two categories contain each participant's measurements of the length of their fourth digits, in millimetres.

<u>Hand Stencil 2D/Hand Stencil 4D</u>

These two categories contain each participant's measurements of the length of their second and fourth digits, measured from their hand stencil, in millimetres.

<u>Left Ratio/Right Ratio/Hand Stencil Ratio</u>

These three categories contain the 2D:4D ratio calculations based off of each participant's individual measurements. Left Ratio therefore divides the left hand anatomical 2D measurements into the left hand anatomical 4D measurements to produce the left ratio. This procedure was the same for the right ratio, and the hand stencil ratio.

<u>Left Binary/Right Binary/Hand Stencil Binary</u>

This category denotes whether the participant produced a ratio that was 'typical' for their sex, i.e. males below 1.00 and females above 1.00. If the participant produced a typical ratio, they were marked with a 1 and if they did not, they were marked with a 0. Creating this binary category simplified my ability to quickly calculate how many male or female ratios were behaving as expected.

<u>Hand Stencil 2D/Hand Stencil 4D</u>

These two categories contain each participant's measurements of the length of their second and fourth digits, measured from their hand stencil, in millimetres.

<u>Anatomical 2D/Anatomical 4D</u>

These two categories contain each participant's measurements of the length of their second and fourth digits in millimetres for whichever hand they selected to make a hand stencil with. In other words, if a participant used their left hand to make a hand stencil, this category reflects the anatomical measurements of the length of the second and fourth digits of the left hand of that participant. The anatomical 2D/4D measurements for the hand that was not used to create a hand stencil were not included in these categories, or this table.

2D Error/4D Error

Error in these categories refers to the difference between the anatomical 2D or 4D and the hand stencil 2D or 4D. It was calculated by subtracting the 2D into the 4D to produce either a positive or a negative number in millimetres, which reflects the amount of error between the anatomical measurements and the hand stencil measurements.

Statistics

In order to answer my research questions, I used SPSS statistical software to analyze the data collected. The samples were analyzed using paired sample t-tests, linear regressions and chi square tests the results of which will be discussed in detail in the following chapter.

Conclusion

The method used for 2D:4D analysis in the clinical studies discussed at the beginning of this chapter has impacted the development of an applicable archaeological method. However, where archaeological uses of the ratio for sex determination are concerned, we must keep in mind that the 2D:4D ratio is first and foremost a technique for medically determining abnormal pathology. This, in conjunction with an understanding of the interrelationship of sex hormones and growth and development as discussed in Chapter 2 are key aspects of the 2D:4D ratio which should form the foundation of any research into utilizing the ratio in an archaeological setting. The archaeological applications of the 2D:4D ratio and the modifications to the clinical method helped form the basis for the method I used to answer my research question. My results are discussed in the following chapter, Results and Analysis.

Chapter 4: Results and Analysis

Introduction

As discussed in Chapter 2, the 2D:4D ratio has been used archaeologically to identify male and female participation in the production of negative hand stencils in rock art. These studies have focused almost exclusively on adult sized hand stencils. Children's hand stencils are rarely mentioned and no research has as of yet, ever been done to apply the 2D:4D ratio to children's hand stencils. These archaeological studies are based primarily on Manning's research of the 2D:4D ratio and on anatomical studies of its application by Manning and by several others. As previously noted in Chapter 2, several of these anatomical 2D:4D ratio studies have used children to determine at what age the ratio is apparent, and sexually dimorphic, among other indices. With this in mind, I have asked the following research question:

Can the 2D:4D ratio be used to determine sex from children's hand stencils in a modern context?

I have asked 'in a modern context' because it is my position that we must first establish that the 2D:4D ratio can be used with living children before applying it to hand stencils in the archaeological record, in much the same way that the archaeologists discussed in Chapter 2 have built upon Manning's research with their fieldwork experiments applying the 2D:4D ratio to the negative hand stencils of Paleolithic adults.

In order to answer my research question, I will consider the following sub-questions. The results of my testing these sub-questions contribute to the overall discussion of the reliability and applicability of using the 2D:4D ratio to determine sex from negative hand stencils, and in this study specifically, children's hand stencils.

1. Is the hand stencil is an accurate reflection of the anatomical hand?
2. Does age effect the amount of error present in the 2D:4D ratios of children and to what degree?
3. Does sex effect the 2D:4D ratios of children and to what degree?
4. Does the 2D:4D ratio 'fix' into place sooner for females than for males, based on the quicker osteological growth and development of their hands (Scheuer & Black, 2000)?

With these sub-questions in mind and building upon the results of the anatomical and archaeological studies discussed in Chapter 2, I predict that:

The 2D:4D ratio is not a viable means of determining sex from children's hand stencils in a modern context.

If my prediction is correct and the 2D:4D ratio is not a dependable measure for sex in this modern context, my results will impact the potential use of this ratio in an archaeological context. Moreover, my results could cast doubt on the validity of the sex determinations from previous archaeological studies of adult-sized hand stencils. However, if my prediction proves false and the 2D:4D ratio is a viable means of determining sex from children's hand stencils within the modern context of my sample, it is foreseeable that future experimentation might include archaeological examples of children's hand stencils. While children's hand stencils are not as prevalent as adult stencils, any ensuing analysis would be an important step in correcting for the bias against children in the archaeological record and in turn, making children of the Paleolithic 'knowable' again.

Sub-Question 1: Is the Hand Stencil an Accurate Reflection of the Anatomical Hand?

If hand stencils are a perfect reflection of the anatomical hand, then 2D:4D ratio calculations derived from archaeological hand stencils would be an accurate means of determining sex. However, if hand stencils are distorted reflections of the anatomical hand, then the results of using the 2D:4D ratio alone would not be a valid means of assessing male/female participation in the production of rock art. Therefore the results of testing my first sub-question, whether we can assume that hand stencils accurately reflect the anatomical hand, will inform both on the use of the 2D:4D ratio in this modern sample, as well as archaeologically in the future.

In order to test this sub question, I calculated the margin of error. As explained in chapter 3, the margin of error is derived from subtracting the length of the anatomical 2D (A2D) from the length of the hand stencil 2D (HS2D) from each participant.

$$A2D - HS2D = Error$$

The same procedure was repeated for the anatomical 4D (A4D) and the hand stencil 4D (HS4D) of each participant.

$$A4D - HS4D = Error$$

Handedness, or whether the participant created a hand stencil with either his or her left or right hand was not taken into account. Error was recorded as either a positive or a negative number. If the error between the anatomical digit and the hand stencil digit was positive, it signified that the participant produced a hand stencil where the length of the digit was less than the length of their anatomical digit.

$$HS2D < A2D$$

or

$$HS4D < A4D$$

If the error between the anatomical digit and the hand stencil digit was negative, it signified that the participant produced a hand stencil where the length of the digit was greater than the length of their anatomical digit.

$$HS2D > A2D$$
or
$$HS4D > A4D$$

It should be noted that in every case for either digit, there was always either a positive or negative error. That is to say that not a single instance of 0 error between the anatomical measurements and the hand stencil measurements existed within this sample.

A total of 318 of the 436 samples collected were included in this data set for analysis. The remaining 118 of the samples were deemed 'immeasurable' (the length of the digits could not be accurately calculated from the hand stencils) and therefore could not be included in the overall sample. Table 2 lists the minimum, maximum and average for the absolute error in millimetres as well as the standard deviation, without taking the sex of the participants into account.

Digit	Minimum +/-	Maximum +/-	Average +/-	St. Deviation
2D	0.07	10.65	2.62	3.10
4D	0.01	12.17	2.67	3.30

Table 2: Minimum, Maximum and Average Absolute Error in mm

Minimum error is quite negligible. Of the total sample of 318, only 71 participants or 22% produced a 2D minimum that was within 1 mm of difference between their anatomical measurements and their hand stencil measurements. Similarly, only 69 participants or again, 22% of the total sample produced a 4D minimum that was within a 1mm difference between their hand and the hand stencil. The minimum error of less than 1mm was present in every age group except age 5 and the instance of error increased in frequency with age. Error and age will be further discussed later in this chapter.

The maximum error for 2D and 4D regardless of sex was 10 and 12 mm respectively. This amount of error within the sample only occurs once for 2D and 3 times for 4D. It is not the result of very young participants, or one sex. The average error for the entire sample, age and sex notwithstanding, is 2.6 mm. This can either be positive 2.6 mm meaning that the anatomical digit is longer than the digit produced in the hand stencil, or vice versa.

To determine whether sex was a factor in this difference, I compared the minimum, maximum and average absolute error in millimetres, as well as the standard deviation, for 2D and for 4D, dividing the data by sex.

Digit	Minimum	Maximum	Average	St. Deviation
Male 2D	0.09	9.67	2.55	3.00
Female 2D	0.07	10.65	2.69	3.21
Male 4D	0.02	12.17	2.86	3.47
Female 4D	0.01	10.03	2.47	3.10

Table 3: Minimum, Maximum and Average Absolute Error in mm by Sex.

As with Table 2, we can see that minimum error is still negligible. However in this table, we can also see that sex is not a factor. Of the 71 participants who produced an error of less than 1mm with their 2D, as discussed above, 37 were male and 34 were female. For 4D, 32 of the 69 participants were male and 37 were female. Maximum error is still significant and it is apparent in this table that both males and females are producing large amounts of error between their hands and their hand stencils.

In both tables and in all categories, minimum, maximum and average error, there is a range of difference between the digits of the anatomical hand and the digits of the hand stencil for each participant. In some cases, the difference is absolutely minimal and in other cases, the difference is substantial. There is however error in every sample, from every participant. Furthermore in Table 3, we can see that the minimum, maximum and average error is not dependent on sex, meaning that both males and females are producing the same range of error. By analysing this data statistically with a series of paired t-tests, we can determine if the error is statistically significant, and if it is statistically significant by sex.

Paired Samples t-Tests

The paired t-test is frequently used to determine if two sets of data are significantly different from each other. In order to answer my first sub-question using statistics, which asked whether the hand stencil is or is not an accurate representation of the anatomical hand, I ran a paired t-test. The paired t-test compared the 2D and 4D digit lengths from the anatomical measurements against the 2D and 4D digit lengths from the hand stencil measurements for each participant. Table 4 shows the results of my first paired t-test.

	T	DF	Significance
A2D - HS2D	-5.661	317	< 0.001
A4D - HS4D	-3.832	317	< 0.001

Table 4: Paired Samples t-Test

In both cases for 2D and for 4D, the error was highly statistically significant with p values of less than 0.001. The results of this paired t-test indicate that there is a statistically significant amount of error between the anatomical digit lengths and the hand stencil digit lengths.

By dividing the data by sex and running two further paired t-tests, one for males and one for females, I was able to look at whether males and/or females respectively were producing more or less error between their anatomical 2D and their hand stencil 2D (A2D - HS2D) as well as their 4D (A4D - HS4D). By running these tests, I was asking whether males and/or females might be producing more or less error between their anatomical hands and their hand stencils.

Males	T	DF	Significance
A2D - HS2D	-4.027	165	< 0.001
A4D - HS4D	-3.563	165	< 0.001

Table 5: Paired Samples t-Test, Males Only

Once again, in both cases for 2D and for 4D, the error was highly statistically significant, indicating that there is a statistically significant amount of error between the anatomical digit lengths and the hand stencil digit lengths for the males of this sample.

Females	T	DF	Significance
A2D - HS2D	-3.968	151	< 0.001
A4D - HS4D	-1.74	151	< 0.084

Table 6: Paired Samples t-Test, Females Only

For the females of this sample, the paired t-test revealed a less straightforward picture. The amount of error found between the 2D anatomical measurements and the 2D hand stencil measurements was highly statistically significant indicating a large amount of error. However for the 4D anatomical measurements and the 4D hand stencil measurements, the error was statistically non-significant with a p value of < 0.084. This indicates that the females of this sample produced less 4D error between their anatomical hands and their hand stencils. Possible explanations for why this may have occurred will be discussed in the following chapter. The results of these tests suggest that the hand stencil is not an accurate reflection of the anatomical hand, thus lending support to my prediction.

Sub-Question 2: Is Age a Factor Affecting the Amount of Error Present in the 2D:4D Ratios of Children and to What Degree?

A linear regression analysis was used to determine whether error was related to the age of the children. Linear regressions are used to model the relationship between a dependent and one or more independent variables. In this case, my dependent variable is 2D Error (or 4D Error) and my independent variables are age and sex. With these linear regressions, I am first quantifying whether there is a relationship between age/sex and 2D Error, (or 4D Error as is the case in the second regression), and second, the strength of that relationship. Establishing whether error reduces with age could indicate that accuracy at creating a hand stencil is correlated with the ontological development of motor and cognitive skills in children. In addition to providing more insight into my second and third sub-questions by determining to what degree age and/or sex are factors affecting the accuracy of the hand stencils, these linear regressions also impart valuable statistical information regarding my final sub-question, whether the 2D:4D ratio ‘fixes’ sooner for females than it does for males.

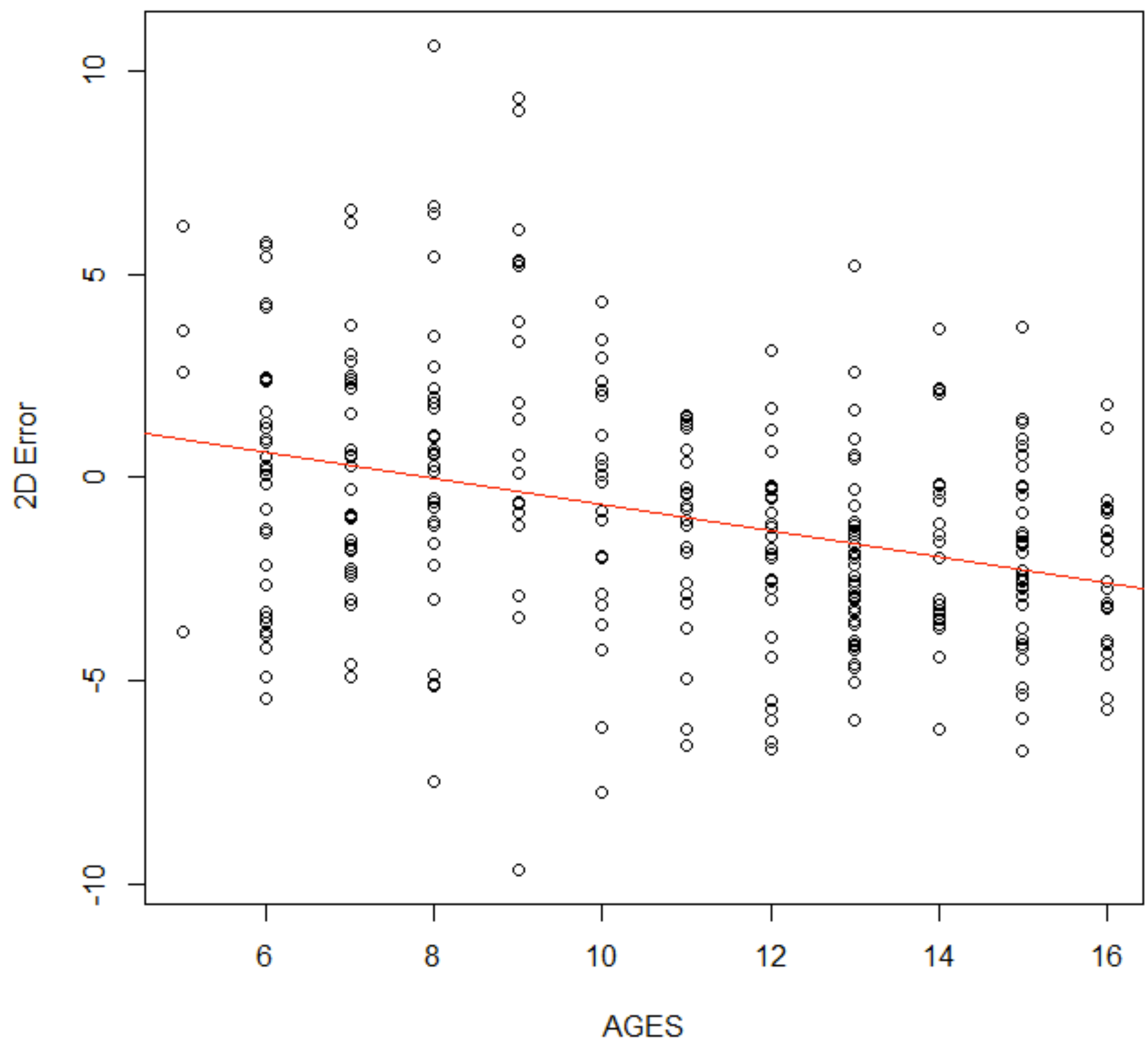

Figure 8: Linear Regression, 2D Error

In the first linear regression, the slope of the line for 2D Error is -.323 and as might be expected, age was highly statistically significant with a P-value of < 0.001. This linear regression indicates that 2D Error decreases with age and that the older the participant in this sample, the greater the accuracy in the production of a hand stencil (the hand stencil better reflects the anatomical hand). Sex in this linear regression was non-significant with a P-value of < 0.818. This means that sex was not a factor affecting the amount of 2D Error between the anatomical hand and the hand stencils of the participants.

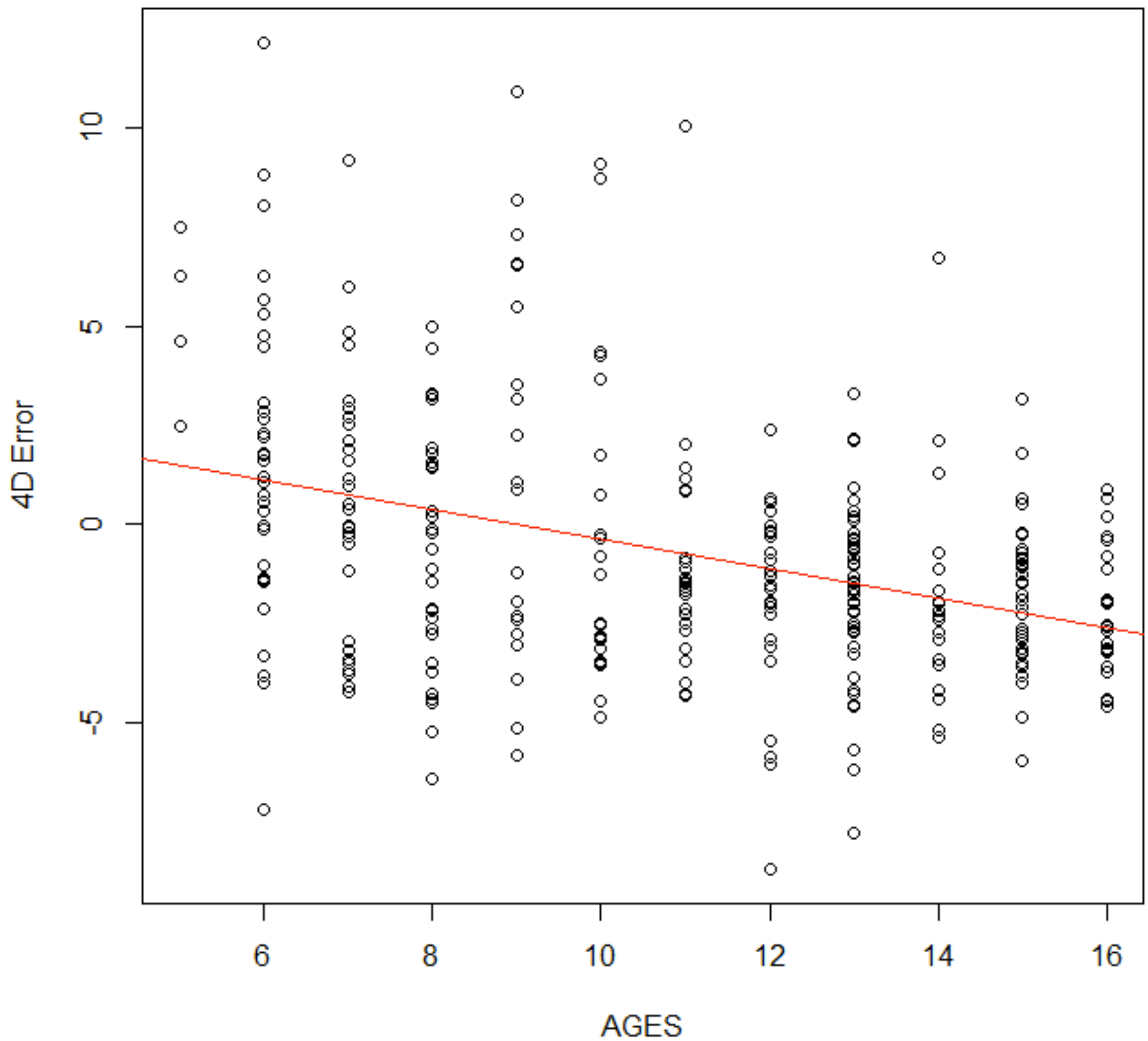

Figure 9: Linear Regression, 4D Error

The slope of the line for the linear regression for 4D error was -.381 and again, age was highly statistically significant with a P-value of < 0.001. In other words, in both linear regressions, 2D error and 4D error are strongly affected by the age of the participant. The results of these linear regressions indicate that accuracy of the hand stencil as a reflection of the anatomical hand increases significantly with the age of the participant.

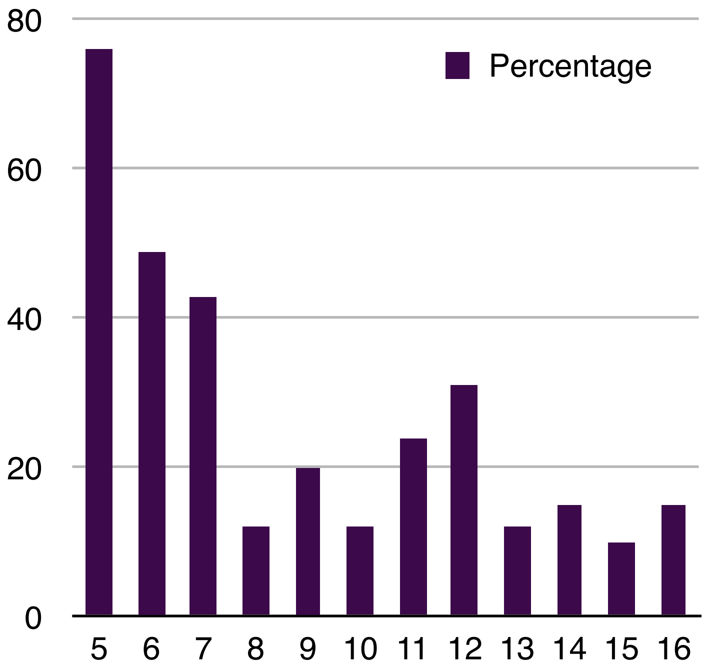

Figure 10: Percentage of Immeasurable Stencils by Age

Age	# of Immeasurable Stencils	%
5	13/17	76%
6	32/65	49%
7	22/51	43%
8	4/34	12%
9	5/25	20%
10	3/25	12%
11	8/34	24%
12	13/42	31%
13	6/52	12%
14	4/26	15%
15	4/39	10%
16	4/26	15%

Table 7: Immeasurable Hands

This leads to an interesting development in the research, we must now ask if there is an age when statistically speaking, we can be confident in the accuracy of the hand stencil, and therefore the accuracy of the results of a 2D:4D ratio calculation derived from the hand stencil.

I will consider this question below but first, we must also note a further difference between these linear regressions; sex was highly significant in the 4D error regression but as discussed, not in the 2D error regression. What this second linear regression reveals is that sex is a factor of 4D error, and that sex did impact the amount of error produced between the anatomical hand and the hand stencil. What this error means and why it is significant will be discussed in the following chapter.

Immeasurable Hands

The slope of the lines in both linear regressions indicate a reduction in the amount of error with age. That is to say that the younger the participant in this study, the greater the error when producing a hand stencil. A complimentary way of looking at accuracy and age is to examine the immeasurable hand stencils. These hand stencils were set aside from the collection and declared immeasurable for a number of reasons including obvious digit length issues or lack of clear wedges between the digits which made 2D:4D ratio calculations impossible. However, the immeasurable hands are still useful. When examined in terms of accuracy and age, they provide an important insight into hand-eye coordination and the development of motor skills in young children.

In Table 7 the participants are divided by age and for each age, the number of immeasurable hands are compared to the total sample of hand stencils collected from their age group. The right most column of Table 7 uses percentages to illustrate the differences in amount of immeasurable hand stencils per age group. Five year old participants are by far the most likely to produce an immeasurable hand stencil out of any age group though collectively, five, six and seven year olds are the most unreliable of the total sample. After seven, we see that the average number of immeasurable hand stencils drops dramatically with little difference between 8 year olds (12%) and 16 year olds (15%).

The bar graph in Figure 10 further illustrates the dramatic drop in immeasurable hand stencils from age 7 on. Figure 11 is an example of how as the age of the participant increased, the likelihood that they would be able to produce a measurable hand stencil also increased. Considered in combination with the above linear regressions which indicated that error reduced with age, these results indicate that age is a prodigious factor in a child's ability to produce a hand stencil which accurately reflects his or her anatomical hand, and is sufficiently defined to facilitate 2D:4D ratio calculations.

Figure 11: Hand Stencil of a 5 Year Old Female

However, these results do not account for the very young participants who were able to produce nearly flawless hand stencils, and the older children in the sample, who did not.

The stencil in figure 11 was produced by a five year old participant. The fingers are clearly defined in terms of width and length, and the tips of the fingers are highly visible. In addition, the spray pattern between the wedges of the digits are apparent, enabling the palmar proximal crease line to be drawn in and 2D:4D ratio calculations to be taken. In other words, this five year old participant has demonstrated above average control of the Blo Pen, as well as directionality and attention to detail.

In contrast however, figure 12 illustrates a hand stencil which was produced by a six year old child. It is frankly, difficult to even identify it as a hand. The entirety of the hand is ill-defined, there is no clear palm, let alone a palmar proximal crease region. Even determining that this is a right hand is difficult and requires the assumption that the greater lump on the left of the digits is a thumb. The digits of the hand are poorly highlighted, the fourth digit is unrecognizable and with the possible exception of the 2D, none of the fingertips of the digits are illustrated here. Though consistent dark splotches between what appears to be this participant's digits are likely to indicate the wedge spaces between the fingers, attempting to draw lines between them to indicate the palmar proximal creases would be unreliable at best. The paint is splattered, more spit than air has evidently been used in this hand stencil's production and as a result, it would be impossible to take any form of realistic measurements from this sample. Compared to the example in Figure 11, this hand stencil is a prime example of a young participant whose sample has been declared immeasurable.

Figure 12: Hand Stencil of a 6 Year Old Male

These two hand stencils reveal considerable difference in skill, despite the fact that the first, measurable hand stencil was made by a five year old participant and the second, immeasurable hand stencil by a six year old participant. These differences are also visible in the hand stencils of older participants. Figure 13 was made by a fifteen year old participant and is a prime example of a hand stencil and is one of the best of the entire sample. The hand is clearly defined and the fingers are perfectly outlined. The tips of the fingers are readily discerned and the participant has taken particular care to define the spaces between his fingers. This made it very easy to draw the lines of the palmar proximal creases between the digits. All of these factors would make 2D:4D ratio calculations derived from this hand stencil highly reliable.

Figure 13: Hand Stencil of a 15 year old Male

Comparatively, the hand stencil pictured in figure 14 was made by a fourteen year old participant. At first glance, this hand stencil might look like a good sample. The fingers appear clearly defined, the hand itself is reasonably outlined, and the tips of the fingers are present. However this hand is actually one of the immeasurables. Despite the fact that the participant has outlined the hand, it is apparent the hand was not flat to the wall. There is a curvature to the hand and the second digit is bent rather than straight. It could indicate that the participant moved the hand during production, or that the second digit is bent. Either way, this makes 2D:4D ratio calculations derived from the second digit unreliable. Furthermore, though the participant has taken care to outline the hand, they have not used the Blo Pen effectively between the digits. There is not enough spray between the third and fourth digits to create the necessary wedge outline. This makes it difficult to draw the required palmar proximal crease line, and it would most likely be inaccurate.

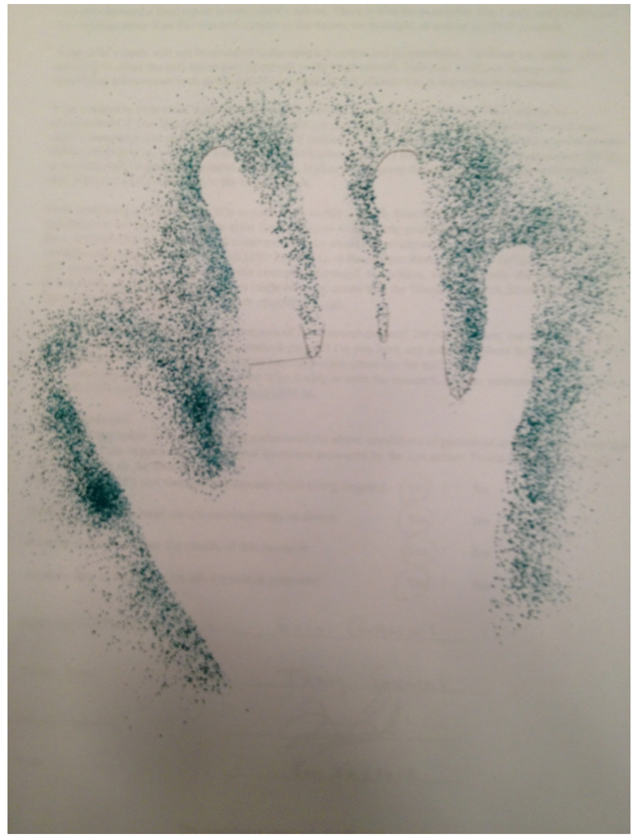
Figure 14: Hand Stencil of a 14 year old Female

Thus, a comparison of these hand stencils reveals that while age is, in the majority of circumstances, the deciding factor in predicting accuracy at portraying the anatomical hand in a hand stencil and the process of producing one, it is not the only factor at work. The individual skill of the child, possibly due to motor skill development and hand-eye coordination, can contribute to a better hand stencil than other children of their age group just as conversely, greater attention to the task at hand can also lead to more accurate hand stencils. Though high frequencies of this occurring are unlikely, based on these results, we must be careful not to assume that all small, well-produced hand stencils in an archaeological setting are the result of guidance and/or interaction with an older, or more experienced, stenciller.

Sub-Questions 3 & 4: What Effect does Sex Have on the 2D:4D Ratios of Children and Does the Ratio 'Fix' Sooner for Females than for Males?

The chi-square test is used to test how likely it is that an observed distribution of data is due to chance. It is designed to analyze categorical data, data which have been counted and divided into categories. I used the chi-square test to analyze whether the 2D:4D ratio could be used to determine sex from children's hand stencils; the subject of my research question. In my sample, I produced the chi-square once for the Left Hand Ratio, once for the Right Hand Ratio, and a final time for the Hand Stencil Ratio. The data was grouped by male and female for each chi-square test and in each case, the categories were 'Typical' and 'Atypical' referring to whether the participants ratios functioned as expected. To reiterate, a typical 2D:4D ratio for a male would be below 1.00 while a typical ratio for a female participant would be above 1.00. Therefore 'typical/atypical' in this case refers to male/female participants whose ratios conformed to this set, sexually dimorphic midpoint.

In tables 8, 9 and 10, we can observe that male ratios were typical whether the ratio was derived from the left hand, the right hand or from the hand stencil. Conversely, females had a high number of atypical ratios in all tables.

Sex	Typical	Atypical
Male	183	41
Female	42	170

Table 8: Chi-Square Right Hand Ratio

Sex	Typical	Atypical
Male	202	22

Sex	Typical	Atypical
Female	36	176

Table 9: Chi-Square Left Hand Ratio

Sex	Typical	Atypical
Male	128	38
Female	48	104

Table 10: Chi-Square Hand Stencil Ratio

Each chi-square test was highly statistically significant. Left hand ratio, right hand ratio and hand stencil ratio all had P-values of < 0.001 which means that in each case, there was a high level of difference between typical male and female ratios. As expected from Tables 8-10, the male participants of this sample had significantly more typical 2D:4D ratios (below 1.00) than the female participants of this sample.

To simplify these results, I looked at the percentages of typical 2D:4D ratios for each category, for both groups, male and female.

Sex	Typical Left Hand Anatomical 2D:4D Ratio	Typical Right Hand Anatomical 2D:4D Ratio	Typical Hand Stencil 2D:4D Ratio
Male	81%	90%	77%
Female	20%	17%	32%

Table 11: Percentages of Accurate Ratios by Sex

As Table 11 shows, males are significantly more likely to have typical 2D:4D ratios in their anatomical hands and to produce a similarly typical male ratio in their hand stencil, unlike the females of this sample. Combining left and right anatomical hand, males are likely to have a 2D:4D ratio that falls below the 1.00 mark 86% of the time and to reproduce this ratio in a hand stencil 77% of the time. Conversely, females are likely to have a 2D:4D ratio above the 1.00 for their left or right anatomical hand only 19% of the time, and are likely to correct this ratio, patterning typically female in their hand stencils only 32% of the time. Were this an archaeological sample of hand stencils from a cave site where, unlike with this modern sample, we could not compare the ratios back to the known sex of the individual from the sample, based on these percentages, we would incorrectly classify female hands as male 68% of the time. This high a degree of potential misclassification is concerning, it suggests that there is a high probability of erasing the presence of female children from the archaeological record using the 2D:4D ratio alone.

Next I asked if typical ratios could be related to the age of the participants? Put another way, as the age of the participants in this sample increases, does the number of typical ratios also increase? I found the best way to answer this question was to graph the percentage of typical 2D:4D ratios for each age group of the participants and to further compare the percentages by sex. In Figure 15, 16 and 17, the Y-Axis represents the percentage of typical ratios from 0 to 100. The X-Axis represents the age range of the participants of this sample from five to sixteen. The yellow in each graph represents the males of the sample and the blue the females.

In all three of the graphs that follow, the division between the percentage of typical ratios, males below 1.00 and females above 1.00 differs significantly regardless of age. Males of the full age range of this sample are significantly more likely to produce the expected ratio. Conversely, the females of this sample are very unlikely to produce the expected ‘female’ 2D:4D ratio regardless of their age. Not only are the percentage of typical ratios significantly different by sex, the percentage of typical ratios never overlaps. Males never drop below 50% and females never rise above it.

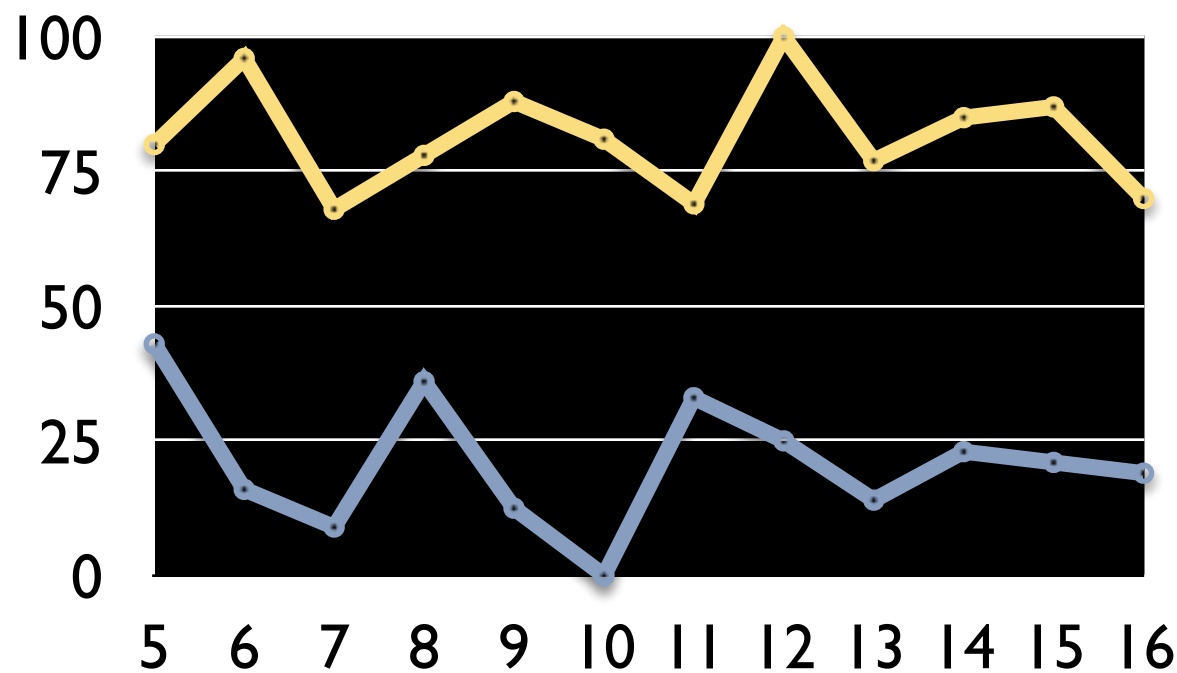

Figure 15: Accuracy of the Left Hand Ratio by Age and by Sex

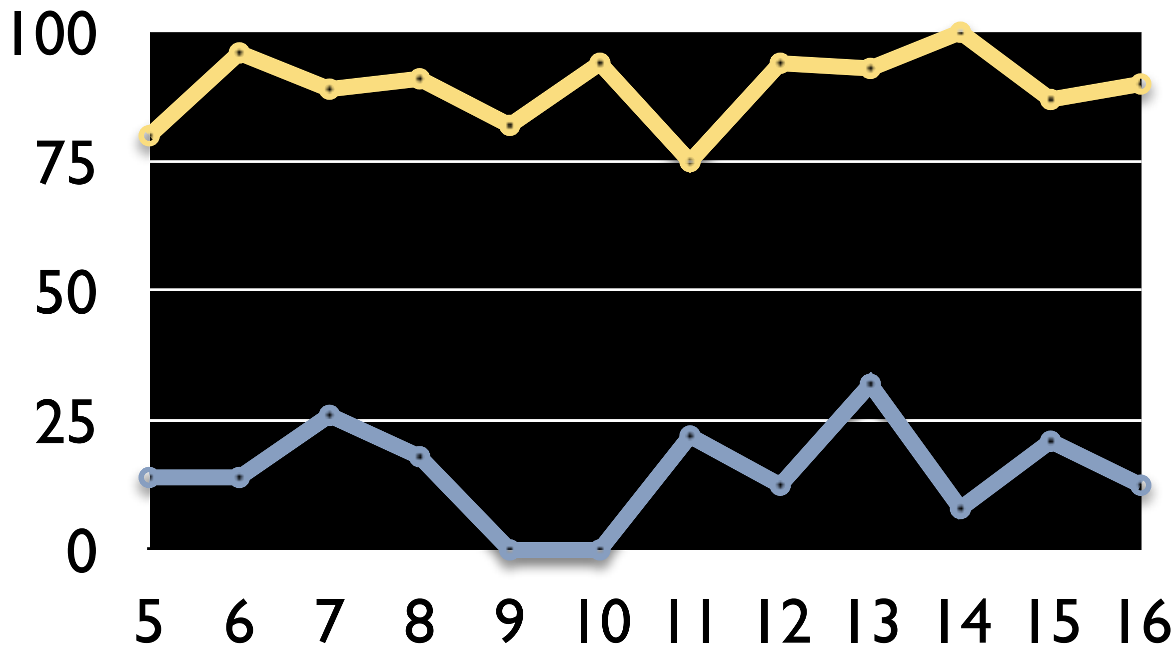

Figure 16: Accuracy of the Right Hand Ratio by Age and by Sex

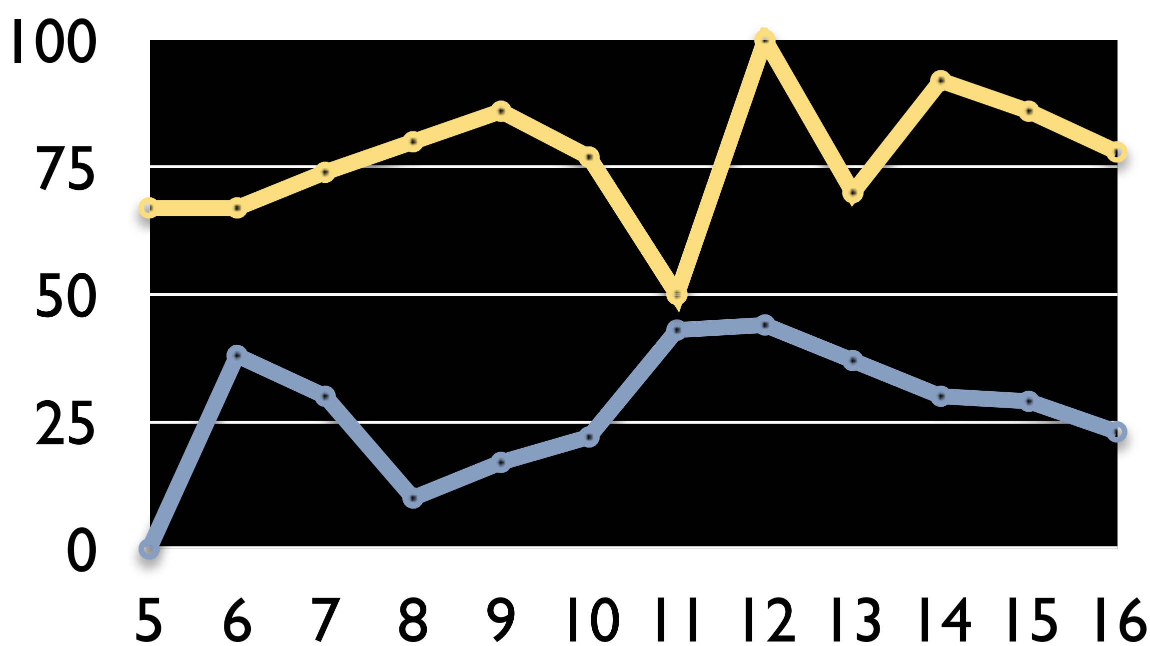

Figure 17: Accuracy of the Hand Stencil Ratio by Age and by Sex

While there is variation with the age of the participants, there is no clear increase in the number of typical ratios with age, for either males or females, as there was in the linear regression tests for error with age.

If we consider only the percentage of females who pattern female in this sample, a particularly relevant aspect of this study is revealed. At no one point for either the left or right hands, or the hand stencils does the ratio become suddenly more typical. My final sub-question asked whether the 2D:4D ratio would 'fix' sooner for females than it does for males, based on the quicker osteological growth and development of female hands (Scheuer & Black, 2000)? What these graphs indicate is that there is no one point, no specific age for this sample of female participants where the 2D:4D ratios of their anatomical hand or indeed their hand stencil suddenly becomes typical and increasingly so as one would expect if the ratio 'fixed' at a specific age. It is certainly not sooner for females than it is for males and in point of fact, as these graphs reveal, there is no one point or age at which the 2D:4D ratio 'fixes' anymore for males than it does for females. Therefore in this sample at least, I conclude that the 2D:4D ratio does not 'fix' sooner for females than it does for males based on differences in the rate of osteological growth and development.

Conclusion

In order to answer my research question regarding the applicability of using the 2D:4D ratio to determine sex from children's hand stencils in a modern context, I asked a subset of questions and conducted a number of statistical tests, the results of which have ultimately allowed me to form a conclusion.

The first sub-question I asked was whether the hand stencil is in actuality, an accurate reflection of the anatomical hand that created it? In order to answer this question, I first compared the minimum, maximum and average error in mm, between the anatomical 2D and 4D, and the hand stencil 2D and 4D for each participant. I then divided the data by sex in order to look at whether sex accounted for the amount of error. While minimum error was negligible, maximum error could be considerable and average error was consistently 2.6 mm of difference, regardless of sex. Error was always present between the hand and the hand stencil to varying degrees which affected the overall accuracy of the hand stencils. To confirm these results statistically, I used the Paired Samples t-Test. These tests corroborated the results of the Minimum/Maximum/Average Error analysis with P-values of less than < 0.001. In other words, the paired t-tests confirmed that there was a highly statistically significant amount of error between the anatomical digits and hand stencil digits. This significance will be elaborated on in the discussion to follow. By sampling by sex with two further paired t-tests, I was able to determine that both 2D and 4D error were statistically significant for males, while only 2D was statistically significant for females.

To determine whether age was a factor which affected the amount of error present in the 2D:4D ratios of the child participants in this sample, the subject of my second sub-question, I ran two linear regressions. These linear regressions allowed me to investigate whether the error between the anatomical hand and the hand stencils found with the paired t-tests were significant by age as well as sex. I found that both 2D Error and 4D Error decreased with age, meaning that the hand stencils more accurately reflected the anatomical hands that produced them, the older a participant in this sample was. Moreover, these linear regressions revealed that sex for 2D Error was non-significant, it was not a factor which affected error. This was not the case for 4D Error, which was statistically significant by sex. These results paralleled that of the female paired t-test on A4D-HS4D.

It should also be noted that while none of the above tests dealt explicitly with my third subset question, whether sex was a factor which affected the 2D:4D ratios of the children in this sample, I did sample by sex and test for an effect in each case. All of the above information provides insight into the aspect of my research which deals with the sexual dimorphism of the 2D:4D ratio in children.

Next I included a study of the hand stencils I had previously declared immeasurable and set aside from the overall sample. The table and the graph I presented in this section demonstrated how the number of immeasurable hand stencils decreased as the age groups of the participants increased. Five year olds in particular but also six and seven year olds were susceptible to producing immeasurable hand stencils. These results are analogous to the results found with the linear regressions. However, I also noted that age was not a standalone explanation for reduced error in creating a hand stencil by doing a comparative analysis of hand stencils by two very young participants from this sample, and two of the older participants.

Lastly, I used the chi-square test to examine the overall accuracy of the 2D:4D ratios produced by the participants of this sample and to determine if there was a statistically significant difference between males and females producing 'typical' ratios . Typical/atypical in this case as I explained, refers to a participant producing the expected ratio for their sex (+/- 1.00). The importance of the chi-square tests cannot be understated. With these tests, I was able to analyze my data in such a way as to address two of my sub-questions at once, and to address my overall research question. The results of the chi-square test for left hand, right hand and hand stencil were all statistically significant with P-values of less than < 0.001. I concluded that there was a highly significant amount of difference between male and female ratios with male 2D:4D ratios being considerably more typical overall. This result, in combination with the above testing on sex provided sufficient evidence to answer my sub-question regarding to what degree sex affects the 2D:4D ratio in this sample. By creating a chart which examined the percentage of accurate ratios and graphing the results by sex and by age, I was able to demonstrate that age was not a factor in terms of the typicalness of the ratio, and that at no one particular age did the ratio suddenly become 'fixed' into place for either females or males of this sample, the subject of my final sub-question.

Therefore to conclude my results and analysis, the results of my sub-questions are as follows:

1. The hand stencil is **not** an accurate reflection of the anatomical hand.
2. Age **did** have an effect on the 2D:4D ratios of the children in this sample. Accuracy of the hand stencil as a reflection of the anatomical hand improved significantly with age.
3. Sex **did** have an effect on the 2D:4D ratios of the children in this sample. The females of this sample displayed highly masculinized 2D:4D ratios which dramatically affected the results of this analysis.
4. The 2D:4D ratio did **not** fix into place sooner for females than for males of this sample, regardless of the quicker osteological growth and development of female hands.

With all of my results taken together, I feel confident in the analysis of my data to accept my prediction and to state conclusively that:

The 2D:4D ratio cannot be used to determine sex from children's hand stencils in the modern context of my sample.

In the next chapter, I will discuss the results of my analysis in detail using supporting evidence and reasoning from outside sources as well as my own observations. I will also discuss further directions that this research could take and the overall significance of my results.

Chapter 5: Discussion and Conclusion

Introduction

Manning's 1998 publication on the sexual dimorphism of the 2D:4D ratio has led to a decade of archaeological experimentation at applying the ratio to numerous hand stencils around the world, some handprints and even some finger flutings (Chazine & Noury, 2006; Greer & Greer, 1999; Sharpe & Van Gelder 2004; 2006a; 2006b; 2006c; Snow, 2006; 2013). With the exception of Sharpe and Van Gelder's work on children's finger flutings, the bulk of the archaeological application of the 2D:4D ratio has focused on adult-sized hand stencils, despite the presence of child-sized hand stencils. On a practical level, this may be because it is possible to differentiate between adult male and adult female hands in living populations by looking at the size alone (Snow, 2006, 2013). While adult male hands tend to be larger globally than adult female hands, sex estimations from size alone cannot be used for children's hands at all (Nelson et al., 2006; Snow, 2006). Even for adults, there is considerable overlap between males with smaller hands that fall at the lower end of the scale and females with large hands at the higher end of the scale. Juvenile male hands further confound the issue as sex estimations derived from the size of their hands often lead to confusion with adult female hands. Combined, all the above factors can make sex estimations obtained solely from hand size unreliable, even when only adult hands are concerned (Nelson et al., 2006; Snow, 2006).

It is therefore understandable that Manning's (1998) early publication on the 2D:4D ratio garnered the attention of archaeologists interested in hand stencils and in the question of male/female participation in the production of rock art. While the 2D:4D ratio may be used to accurately predict sex with a higher degree of probability than assessing adult hand stencils by size alone, the ratio is not accurate in all cases, at all times. Despite this, as Snow (2006; 2013) has pointed out, archaeologists have continued to pursue studies of the 2D:4D ratio and its efficacy at determining sex from rock art hand stencils because the success rate is high enough that it can inform on trends in larger populations. According to Snow (2006), the accuracy of the ratio at predicting sex will increase as we increase the number of archaeological hand stencils observed and analyzed.

However, if the hand stencil is not an accurate reflection of the anatomical hand as my results suggest, then it does not matter how many hand stencils have been or will be analyzed using the 2D:4D ratio as we are building our results and drawing our conclusions based on a fundamentally false assumption. Chazine and Noury's 2006 work and Snow's 2006 and more recent 2013 research take it for granted that because the 2D:4D ratio has been proven to be sexually dimorphic in living populations where anatomical measurements of the digits are possible, that the ratio is a viable means of determining sex from archaeological hand stencils. Yet we have no way of taking anatomical measurements of the digits (soft-tissue) from Palaeolithic peoples to compare with the measurements taken from the digits of their hand stencils to demonstrate that error between the two is non-significant, and that it has no effect on the predictability of sex derived from the 2D:4D ratios. We can and I have however, taken these steps with my modern sample. Moreover, while anatomical studies of the sexual dimorphism of the 2D:4D ratio in living adults has been well established, few studies have determined its presence in children, thus my focus in this sample, as well as the effect of age on error between the hand and the hand stencil, and the success rate of the overall ratio (Malas et al., 2006; Manning et al., 1998).

Sub Question 1: Hand Stencils are NOT an Accurate Reflection of the Anatomical Hand

Accuracy of the hand stencil as a reflection of the anatomical hand was determined by looking at the amount of error that was present in the production of a hand stencil. This error ranged from less than 1 mm to upwards of nearly 13 mm. Error was present in the hand stencils in all cases and it occurred regardless of sex or age. An average error of 2.6 mm was observed suggesting that instances of substantial error were outliers within the sample. To illustrate the range of error, I used a table to demonstrate the distribution of the error either positively (Hand Stencil digit measurements < Anatomical digit measurements; the fingers were shorter in the hand stencil than anatomically) or negatively (hand stencil digit measurements > anatomical digit measurements; the fingers were longer in the hand stencil than anatomically). One hundred and six participants created a positive distribution of error of 3 mm or less with ten participants producing an error of 4 mm. The range of participants who fell into the negative distribution doubled that of the positive distribution. Of the 212 participants who produced a negative error, 14 produced 5 to 6 mm of 2D error and 9 produced this amount of error with their 4D, though the majority produced 4 to 5 mm or less. While instances of substantial error of 10 to 12 mm occurred only once for 2D and three times for 4D and therefore could be classified as outliers, the fact remains that error is present in every hand stencil within this sample.

It is interesting that two thirds of the participants in this sample created a negative error rather than a positive. Logically when we think about creating a hand stencil, placing our hand up against a flat surface and blowing paint around our digits, the spray is likely to flare up and over our fingers unless particular care is taken when spraying around the tips. Fingernails only exacerbate the situation. Another factor affecting the spray pattern could be how level the hand placement was to the mouth. If the hand is higher than the mouth, it is more difficult to accurately encircle the digits. If the hand is lower than the mouth, paint may be sprayed downwards below the tips of the fingers, thereby creating a positive error. Since these factors affected the accuracy of the hand stencils in a lab setting where flat walls and modern materials were employed, it is not difficult to extrapolate that in an archaeological setting, where the mutative aspect of nonuniform cave walls and materials that would presumably be more difficult to work with, that these factors which yielded error in the hand stencils would only be amplified.

Statistically, the presence of error in the hand stencils was confirmed through a series of paired t-tests. The test which compared the A2D-HS2D and the A4D-HS4D of the entire sample were both highly statistically significant with p values of <0.001 each. Such a high degree of significance indicated that there was a strong difference between the anatomical digit lengths and the hand stencil digit lengths of this sample. The second paired t-test focused on the males of the sample only and likewise the results were highly statistically significant with P values of <0.001, also indicating a strong difference. The final paired t-test which tested only the females of my sample was, as previously discussed, less straightforward. While the A2D-HS2D was also highly statistically significant at <0.001, the A4D-HS4D was statistically non-significant with a P value of <0.084. In other words, the females of my sample produced less error between their anatomical hand and their hand stencils with their fourth digits.

These results were unexpected and I am uncertain why the females produced less error with their fourth digits than their second digits and or less error overall than their male counterparts and I am unaware of any reason for why this might have occurred beyond sample size. The fact that the females of this sample produced less error with their fourth digits does not have any bearing on the sexual dimorphism of the 2D:4D ratio as we are merely talking about the greater accuracy of a single digit, rather than a comparison between 2D and 4D. At most, what greater accuracy of the 4D indicates is that the females of this sample were more accurate at encircling their fourth digits while creating a hand stencil. Moreover since 2D:4D ratio analysis require both the second and the fourth digits to be compared against one another through the ratio, if only one digit of a hand stencil (in this case the 4D) is an accurate reflection of the anatomical hand but the other is not (the 2D is either longer or shorter in the hand stencil), any 2D:4D ratio calculations derived from such a hand stencil would be inaccurate. Depending on how great the inaccuracy of the second digit length in the hand stencil, the greater the chance that the sex of the individual concerned would be misclassified.

As the 2D:4D ratio is meant to be a tool with which we can classify sex from hand stencils, avoiding the misclassification of sex should be our number one concern. In general, we can assume that the lesser the error, the more accurate the hand stencil would be as a reflection of the anatomical hand. Just as obviously, the greater the error in either the 2D or the 4D separately or together, the more likely that any 2D:4D ratio calculations derived from these measurements would be inaccurate and could therefore lead to a misclassification of sex. A difference of 1 mm between the anatomical hand and the hand stencil is unlikely to cause such a misclassification. There is always the potential that it could based on the distribution of the error and without knowing the sex of the individual. However a hand stencil with these parameters is more likely to be classified as indeterminate. On the other hand, a maximum error of 10 to 12 mm would be problematic, particularly if, as in a field setting, the anatomical measurements and the true sex of the individual were unknown. Fortunately as I mentioned, instances of substantial error were rare and represented the outliers of this sample. The mean error of 2.6 mm is where we should be focusing our attention.

It should be noted that 2.6 mm is not a large amount of error, but is it negligible? As I have explained, any variation in digit length between a hand and a hand stencil has the potential to lead to a misclassification of sex as it alters the existing parameters of the anatomical hand. The greater the variation, the more likely that this is to occur, but it is not a guarantee of misclassification. There are numerous scenarios in which error could exist in a hand stencil which would not affect the 2D:4D ratio. For example, if error in the hand stencil occurred due to both digits simultaneously exhibiting a positive or negative distribution either identical to the anatomical hand (in which case the existing parameters would be maintained) or different but not enough to alter the existing sexual dimorphism. In other words, it is not necessarily the presence of error in the hand stencils which can create a situation where misclassification of sex can occur, but rather the distribution of that error.

Bearing this in mind, can we take the mean error of 2.6 mm and create a formula where +/- 2 is a threshold by which we can discount outliers and we can assume an acceptable amount of error present in the hand stencils? Such a formula would possibly vary from population to population as does the midpoint of the 2D:4D ratio, therefore, it would need to be established cross-population. In theory, a constant of +/- 2 would allow archaeologists to reject hand stencils which exhibit substantial error and to be confident in results derived from a sample where roughly 2.6 mm of error was the mean. However in practice, this theory is unrealistic. In an archaeological setting, beyond obvious examples of exaggerated hands, we have no way of estimating which hand stencils have fallen victim to substantial amounts of error and which ones are only off by +/- 2. Beyond accepting and being aware that error exists in hand stencils as it did in every example that the participants of this sample produced, and excluding examples of obviously exaggerated or malformed hand stencils from a sample as is currently common practice, I do not believe that there is a method by which we can account for error in our analysis.

Therefore, if 2D:4D analysis of hand stencils is to continue in an archaeological setting, I believe that the greatest means at an archaeologists' disposal is the acknowledgement that error is present and a constant factor of hand stencils. If nothing else, recognizing that hand stencils are not an exact replica of the anatomical hand and that error exists, independent of sex, should cause a reasonable degree of caution to be expressed, especially in regards to our interpretations of the results based off of any 2D:4D ratio calculations. Just as Snow (2006) advocates first analysing the 2D:4D ratios of descendent populations to verify the ratio before approaching archaeological examples of hand stencils, we should be verifying what amount of error is present in adult hand stencils before undertaking analysis of archaeological examples of adult hand stencils.

Sub Question 2: Age is a Factor which Affects the Amount of Error Present in the 2D:4D Ratios of Children

Along with establishing whether error reduces with age, the linear regressions also confirmed the results of the paired t-tests for sex. The relationship between 2D error and sex was non-significant with a p-value of <0.818. In other words, sex was not a factor affecting the amount of 2D error between the anatomical hand and the hand stencils of the participants. Conversely, the relationship between 4D error and sex was significant with a p-value of <0.036

indicating that sex was a factor in this instance. The significant relationship between sex and 4D error was undoubtedly influenced by the greater female 4D accuracy of the hand stencils as discussed in the results of the paired t-test. In terms of the relationship between error and age, the slopes of the lines in both linear regressions for 2D (-.323) and for 4D (-.381) were both highly statistically significant (<0.001), indicating that error decreased with the age of the participants.

These results are not surprising, especially when we consider the immeasurable hands. Of the total 436 participants, the immeasurable hand stencils account for 27% of the total sample. All of these stencils had to be discarded from the statistical analysis, but they still provide valuable insight into the effect of age on accuracy. On the one hand, confirming that age is a contributing factor in the accuracy of a hand stencil is relevant because it suggests that accuracy could be concomitant with the ontological development of motor and cognitive skills in children. On the other hand, accuracy of the hand stencil increasing with age could also suggest that the 2D:4D ratio may be a viable tool for determining sex from adult hand stencils, rather than those of children. If error in the hand stencil reduces with age, than the hand stencils of adults should be the most accurate and the least prone to variation. This has obvious implications for the archaeological use of the 2D:4D ratio.

As Table 7 indicates, five year olds were by far the most likely to produce an immeasurable hand stencil at 76%. In fact, only four of the seventeen five year olds hand stencils were included in the overall sample for analysis. Very nearly half of the six year olds-49%, and 43% of seven year olds also produced immeasurable hand stencils. However after seven, the number of immeasurable hand stencils dropped off dramatically with eight year olds at only 12% of their total age group. Moreover between eight and sixteen, there was very little difference in terms of the percentages with sixteen year olds having 15% of their hand stencils set aside. With the exception of the twelve year olds of this sample who produced 31% immeasurable hand stencils, between eight and sixteen, less than a quarter of each age group produced immeasurable hand stencils. This is a dramatic drop compared to the 50% of six and seven year olds and over three quarters of the five year olds.

Possible explanations for the amount of immeasurable hands for five, six and seven year olds are numerous and come mainly from observation of the participants during stencil production. Concentration and commitment to the task at hand was not always evident. The youngest children of this sample were highly susceptible to distractions among which included the summer camp volunteers playing games with the children who were waiting their turn. It was evident in numerous cases that the children busy creating their hand stencils rushed the process to get back to playing that much sooner. It was my opinion as well as that of my research assistants that the older participants who perhaps understood the task more thoroughly were better able to concentrate at creating their hand stencils, were not as easily distracted, or given to rushing the stencilling. Perhaps some of the difference between the younger participants, who were recruited from their summer camp and the older participants, who were recruited from their middle and high schools was that the activity was part of their assignments for the day, rather than a 'fun activity.'

Six, seven and in particular the five year olds of this sample had significant difficulty in operating the BloPens which undoubtedly contributed to the rate of immeasurable hand stencils. Young participants had difficulty holding and operating the pens while simultaneously holding their hand to the paper against the wall. This frequently led to the participants removing their hand from the paper and then replacing it, often in a different spot. Quite often the result of this was a hand-blob rather than a hand with visible, separate digits. In addition to having difficulty keeping their hand on the paper, where the participants placed their hand on the wall had a significant impact on the outcome of their stencil. The most effective placement of the hand while creating a hand stencil with a BloPen appears to be directly in front of the face, roughly level with the mouth. This position allows the stenciler to effectively encircle their digits with minimal error. When the hand is placed too high, the digits are more likely to appear longer in the stencil, possibly accounting for the error discussed previously. Conversely, when the hand is placed lower than the mouth causing the participant to blow downwards, the digits may be encircled, but the paint may also reach underneath the digits, making the digits appear shorter than the anatomical hand. During data collection, it was observed that the older participants naturally placed their hands on the wall roughly level with their mouth without conscious thought. However 'correct' hand placement did not frequently occur to the younger participants, particularly the five, six and seven year olds of the sample. Instead, these participants were more likely to place their hands either too high and/or too low, which often led to the participants removing their hand, readjusting and the ultimate creation of a hand-blob.

Extrapolating from these observations regarding hand placement raises interesting questions regarding archaeological hand stencils. For example, in an archaeological setting, could we assume that hand stencils which were created roughly at eye level are the most anatomically accurate of all hand stencils? If we assume based on size that the hand stencils were all made by adults and with consideration towards Palaeolithic stature, this could provide a range on a panel where we might assume that the hand stencils within this range are the most likely to accurately reflect the anatomical hands of the Palaeolithic stencillers and which we can be more confident regarding the use of the 2D:4D ratio. Furthermore, where children's hand stencils are concerned, could we determine based on the height of the stencil, whether an adult or an older child helped to create it? I believe further observations on stencil production could provide valuable insight into the archaeological production of negative hand stencils.

Moreover the difficulty with the pens extended to indecision over which hand to use to hold the pen. I questioned several of the children who I observed using their left hand to hold the pen while stencilling if they were left handed. None of the participants I asked this question to answered that they were which leads me to believe that even though handedness has undoubtedly presented itself by this age, there is still some indecision over task orientation and handedness. Today, the majority of people worldwide are right-handed and when holding either a pen or by extension a pigment tube or BloPen, they do so with their right hand (Snow, 2006). On the other hand, during Lorblanchet's (1991) experiment of recreating the spotted horse panel at Pech Merle, he found the easiest way to match the archaeological hand stencils in production was to turn his left hand over so that the back of his hand was against the wall. It is possible that his hand could therefore be misinterpreted as being a right, created with the left hand rather than the right holding the pigment tube. However, the higher frequency of left hands in Palaeolithic caves most likely indicates that right-handedness was as prevalent in the past as it is today and that we should assume that the majority of hand stencils were created with the palm of the hand to the wall, rather than the back (Snow, 2006). An experiment involving a modern sample of 179 people resulted in 22.8 percent of the participants creating a hand stencil with their right hand rather than the more frequently used left (Faurie & Raymond, 2004). While handedness was not one of my research questions and therefore the information was not recorded from the participants of my sample, instances of ‘unusual’ hand choice were observed and discussed. It’s conceivable that some individuals are less strongly handed than others and it’s possible that hand choice for some individuals when creating a hand stencil is random (Snow, 2006). It would be interesting to follow up on these observations with further testing to determine if children who use a hand that is not dominant with which to stencil are the most likely to produce immeasurable stencils or if effectiveness at creating a hand stencil is unrelated to handedness. As well as if handedness is something that becomes more ‘set’ with age.

Without doubt, the greatest difficulty I observed the youngest participants having with the BloPens and which affected the production of their hand stencils was the ability to hold a steady exhale. Very young children frequently have difficulty blowing air out in a long burst and are more given to short, punctuated breaths. This is probably not surprising to anyone who has ever observed a young child in the process of blowing out birthday candles. Unfortunately, a steady exhale verges on being a necessity for producing a negative hand stencil with a BloPen. The longer and the steadier one can blow through the BloPen, the more unwavering the outline of the hand. There were, among the older participants, a good number who had the lung capacity with which to create their hand stencil with a single, steady exhalation. On the other hand, the younger the participant, the more difficult it was for them to blow air out in a long and stable stream. In fact, many of the youngest participants hand stencils were created with more saliva than air.

However whether a steady exhale was a prerequisite for hand stencilling in the Palaeolithic is debatable. There appears to have been two methods for creating a hand stencil, one which included the use of a pigment filled tube and or using solely a pigment filled mouth and pursed lips (Snow, 2006). The use of a BloPen in this experiment was meant to equate to the Palaeolithic use of a pigment filled tube as opposed to the latter example of a pigment filled mouth. It was a conscious choice on my part to use the BloPen alternative while designing my experiment as firstly, I recognized that a BloPen would be much easier to use, particularly with regard to the age-range of my intended sample. Secondly and perhaps most importantly, I knew that even though non-toxic charcoal is available, it would undoubtedly be easier to convince parents, the participants themselves as well as the ethics board to allow me to conduct my experiment if the materials involved were children's non-toxic art supplies. A pigment filled-tube like a BloPen in the Palaeolithic would most likely have required a steady exhale. On the other hand, blowing pigment through pursed lips alone would most likely have required rapid, punctuated bursts. From personal experience, I can say that it is also difficult to acquire the right consistency with charcoal pigment in the mouth, diluting the substance with saliva and water (see also Lorblanchet, 1991). From observation of the difficulty with which the young participants of my sample demonstrated in using the BloPens, I would argue that blowing pigment through pursed lips to create a hand stencil would have been beyond there ability in the vast majority of cases, especially without considerable practice. Perhaps we could infer from this that archaeological examples of children's hand stencils were most likely created using a pigment filled tube rather than a pigment filled mouth, if they did not receive assistance from an adult or at the very least, an older, more practiced child.

In sum, Table 7 and Figure 3 both serve to illustrate the results of the paired t-tests and the linear regressions. As the statistical analyses inferred, age of the individual is a key factor affecting the ability to create a hand stencil that accurately reflects the anatomical hand. Accuracy at creating a hand stencil that defines the digits and embodies the hand is a crucial aspect that must be present in order to use the 2D:4D ratio with a high degree of confidence. These statistical analyses demonstrate that as the age of the individual increases, so too does the accuracy at creating a hand stencil which can stand in for the anatomical hand. Nonetheless, as I discussed in my results and analysis, age is not the sole factor influencing accuracy, individual artistic skill must also be taken into account.

The two examples I included from the youngest participants of this sample, a five and a six year old as well as the two images of hand stencils produced by older participants, a fourteen and a fifteen year old, demonstrate the range of skill present in this sample. Of the four images, two demonstrate the skill of the participants at creating a hand stencil with minimum error in their representation of their anatomical hands. One belongs to a five year old and the other to a fifteen year old. On the other hand, the two examples of immeasurable hand stencils belong to a six year old and a fourteen year old. What these hand stencils exemplify is that age is not the only relevant factor involved in hand stencil production.

While these images represent a comparison of skill, it is important to keep in mind that the five year old's stencil is truly rare. Only four of the five year old's hand stencils were included in this sample, while thirteen other stencils belonging to the five year old's age group were discarded as immeasurable. No participant was aided in the production of their hand stencil beyond general instruction, therefore the five year old's hand stencil is the result of her own skill.

It's possible that this participant is more artistic than others in her age group, more practiced at hand-eye coordination, or even has a greater lung capacity. It is also possible that she understood the task at hand in more depth than her cohort, or was less given to distraction. This participant's unusual hand stencil is relevant because it indicates that age strongly predetermines skill. Just as this participant proved to be the exception, it is possible that even in an archaeological context, a very small hand stencil could have been the result of a highly skilled, or more practiced child who did not require assistance from an older child or an adult, though it is highly unlikely.

I do not believe that the two stencils from the fourteen and fifteen year old participants necessarily reflect a difference in skill from one another. The fifteen year old created a highly accurate hand stencil with clearly defined digits as well as wedge spaces. It is obvious from the spray pattern that the fifteen year old participant took extra time and care to define these elements and to make the most exact hand stencil within their capabilities and with the materials at hand. The fourteen year old participant's hand stencil is neither the worst nor the best example of her age group. Two factors preclude the fourteen year old's hand stencil from being included in the sample. First, the bent index finger could be an indication that she either moved, or removed and replaced her hand on the paper, altering the extension of the digit. Second, and most important, the hand stencil was determined to be immeasurable because the wedge spaces between the digits are not clearly defined. Attempting to calculate the 2D:4D ratio from this participant's hand stencil would have involved 'guessing' where the approximation of the palmar proximal crease might be and extrapolating the wedge spaces from there. Essentially, as the participant's spray pattern insufficiently defines the digits and the bent index finger most likely indicates removal and replacement of the hand, I could not be confident that any measurements taken from this sample would be precise.

While it is evident from the spray pattern of the fifteen year old participant's hand that he took extra time and care in producing his hand stencil, the same cannot be said for the fourteen year old participant. However, the fourteen year old participant is clearly capable of producing a more accurate hand stencil and if she had been given clearer instructions or had practiced ahead of time, she undoubtedly would have been able to match the fifteen year old participant's skill. What these two examples, the five and six year old and the fourteen and fifteen year old participants' hand stencils tell us, is that while age is indisputably the central aspect affecting accurate hand stencil production, individual skill of the stenciller must also be taken into account. Focus, attention to detail and perhaps practice might all lead to even the youngest participants being able to produce highly accurate hand stencils that do not require aid from an older individual. It is not a huge leap to infer that if such variation in skill is possible in a modern sample of children, that the same variation in skill might have existed amongst children in the Palaeolithic.

<u>Sub-Question 3 & 4: Sex Does Impact the 2D:4D Ratios of Children and the Ratio Does Not 'Fix' Sooner for Females than for Males.</u>

At its core, the 2D:4D ratio is a diagnostic tool for medical practitioners to examine abnormal pathologies and behavioural irregularity in both premature and newborn babies, as well as small children (Manning et al.,1998; 2001; 2001; 2002; 2003; 2004; McFadden et al., 2002). The sexual dimorphism that the ratio is capable of revealing in hands is a secondary characteristic of its medical function. Nevertheless, Manning et al.'s (1998) research demonstrated that the sexual dimorphism of the ratio is apparent in utero though this research was unsupported by the results of Malas et al.'s (2006) study. Manning et al.'s (2002; 2004) later cross-sectional study of the 2D:4D ratio in Caucasian English adults and children indicated that sex differences in the ratio were apparent from the age of 2 onwards. In another study by Williams et al. (2003) involving Scottish children between the ages of 2 and 5, low ratios were observed in males and there was weak evidence to suggest that the reliability of the 2D:4D ratio increased with age. In 2004, Manning et al. investigated sex and 'ethnic differences' in the 2D:4D ratios of 798 children from various biological populations. All of the children were between the ages of five and fourteen. From this study, Manning et al. (2004) concluded that the sexual dimorphism of the 2D:4D ratio was commonly expressed in the children from his sample and that it was both significant and widespread. Taken together, these studies indicate that while acceptance of the sexual dimorphism of the 2D:4D ratio is controversial in utero, its reliability increases with age, setting into place by middle-childhood. The results of these studies formed the basis for sub-question 3, whether sex was a factor of the 2D:4D ratio in my sample.

Sub-question 4 is also related to sex and was formulated around research which indicates that differential rates of growth and development of the hand begin in-utero, and progress from birth through adolescence. As was mentioned in chapter 2, male hands typically develop at a faster rate in-utero until birth, when female hands commence a faster rate of development at an increasing rate until adolescence, when female hands are 'adult-sized' a full two years earlier than male hands (Scheuer & Black, 2000). There is evidently a relationship between fetal estrogen, fetal testosterone and the sexual dimorphism of the 2D:4D ratio, as well as *Hox* genes; the genes responsible for the development of the urinogenital system and the appendicular skeleton (Austin et al., 2002; Kondo et al., 1999; Lutchmaya et al., 2004; Manning et al., 1998; 2001; 2001; 2004; Williams et al., 2003). What this suggests to me is that it would be reasonable to assume that the 2D:4D ratio may 'set-into place' for females sooner than it does for males. I asked this sub-question because if the ratio does 'fix' earlier for females, it could impede the accuracy of sex determination from the hand stencils of children, thereby making the 2D:4D ratio an unsuitable tool in either a modern or an archaeological context where children are concerned.

To answer both of these sub-questions, I used the chi-square test. Running three chi-square tests, one for the Left Hand Ratio, one for the Right Hand Ratio and one for the Hand Stencil Ratio, I grouped the data by male and female for each test and created a 'Correct and an 'Incorrect' category which referred to whether or not the participants 2D:4D ratios patterned as male or female, reflecting their known sex. In each chi-square test, it was observed that male patterned correctness was high and patterned female correctness was low. Moreover each chi-square test was highly statistically significant with p-values of <0.001 indicating a high level of difference between patterned male and patterned female 2D:4D ratios.

Over three-quarters of the male participants of this sample had patterned male 2D:4D ratios below the sexually dimorphic midpoint of 1.00. Conversely, only roughly a quarter of the female participants of this sample had patterned female 2D:4D ratios above the 1.00 midpoint. Therefore within this sample, male participants were significantly more likely to have conventionally accurate 2D:4D ratios that patterned below the 1.00 midpoint while very few of the females of this sample have 2D:4D ratios which conformed as expected above 1.00. For three-quarters of the female participants of this sample to have 2D:4D ratios that essentially patterned male, not conforming to the expected results, something more than random chance, or error in the measurements must be occurring. Moreover, the 2D:4D ratios of the female participants are not simply not conforming in the hand stencils, but anatomically as well. While error in the anatomical measurements during the data collection procedure may be a factor affecting these results, it does not account for the gross deviation from the norm. During data collection, it was observed that the female participants digit ratios diverged from the expected results more often than not. The variance was noted while measuring and recording the length of the digits of each hand-for a female participant whose 2D:4D ratio conformed as expected, we would presume that after measuring the second digit, which if patterned correctly, would be longer than the fourth digit, the gap between the points of the calipers would need to be reduced in the process of measuring the fourth digit. Rather the opposite was frequently observed; the gap between the point of the calipers had to be regularly enlarged.

Beyond the potentially masculinized sample base, a further interesting phenomenon was revealed by the chi square tests. Male patterned 2D:4D ratios dropped from 86% ‘typicalness’ in the anatomical hands to 77% ‘typicalness’ in the hand stencils while female patterned 2D:4D ratios increased from 19% ‘typicalness’ in the anatomical hands to 32% ‘typicalness’ in the hand stencils. While it was not a statistically significant drop in typical ratios for the male participants as three quarters of the male sample base continued to pattern male with their hand stencil ratios, the rise from 19% to 32% among the female participants was a significant jump, representing over a quarter of the female sample base whose ratios were corrected in the hand stencils.

Why male 2D:4D ratios in the hand stencils were less typical and did not pattern male as consistently as their anatomical hands and why conversely the female 2D:4D ratios in the hand stencils suddenly patterned female in greater numbers is an interesting question. I can think of no particular reason why this phenomenon would occur other than sample size and as no similar studies to my own have ever been conducted, I have no data with which to compare to conclude whether this occurrence is normal or abnormal. It's possible that this event is due to chance and therefore non-repeatable. It could be a factor of the attention span of the participants and therefore reflect how much attention to detail was employed during the production of their hand stencils. My educated guess on the subject would be that the angle of the wrist played an integral part in these results. When anatomical measurements of the digit lengths are recorded, the hand is kept straight, the wrist and digits aligned, and the digits together rather than spread wide as during the production of a hand stencil. It would be decidedly uncomfortable if not impossible to hold one's hand directly in front of ones face, in a vertical line, without angling the wrist at all and hand stencils are not naturally produced with the digits together. Yet, as has been noted by Peters et al., (2002), if the hand is not kept perfectly straight with the second, third and fourth digits together, as the fingers move, the second digit will sometimes appear longer than the fourth and vice versa depending on the angle of the wrist. This must be addressed as a core issue in the method of measurement for both positive handprints and for negative hand stencils as the angle of the wrist as well as the splaying of the fingers-which can also lengthen or shorten the digits dependent on the angle of abduction-is likely to have a pronounced effect on any 2D: 4D ratio calculations derived from the length of the digits (Nelson et al., 2006; Peters et al., 2002). It is this factor, the angle of the wrist and the splaying of the digits which I believe influenced the greater number of patterned female ratios in the male hand stencils, and the drop in patterned male ratios in discussion. Repeating the experiment would likely produce similar variation but not the same results exactly.

The issue, however, is accounting for this factor in our assessment of hand stencils, particularly archaeological hand stencils where the true sex of the individual is not known. Considering these results, we could expect to incorrectly classify female hands as male 68% of the time in this sample, were the sex of the participants unknown. 68% represents a significant potential for misclassification. If we were to extrapolate these results to an archaeological setting, there would be a high probability of mistakenly asserting a male dominance in the production of hand stencils. Delving further, what this really signifies is a strong chance of erasing the female presence from the archaeological record of rock art production if we rely on the application of the 2D:4D ratio to determine sex from hand stencils alone, particularly where children are concerned.

The purported sexual dimorphism of the 2D:4D ratio did not present as I had expected in the hand stencils of the child participants of this sample. This begs the question, does the sexual dimorphism of the ratio increase with the age of the participants? Put another way, is there a particular age within this sample where the 2D:4D ratio begins to be consistently expressed as with the onset of puberty, for example? If so, does the age at which the 2D:4D ratio becomes a more reliable tool for determining sex from children's hand stencils differ between the males and the females of the sample, based on the differential rates of growth and development of the hands (Scheuer & Black, 2000)? As I said in my results and analysis, the best way to answer this question was to plot the data in a series of figures. In Figures 4, 5 and 6, the percentage of correctly patterned ratios, either male or female are plotted along the Y-axis. The X-axis plots the age range of the participants from this sample from five to sixteen. Figure 4 plotted Left Hand Ratio Accuracy, Figure 5 Right Hand Ratio Accuracy and Figure 6 Hand Stencil Ratio Accuracy. What was revealed by the graphs was a strict division in the percentage of correctly patterned ratios between males and females, regardless of age.

The male participants of this sample demonstrated consistent 2D:4D ratios that patterned male anatomically, as well as in their hand stencils. It was very unlikely on the other hand for the female participants to produce 2D:4D ratios that patterned female either anatomically or in their hand stencils. These results are not surprising as the graphs are derived from the results of the chi-square tests. What is surprising is that these 2D:4D ratio are not altered in any capacity by the age of the participants in this sample. In other words, at no one age does the 2D:4D ratios of any aged participant suddenly begin to pattern in the expected way, below 1.00 for males and above 1.00 for females. Rather what the graphs reveal is more like a continuum along which the 2D:4D ratios are expressed for each age range of the participants, without drastic variation. This to me indicates that puberty is not a factor affecting the sexual dimorphism of the 2D:4D ratio in this sample. Moreover, if as I expected to find, the increased rate of growth and development of female hands were a significant factor affecting the expression of the 2D:4D ratio in females, I would have expected to see that at a specific age, the graphs would suddenly take an upswing, indicating that the 2D:4D ratios were beginning to pattern above 1.00 as anticipated. Instead, the graphs show that the data are flat, the number of male participants whose 2D:4D ratios pattern as male below 1.00 never drops below 50% at its lowest and the number of female participants whose 2D:4D ratios pattern as female above 1.00 never even rises above 50%.

In short, the chi square tests indicated that the male participants of this sample had anatomical 2D:4D ratios that patterned male as expected. Likewise, the 2D:4D ratio calculations derived from their hand stencils also patterned male, i.e. <1.00. For the female participants, the chi square tests indicated that the 2D:4D ratios derived from the anatomical measurements of the hands as well as the hand stencils failed to pattern female, i.e. >1.00. There was an unusual variation in the results of the hand stencils, with the percentage of male 2D:4D ratios that patterned male dropping and the percentage of female 2D:4D ratios that patterned female increasing. A scientific explanation for this phenomenon is unknown, though I supposed that the angle of the wrist and the splaying of the digits could account for these discrepancies. The results would most likely be repeated in any sample, though the exact percentages that these discrepancies would occur would most likely differ. It is likely that the result of the 2D:4D ratio failing to be sexually dimorphic in this sample was not due to the ratio itself, but rather to the masculinized 2D:4D ratios of the female participants, as was revealed in their anatomical measurements. Owing to those measurements, it was inevitable that the female participants would fail to produce patterned female 2D:4D ratios in their hand stencils. Therefore, within this sample, sex did have an impact on the 2D:4D ratios of the child participants, but not as expected. The 1.00 midpoint for the 2D:4D ratio could not be successfully applied, digit lengths did not conform to the standard of sexual dimorphism purported by Manning's finger ratio.

Finally, Figures 4, 5 and 6 corroborated the results of the chi square tests, displaying the high percentage of patterned male 2D:4D ratios, and the low percentage of patterned female 2D:4D ratios. Furthermore as explained, the continuum exhibited by the graphs in each figure established that age was not a factor in the percentage of correctly patterned male or female ratios in this sample. What's more, neither puberty or the accelerated growth and development of female hands influenced the continuum shown by the graphs.

The masculinized ratios among the female participants of this sample drastically affected the results as well as my perception of the usefulness of the ratio as a tool for sex determination, particularly in an archaeological setting. Further research is needed to identify whether the masculinization of the female digit ratio experienced in this sample is relevant only to the location of the sample base, or whether it is a wider issue found throughout North America. Clearly, this masculinization is not a one-off occurrence as it affected the Pennsylvania derived sample base in Snow's (2013) most recent publication as well. Variation in the digit ratio was also a factor in Manning et al.'s 2004 publication in which it was concluded that the 2D:4D ratio was significantly lower in males than it was in females of Uygur, Han and Jamaican origins. Moreover, there were significant differences in the ratio between populations; the Han population had the highest mean 2D:4D ratio, followed by the Berbers and the Uygurs. The lowest mean ratios was found in the Jamaican sample (Manning et al., 2004). While statistically significant male-female differences are common within a given population such as Southeast Asia, nearly insignificant male-female differences have been noted in the Nalgonda District of India (Napier, 1993; Ramesh & Murty, 1997 as cited in Snow, 2006). Moreover, Zulu, Finnish and Jamaican women have all been noted for having male-like digit ratios which are more pronounced than Polish, English or Spanish males (Manning 2002 as cited in Snow, 2006). What this suggests is that there is significant difference between populations of living people, where anatomical measurements of the 2D:4D ratio are possible. Archaeological attempts to determine sex from handprints and hand stencils from as far back as the Gravettian using the same 2D:4D ratio and without the ability to take anatomical measurements should therefore send up 'red flags.' Arguably, this issue would only be exacerbated with children's hand stencils.

Utilizing the 2D:4D ratio to determine sex from hand stencils in an archaeological context has great potential to inform researchers about lifeways, communities of practice, and to recognize the individual in the archaeological record. However, it is so important that this technique be used with caution, and with a complete understanding of the inherent risks in the formula. Biologically speaking, the ratio is subject to a number of issues, such as population variation and asymmetrical growth patterns when applied to living populations; these issues are only exacerbated when the ratio is applied to archaeological hand stencils (Nelson et al., 2006). Population variation in particular is one of the major issues with using the 2D:4D ratio in an archaeological setting. Chazine and Noury (2006) for example, were aware during the course of their investigation that the 2D:4D ratio varied from population to population and that Manning's research was based on a European population, not an Indonesian one (Nelson et al., 2006). Despite this, Chazine and Noury (2006) justified their application of the ratio to an 'equatorial population' based on evidence elsewhere that populations of this region have a weaker ratio overall, though as they stipulate, the sexual dimorphism between males and females appears to remain consistent. But due to the variation within and between populations, Nelson et al. (2006) argue that their results may have been more valid had they compared the ratios of indigenous populations that were genetically closer to the rock art artists.

By contrast, the issue of population variation was addressed in Snow's (2006) research which relied on the use of a genetic study of a modern living European population. The genetic evidence revealed that 95% of all modern European Y chromosome carriers are descendants of

10 lineages which have been present in Europe since the Upper Palaeolithic. As a result of Snow's research, we can say for certain that among Europeans, adult males tend to have larger hands on average than European females. However, as Snow pointed out, because there is very little variation in the length and breadth of either male or female European hands, this measurement is not sufficient to differentiate between female hands and the hands of preadolescent boys (Snow, 2006). Moreover, there is a significant level of ratio overlap not only between populations, but within populations as well. It is therefore really critical that we use the most appropriate modern sample, as Snow (2006) did, before applying the ratio archaeologically (Nelson et al., 2006).

Summary of Research

Bednarik (2008) argued that any metrical data determined from archaeological hand stencils was controversial as sex is difficult to determine reliably and only broad estimations can be made regarding the age of rock art artists. The results of my experiment as discussed throughout this chapter would seem to support Bednarik's view. Primarily because as I explained in response to my first sub-question, hand stencils are not an accurate reflection of the anatomical hand. While, as the minimum, maximum and average error calculations as well as the Paired t-test demonstrated, there is a range of error that crosses sex and all age groups, error is a constant factor in the production of a hand stencil. Even minimal error could cause a misclassification of sex, though the odds of this occurring increases with the range of error produced. It is rather, as I explained, the distribution of the error which is cause for concern. It is unpredictable and as I said, apparent in the hand stencils of both male and female participants, regardless of age. In short, there is no way that I am aware of to predict the error that will be produced in the production of a hand stencil and therefore no way to account for it, before conducting further analysis with a technique like the 2D:4D ratio. If we cannot predict it but can only be aware of the existence of error, we must pursue any studies involving the 2D:4D ratio with extreme caution and the foreknowledge that our results are likely to be skewed. For myself, I believe the risk is too great to recommend continuing with any 2D:4D analysis of archaeological hand stencils produced by children, unless some means of accounting for the error is devised.

However, I continued regardless on the basis that answering my last three sub-questions would increase my understanding of all the factors affecting sex determination from hand stencils in a larger context than my sample. For example, it was important to analyze whether age was a significant factor affecting the accuracy of the hand stencils. It was important because my sample involved children ranging from five to sixteen and if age played a significant part in the amount of error apparent in their hand stencils, which it did, it inferred two things. One, that while as I said above, hand stencils are not an accurate reflection of the anatomical hand, that error is constant and unpredictable, the age of the artist has a statistically significant affect the amount of error produced. In other words, as error reduces with age, the possibility that hand stencils will become more accurate increases. Error is still present, and we still need to be aware that it exists and that it cannot be predicted, but it is significantly reduced with the age of the stenciller. This brings me to the second point, which is that there may be a benefit in redoing this experiment with an adult sample. If adolescents produce less error, how much more accurate could adult hand stencils be? Moreover as the number of adult hand stencils far outweigh the number of children's hand stencils in an archaeological context, there is reason to support recreating this experiment with an adult sample. Fundamentally, the results of my analysis indicate that due to the amount, range, and unpredictability of the error present in children's hand stencils, it would not be wise to pursue 2D:4D ratio calculations in an archaeological context. However, as the amount of error reduces significantly with age, it is possible with further experimentation to determine if accuracy of the hand stencil as a reflection of the anatomical hand increases enough to suggest that the 2D:4D ratio would be applicable for adult hand stencils.

Unsurprisingly, the results of the chi-square tests indicated that patterned male 2D:4D ratios were high and patterned female 2D:4D ratios were low. Having noticed the highly masculinized nature of the sample during data collection, I had anticipated these results. Research on Upper Palaeolithic skeletal populations reveals a much more pronounced level of sexual dimorphism of the long bones than is found today (Formicola & Giannecchini, 1999). According to Snow's (2013) comparative analysis of archaeological hand stencils and hands from a modern sample, we can extend this greater sexual dimorphism of the long bones to also have included the hand. Hands appear to have displayed a more pronounced sexual dimorphism in the past than is currently expressed in modern European descendent populations (Snow, 2013). As I have discussed, present population variation of the 2D:4D ratio is documented. What I find interesting is that Snow (2013) also experienced a masculinized sample base in Pennsylvania. Could this consistency of masculinized digit ratios be a North American variation?

Regardless, the lack of female conformity within this sample made it impossible to effectively apply the 2D:4D ratio. Moreover, with the amount of error present in the hand stencils, we cannot be certain that the results of the 2D:4D analysis were not skewed. Finally, as demonstrated by Figures 15, 16 and 17, there was no evidence to support that the 2D:4D ratio became fixed sooner for females than for males. As these results were based off of the chi-square tests which were themselves based off the 2D:4D ratios derived from a nonconformist, masculinized sample base, it is also not surprising. As the figures clearly demonstrated, at no particular age, such as the advent of puberty, did female 2D:4D ratios become more feminized and pattern female from there onwards. Instead what was revealed was a consistently homogenized overlap of 2D:4D ratios which frequently hovered below 1.00 regardless of age or sex.

The Larger Picture

Even though the results of my research indicate that the 2D:4D ratio is not a viable means of determining sex from children's hand stencils, and even though I would not recommend applying the ratio in an archaeological setting where aspects like the irregularity of the cave wall might exacerbate the difficulty in attaining 'accurate' hand stencils, this research, when situated within the larger body of work related to the Archaeology of children, is still important. Even should replication studies of the 2D:4D ratio and children's hand stencils be pursued, perhaps with an eye to ascertaining the 'ethnic' variation of the ratio between populations of children, and prove the ratio to be ineffectual in the larger picture, these studies are vital to the growing literature on the topic of ancient children. All studies on children of the past add another dimension to our understanding of what it meant to be a child during the Palaeolithic. Handprint making is just one aspect of this larger picture of which children contributed.

Studying handprints is a powerful means of returning identity to anonymous Ice Age artists, to Ice Age children whose representation on the landscape has too often been ignored or overlooked. These and other ephemeral practices bear further scrutiny if we are to correct for the underrepresentation of children in the archaeological picture and to rectify the bias in archaeological practice. It is important to keep in mind that children in the past were likely an integral aspect of Palaeolithic lifeways, just as children are integral to society today and that overlooking their presence and the contributions that they made can only lead to a false understanding of the past. Handprints are one way that we can witness children actively participating in Palaeolithic lifeways. Not only do they tell us that children were present in the caves but that they were active participants in the production of rock art.

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Appendix A: Ratio Data Table

Sex	#	AGES	LF 2D	LF 4D	Left Ratio	RF 2D	RF 4D	Right Ratio	HS 2D	HS 4D	Ratio
1	1	5	48.72	47.67	.0220264317180	49.86	51.08	9761158966327	52.51	45.18	1.1622399291722
1	2	5	46.57	48.13	9675877830874	47.55	46.79	.0162427869202			
1	3	5	52.96	53.94	9818316648127	52.14	52.17	9994249568717			
1	4	5	45.78	51.53	8884145158160	46.08	51.53	8942363671647	43.47	44.04	).987057220708447
1	5	5	49.54	47.9	.0342379958246	45.13	48.75	.925743589743			
1	6	5	47.24	48.27	9786616946343	48.11	49.57	9705467016340			
1	7	5	48.9	51.15	9560117302052	47.37	50.03	9468319008594			
1	8	5	45.23	47.56	9510092514718	43.49	48.77	.891736723395			
1	9	5	46.06	52.65	8748338081671	47017	52.69	92.3325109128			
1	10	5	49.61	53.74	9231484927428	50.03	53.67	9321781255822	43.44	47.48	).91491154170176
1	18	6	47.9	52.84	9065102195306	48.97	54.12	9048410938654	46.56	54.22	).85872371818517
1	19	6	55.66	54.76	.0164353542731	52.7	57.9	9101899827288			
1	20	6	45.86	46.75	.980962566844	45.62	49.48	9219886822958			
1	21	6	48.15	52.19	.922590534585	47.52	50.65	9382033563672			
1	22	6	49.72	53.45	.930215154349	47.86	51.53	9287793518338			
1	23	6	44.79	45.15	.992026578073	44.67	46.2	9668831168831			
1	24	6	54.91	56.69	9686011642264	53.04	56.62	9367714588484	56.85	56.06	1.01409204423832
1	25	6	49.81	52.2	9542145593869	50.1	52.25	9588516746411	47.35	46.51	1.01806063212212
1	26	6	49.92	52.02	9596309111880	48.04	52.85	9089877010406	53.38	59.2	).90168918918918
1	27	6	52.5	56.18	9344962620149	53.86	58.7	9175468483816			
1	28	6	52.01	55.22	9418688880840	50.72	54.96	9228529839883			
1	29	6	53.77	56.23	9562511115063	50.58	56.93	8884595116810	57.09	60.21	).94818136522172
1	30	6	49.78	55.49	8970985763200	49.69	56.06	8863717445594			
1	31	6	49.49	53.25	9293896713615	46.79	51.94	9008471313053	48.26	53.27	).90595081659470
1	32	6	47.72	51.71	9228389093018	45.93	51.5	8918446601941			
1	33	6	50.97	53.35	9553889409559	51.32	54.22	9465142014016	50.67	56.68	).89396612561750
1	34	6	49.21	50.6	9725296442687	48.33	50.14	9639010769844			
1	35	6	46.57	50.46	9229092350376	45.85	50.7	9043392504930	49.42	52.15	).94765100671140
1	36	6	47.96	52.27	9175435240099	46.22	53.67	8611887460406	49.32	40.1	1.22992518703242
1	37	6	48.85	49.84	9801364365971	46.29	47.95	9653806047966			
1	38	6	49.01	52.28	9374521805661	47.74	51.61	9250145320674	43.57	50.54	).86208943411159

Sex	#	AGES	LF 2D	LF 4D	Left Ratio	RF 2D	RF 4D	Right Ratio	HS 2D	HS 4D	Ratio
1	39	6	54.77	58.44	93720054757015	53.05	55.87	94952568462502	60.22	61.77	.97490691274081
1	40	6	50.24	51.65	.972700871248	51.52	51.37	.0029199922133			
1	41	6	51.96	56.47	92013458473525	52.96	56.32	94034090909090	54.12	51.97	1.04137002116606
1	42	6	48.44	49.98	96918767507002	47.06	51.18	91949980461117			
1	43	6	54.18	58.17	93140794223826	53.53	58.78	91068390609050			
1	44	6	50.14	51.91	96590252359853	46.05	52.71	87364826408651			
1	45	6	46.32	48.33	95841092489137	47.89	51.43	93116857865059			
1	83	7	51.62	54.07	95468836693175	50.94	52.34	97325181505540			
1	84	7	49.45	50.46	97998414585810	47.71	50.65	94195459032576	51.78	54.52	.94974321349963
1	85	7	54.21	61.02	88839724680432	52.21	61.27	85212991676187	53.21	58.55	.90879590093936
1	86	7	53.5	54.55	98075160403299	53.14	56.83	93506950554284	54.79	55.65	.98454627133872
1	87	7	55.01	53.45	.029186155285	53.45	54.49	98091392916131			
1	88	7	52.66	51.55	.021532492725	50.46	51.11	98728233222461			
1	89	7	50.93	52.15	97660594439117	53.19	53.69	99068727882287			
1	90	7	56.28	59.06	.952929224517	58.67	57.32	.0235519888346	60.91	57.55	1.05838401390096
1	91	7	56.53	60.41	93577222314186	54.92	60.51	90761857544207			
1	92	7	47.33	49.88	.9488773055332	47.8	51.23	.93304704274833	52.71	49.62	1.06227327690447
1	93	7	53.07	56.95	93187006145741	52.9	57.8	.9152249134948	50.65	60.37	.83899287725691
1	94	7	53.16	52.64	.009878419452	50.55	52.66	95993163691606	50.65	53.13	.95332204027856
1	95	7	60.12	59.05	.018120237087	56.74	58.2	97491408934707			
1	96	7	59.53	64.08	92899500624219	56.21	62.05	90588235294117	56.49	63.54	0.8890462700661
1	97	7	54.55	54.47	.001468698366	55.86	56.69	.98535896983599	53.88	51.54	1.0454016298021
1	98	7	54.45	58.2	93556701030927	54.3	57.01	95246447991580	56.27	57.22	.98339741349178
1	99	7	52.7	56.76	.928470754052	51.41	54.4	94503676470588	53.17	54.02	.98426508700481
1	100	7	49.17	51.6	95290697674418	46.49	50.68	91732438831886	49.61	54.37	.91245171969836
1	101	7	52.44	54.61	96026368796923	52.42	55.79	93959490948198	48.69	58.1	.83803786574870
1	102	7	54.7	57.62	94932315168344	53.58	53.74	99702270189802	48.43	51.61	.93838403410191
1	103	7	55.44	57.18	96956977964323	54.69	57.86	94521258209471	54.42	59.01	.92221657346212
1	104	7	52.3	54.05	96762257169287	51.12	55.3	92441229656419	56.9	58.26	.97665636800549
1	105	7	46.63	44.92	.038067675868	46.75	46.02	.0158626684050	47.04	46.34	1.01510574018127
1	106	7	56.94	57.67	98734177215189	55.72	57.78	96434752509518	56.44	52.82	1.06853464596744
1	107	7	50.35	50.22	.002588610115	49.53	49.52	.0002019386106			

Sex	#	AGES	LF 2D	LF 4D	Left Ratio	RF 2D	RF 4D	Right Ratio	HS 2D	HS 4D	Ratio
1	108	7	54.98	58.9	9334465195246	55.33	61.11	9054164621174	52.66	62.05	0.84867042707494
1	109	7	56.55	56.09	.00820110536636	52.99	54.84	9662654996353			
1	110	7	54.8	53.92	.01632047477744	55.15	55.42	9951281125947			
1	134	8	61.1	59.08	.034190927555	58.69	58.02	.011547742157	63.54	64.44	.98603351955307
1	135	8	58.32	58.6	9952218430034	56.58	59.14	9567128846804	59.05	59.74	0.98844994978239
1	136	8	50.44	49.63	.01632077372554	46.15	48.04	9606577851790	50.15	51.8	.96814671814671
1	137	8	50.29	52.31	9613840565857	50.81	53.94	9419725621060			
1	138	8	50.19	50.76	9887706855791	46.89	50.23	9335058729842	57.66	55.17	1.04513322457858
1	139	8	56.1	58.54	9583190980526	56.5	58.77	9613748511145	61.18	62.01	0.98661506208676
1	140	8	47.5	52.84	.8989401968205	49.47	51.75	9559420289855	46.83	52.64	.88962765957446
1	141	8	55.54	56.4	9847517730496	57.36	59.49	9641956631366	58.56	59.89	.97779261980297
1	142	8	58.27	52.05	.119500480307	50.76	52.85	9604541154210	58.77	56.54	1.03944110364344
1	143	8	47.28	52.64	8981762917933	45.94	53.82	8535860274990	48.36	54.74	.88344903178662
1	144	8	51.4	55	934545454545454	53.27	55.55	9589558955895	54.89	56.16	0.97738603988604
1	145	8	53.01	53.27	9951192040548	52.92	51.74	.022806339389	53.62	55.91	.95904131640135
1	146	8	50.65	53.47	9472601458761	52.5	55.17	9516041326808	53.65	53.66	.99981364144614
1	147	8	57.73	57.09	.0112103695918	57	60.29	9454304196384	55.52	55.54	.99963989917176
1	148	8	48.51	52.65	9213675213675	49.54	53.3	92945590994371			
1	149	8	59.42	64.79	9171168390183	59.15	67.72	8734494979326	55.93	67.13	.83315954118873
1	150	8	55.16	59.19	9319141746916	58.84	59.43	9900723540299	57.3	60.63	.94507669470559
1	151	8	54.91	54.45	.00844811753909	54.05	55.27	.977926542428	53.92	57.21	.94249257122880
1	152	8	55.65	58.28	.954873026767	54.69	58.75	9308936170212	53.96	58.38	.92428914011647
1	153	8	56.02	56.41	9930863322106	54.69	57.07	9582968284562	55.89	52.62	1.06214367160775
1	154	8	50.1	50.65	9891411648568	48.72	50.5	96475247524752			
1	155	8	58.14	58.2	9989690721649	56.31	56.57	9954039243415	57.99	62.45	.92858286629303
1	156	8	50.86	54.34	9359587780640	52.14	52.84	9867524602573	57.28	56.56	1.01272984441301
1	168	9	55.1	56.63	9729825180999	54.42	58.22	9347303332188	53.24	59.65	.89253981559094
1	169	9	57.41	59.22	9694360013508	57.51	59.94	9594594594594	52.17	49	1.06469387755102
1	170	9	59.36	61.6	9636363636363	59.48	62.08	9581185567010	50.02	55.03	.90895874977285
1	171	9	53.92	55.02	9800072700836	52.24	55.62	9392304926285	50.78	49.06	1.0350591112923
1	172	9	59.72	64.17	9306529530933	57.72	61.71	9353427321341	67.39	67.54	.99777909387029
1	173	9	56.43	58.46	9652754019842	54.39	56.75	.958414096916	52.58	59.68	.88103217158176

Sex	#	AGES	LF 2D	LF 4D	Left Ratio	RF 2D	RF 4D	Right Ratio	HS 2D	HS 4D	Ratio
1	174	9	57.41	57.23	.0031452035645	56.18	58.05	96778639104220			
1	175	9	55.65	59.01	9430604982206	56.51	58.41	96747132340352			
1	176	9	65.11	71.07	9161390178697	62.53	69.85	8952040085898	59	63.74	.925635393787261
1	177	9	53.67	56.61	9480657127715	54.73	57.92	94492403314917	56.59	58.93	.960291871712201
1	178	9	51.72	54.55	9481209899175	55.28	55.25	.0005429864253			
1	179	9	56.63	59.88	9457247828991	56.92	59.91	9500918043732	51.71	56.75	.91118942731277
1	180	9	50.24	53.57	9378383423557	49.36	55.39	.8911355840404	50.88	52.49	.96932749095065
1	181	9	56.41	54.6	.0331501831501	55.54	54.67	.0159136638009	56.32	57.35	0.98204010462075
1	182	9	54.91	59.2	9275337837837	58.59	59.14	9907000338180	49.59	51.02	.97197177577420
1	183	9	55.76	60.92	9152987524622	55.16	61.11	9026345933562	58.6	65.03	.90112255881900
1	184	9	56.55	59.41	9518599562363	58.69	57.3	.0242582897033	54.73	55.86	.97977085571070
1	193	10	62.14	65.16	.9536525475752	60.01	63.96	9382426516572	64.06	56.43	1.13521176679071
1	194	10	54.84	57.89	9473138711349	53.89	59.38	90754462782081	59.1	62.73	.94213295074127
1	195	10	60.12	63.98	9396686464520	60.12	62.26	9656280115644	66.29	66.53	.99639260483992
1	196	10	59.76	61.5	9717073170731	58	61.91	9368438055241	56.37	59.76	.94327309236947
1	197	10	56.79	54.51	.0418271876719	60.56	57.34	1.056156260899	54.76	57.42	.95367467781260
1	198	10	67.49	67.98	9927919976463	66.59	68.39	9736803626261	68.55	63.71	1.07596923559881
1	199	10	62.6	63.67	9831945971415	63.51	64.93	9781302941629	62.31	64.48	.96634615384615
1	200	10	58.55	58.26	.0049776862341	55.62	58.82	9455967358041	56.19	57.52	.97687760778859
1	201	10	59.07	63.12	9358365019011	58.68	63.53	.9236581142767	59.17	67.58	.87555489789878
1	202	10	61.73	61.06	.0109728136259	60.89	61.84	98463777490297			
1	203	10	60.53	64.68	9358379715522	60.49	64.97	93104509773741	60.08	65.03	.92388128556051
1	204	10	60.76	64.46	9426000620539	59.2	61.91	9562267808108	56.42	55.35	1.0193315266486
1	205	10	57.36	58.21	9853976979900	60.1	62.83	95654941906732			
1	206	10	60.38	65.31	9245138569897	58.97	64	0.92140625	62.35	68.13	.91516218993101
1	207	10	57.97	65	8918461538461	59.21	64.35	.9201243201243	60.85	68.54	0.88780274292384
1	208	10	57.43	59.92	9584445927903	56.94	62.02	91809093840696			
1	218	11	64.43	64.93	.9922993993531	65.07	67.15	9690245718540	65.63	63.76	1.0293287327478
1	219	11	61.59	60.69	.0148294611962	62.12	60.51	1.0266071723682			
1	220	11	64.1	64.72	9904202719406	63.27	64.32	98367537313432			
1	221	11	57.9	64.03	9042636264251	58.43	62.23	9389362044030	58.61	68.04	0.8614050558495
1	222	11	58.97	56.56	.0426096181046	59.63	58.51	.0191420270039	58.28	59.68	.97654155495978

Sex	#	AGES	LF 2D	LF 4D	Left Ratio	RF 2D	RF 4D	Right Ratio	HS 2D	HS 4D	Ratio
1	223	11	62.19	62.92	98839796567069	60.27	63.9	94319248826291	60.81	64.68	.9401669758812626
1	224	11	67.52	70.06	963745361119 0	68.45	70.55	97023387668320	67.76	68.62	.987467210725736
1	225	11	62.29	58.19	.07045884172535	59.07	59	.001186440677 9	60.81	59.05	1.02980524978832
1	226	11	63.66	66.74	95385076415942	64.77	67.35	96169265033407	62.37	65.87	.946865037194474
1	227	11	59.26	59.2	.00101351351355	55.31	58.79	94080625956795	61.51	60.9	1.01001642036125
1	228	11	66.85	67.45	.99110452186800	62.92	66.39	94773309233318	65.61	65.41	1.00305763644703
1	229	11	67.92	70.42	.9644987219539	67.96	69.22	98179716844842	71.65	70.7	1.01343705799151
1	230	11	62.59	63.36	98784722222222	62.69	64.37	.9739008855056			
1	231	11	67.53	67.08	.00670840787 12	67.86	68.73	98734177215189	67.97	71.37	.952360935967493
1	232	11	64.61	65.3	98943338437978	64.62	66.96	.9650537634408			
1	233	11	61.47	64.71	94993045897079	63.53	63.48	.0007876496534	64.07	63.57	1.00786534528866
1	252	12	63.5	68.29	.92985795870556	64.55	68.8	93822674418604			
1	253	12	68.2	68.98	98869237460133	67.2	69.93	96096096096096	66.51	70.3	.946088193456615
1	254	12	68.22	69.03	98826597131681	68.95	70.2	98219373219373	70.94	71.35	.994253679046952
1	255	12	70.17	75.36	93113057324840	71.51	75.02	95321247667288			
1	256	12	63.4	66.5	95338345864661	61.47	66.31	92700950082943			
1	257	12	64.29	69.48	92530224525043	63.11	67.65	93288987435328	67.3	71.43	.942181156376872
1	258	12	67.79	71.06	95398254995778	67.9	66.88	.0152511961722			
1	259	12	64.01	69.91	91560577885853	66.61	70.98	93843336151028			
1	260	12	67.64	67.7	99911373707533	67.34	68.67	98063200815494	69.24	70.67	.979765105419556
1	261	12	70.44	71.56	98434879821129	70.83	71.24	99424480628860			
1	262	12	68.01	72.23	94157552263602	67.41	72.73	92685274302213	69.94	72.05	.970714781401804
1	263	12	74.81	81.78	91477133773538	77.65	83.07	93475382207776	80.8	84.87	.952044303051726
1	264	12	71.08	71.85	.98928322894922	71.8	73.68	97448425624321	72.08	73.32	.983087834151664
1	265	12	64.1	67.45	95033358042994	66.7	69.37	96151073951275	66.85	72.9	.917009602194787
1	266	12	69.78	73.58	94835553139440	68.93	73.23	94128089580772	69.13	76.49	.903778271669499
1	267	12	60.56	62.11	97504427628401	61.15	63.86	95756341998120	57.44	68.16	.842723004694836
1	268	12	60.04	66.19	.9070856624867	61.18	64.45	94926299456943	63.99	66.91	.956359288596622
1	269	12	65.42	72.38	90384084001105	64.2	70.67	90844771473043			
1	294	13	67.36	73.26	91946491946491	67.14	75.22	89258176017016	69.27	75.74	.914576181674148
1	295	13	74.55	76.84	.9701978136387	75	79.39	94470336314397	76.55	81.43	.940071226820582
1	296	13	62.83	69.84	89962772050400	66.65	68.93	96692296532714	67.06	67.71	.990400236301876

Sex	#	AGES	LF 2D	LF 4D	Left Ratio	RF 2D	RF 4D	Right Ratio	HS 2D	HS 4D	Ratio
1	297	13	71.53	71.37	.0022418383074	70.32	71.9	97802503477051	74.08	72.83	1.01716325689963
1	298	13	69.12	70.95	97420718816067	70.23	73.91	95020971451765	66.51	71.57	.929299986027665
1	299	13	78.79	81	97271604938271	79.27	79.28	99987386478304			
1	300	13	66.81	68.88	96994773519163	68.64	68.91	99608184588593	69.77	70.17	.994299558215762
1	301	13	68.31	74.15	.9212407282535	70.88	71.62	98966769058922	72.79	73.85	.985646580907245
1	302	13	63.78	64.11	99485259709873	61.56	64.05	.9611241217798	64.89	64.51	1.00589055960316
1	303	13	70.18	65.45	.0722689075630	67.92	67.81	.0016221796195	71.69	71.61	1.00111716240749
1	304	13	73.46	76.7	95775749674054	74.28	76.47	97136131816398	76.7	76.35	1.00458415193189
1	305	13	68.24	69.19	98626969215204	68.14	69.72	97733792312105			
1	306	13	62.15	64.44	96446306641837	61.74	64.82	95248380129589	63.32	67.02	.944792599224112
1	307	13	67.5	67.42	.0011865915158	67.07	69.26	96838001732601	72.09	71.68	1.00571986607143
1	308	13	67.88	77.31	87802354158582	67.65	77.54	87245292752127	71.98	78.81	0.91333587108235
1	309	13	65.4	65.08	.0049170251997	64.58	67.03	96344920184991	60.17	66.71	.901963723579673
1	310	13	74.7	72.89	.0248319385375	71.67	75.77	94588887422462	78.84	73.54	1.07206962197444
1	311	13	71.85	75.49	95178169293946	70.85	74.78	94744584113399	73.74	77.17	.955552675910328
1	312	13	67.17	71.19	94353139485882	68.99	70.23	98234372775167	70.69	73.34	.963866921188983
1	313	13	76.75	78.5	97770700636942	75.51	79.19	95352948604621	72.9	78.99	.922901633118116
1	314	13	65.83	64.77	.0163656013586	63.56	63.36	.0031565656565	69.86	68.64	1.01777389277389
1	315	13	69.34	73.74	94033089232438	70.96	72.98	97232118388599			
1	316	13	71.05	70.92	.0018330513254	70.16	71.87	97620704048977	73.85	72.91	1.0128926073241
1	317	13	69.73	72.05	96780013879250	71.13	74.41	95591990323881	73.06	75.33	.969865923270941
1	318	13	64.44	69.93	92149292149292	63.02	66.54	94709948902915	67.73	67.76	.999557260920897
1	319	13	79.17	81.77	96820349761526	79.42	84.73	93733034344388	81.58	89.56	.910897722197409
1	320	13	77.04	81.26	94806793010091	77.34	80.74	.9578895219222	76.58	84.36	.907776197249881
1	321	13	75.08	80.17	93650991642759	75	79.08	94840667678300	74.11	81.13	.913472205102921
1	322	13	67.49	69.98	96441840525864	68.87	72.43	95084909567858	68.19	71.74	.950515751324226
1	323	13	66.69	69.18	96400693842150	67.18	72.57	92572688438748	72.67	74.86	.970745391397275
1	346	14	67.74	68.37	99078543220710	66.68	67.4	98931750741839	65.6	71.08	0.92290377039955
1	347	14	72.68	76.36	95180722891566	73.02	74.66	97803375301366	72.82	77.46	0.94009811515621
1	348	14	71.37	73.78	96733532122520	70.52	72.8	96868131868131	72.51	75.7	.957859973579921
1	349	14	66.52	69.22	96099393238948	66.59	69.83	95360160389517	70.22	72.13	.973520033273257
1	350	14	75.06	77.58	96751740139211	74.66	74.71	99933074554945	78.14	76.68	1.01904016692749

Sex	#	AGES	LF 2D	LF 4D	Left Ratio	RF 2D	RF 4D	Right Ratio	HS 2D	HS 4D	Ratio
1	351	14	72.23	76.55	.94356629653827	71.93	74.39	96693103911816	74.94	77.29	.96959503169879
1	352	14	66.64	69.45	95953923686105	67.12	71.85	93416840640222			
1	353	14	71.24	71.45	99706088173547	69.07	71.24	96953958450308	73.24	73.37	.99822815864794
1	354	14	77.07	76.29	.01022414471097	75.56	75.71	99801875577862	80.34	81.67	.98371495041018
1	355	14	73.09	76.44	95617477760334	71.69	77.09	92995200415099	72.24	74.95	.96384256170780
1	356	14	74.64	77.8	95938303341902	75.33	78.2	96329923273657	74.83	82.19	.91045139311351
1	357	14	75.64	79.1	95625790139064	76.83	79.26	96934140802422	73.6	77.81	.94589384397892
1	358	14	69.28	68.74	.007855688100	68.44	70.54	97022965693223	70.7	72.28	0.9781405644715
1	372	15	69.72	74.51	93571332707019	69.4	75.22	.92262696091466	69.63	76.1	.91498028909329
1	373	15	75.68	80.27	94281798928615	74.31	82.15	90456482045039	76.72	83.62	.91748385553695
1	374	15	78.67	78.95	99645345155161	78.95	80.42	98172096493409	80.63	83.21	.96899411128470
1	375	15	71.43	73.19	97595299904358	68.5	74.44	92020419129500	75.64	75.27	1.00491563703999
1	376	15	72.37	75.89	95361707734879	72.53	76.02	95409102867666	75.26	78.77	.95543988828234
1	377	15	73.91	75.98	97275598841800	74.02	79.39	93235923919889	73.36	79.11	.92731639489318
1	378	15	71.6	71.9	99582753824756	71.59	71.08	.00717501406866	73.45	72.61	1.01156865445531
1	379	15	70.69	70.65	.0005661712668	70	71.79	97506616520406	73.22	74.65	.98084393837910
1	380	15	66.75	70.57	94586934958197	68.66	70.24	.9775056947608			
1	381	15	69.95	71.15	98313422347153	69.25	72.49	95530417988688	72.67	76.01	.95605841336666
1	382	15	69.56	73.64	94459532862574	69.03	73.99	93296391404243	75.76	75.87	.99855015157506
1	383	15	69.65	77.07	90372388737511	70.02	74.86	93534597916110	69.38	80.28	.86422521175884
1	384	15	80.71	82.62	97688211086903	80.84	83.84	96421755725190	82.3	88.58	.92910363513208
1	385	15	70.3	69.8	.007163323782	69.79	72.65	96063317274604	72.21	73.67	.98018189222207
1	386	15	67.16	68.5	98043795620437	67.27	65.11	.0331746275533	68.16	68.67	.99257317605941
1	411	16	78.69	77.41	.016535331352	77.34	81.14	95316736504806	81.47	80.27	1.01494954528466
1	412	16	75.98	75.06	.0122568611777	73.28	78.61	93219692151125	76.49	77.95	.98127004490057
1	413	16	81.61	83	98325301204819	82.17	86.39	95115175367519	84.18	84.95	.99093584461447
1	414	16	76.99	77.98	98730443703513	75.75	77.18	98147188390774	77.55	77.76	.99729938271604
1	415	16	72.64	73.3	99099590723055	72.89	73.9	98633288227334			
1	416	16	75.58	76.58	98694176025071	75.32	78.51	.9593682333460	76.47	79.7	.95947302383939
1	417	16	70.12	75.62	92726791854006	69.87	75	0.9316	72.85	78.28	.93063362289218
1	418	16	72.35	77.42	93451304572461	70.51	77.08	.91476388168137	71.12	79.93	.88977855623670
1	419	16	70.53	72.22	97659927997784	70.46	73.67	95642731098140	71.26	74.81	.95254645100922

Sex	#	AGES	LF 2D	LF 4D	Left Ratio	RF 2D	RF 4D	Right Ratio	HS 2D	HS 4D	Ratio
1	420	16	66.38	63.56	.0443675267463	66.47	64.34	.0331053776810	67.99	64.71	1.05068768351105
2	11	5	46.26	49.19	94043504777393	47.82	50.18	95296931048226			
2	12	5	49.09	52.52	93469154607768	49.9	53.83	92699238342931	45.47	47.88	).949665831244779
2	13	5	49.67	50.9	97583497053045	50.73	50.07	.0131815458358			
2	14	5	50	50	1	48.43	50.49	95919984155278			
2	15	5	54.44	52.91	.0289170289170	52.41	53.9	97235621521335			
2	16	5	46.85	49.77	94133011854530	45.6	49.72	91713596138374			
2	17	5	49.39	49.06	.006726457399	50.9	52.9	96219281663516			
2	46	6	55.36	53.4	.0367041198501	54.56	54.17	.0071995569503			
2	47	6	50.86	57.25	88838427947598	50.19	56.24	89242532005689	49.92	48.43	1.0307660540987
2	48	6	48.56	51.27	94714257850594	47.92	51.25	93502439024390			
2	49	6	49.1	53.18	92327942835652	49.63	52.35	94804202483285	46.7	45.14	1.03455914931325
2	50	6	49.52	51.26	96605540382364	47.59	50.22	.9476304261250			
2	51	6	50.77	55.33	91758539671064	53.59	52.96	.0118957703927	52.05	50.01	1.04079184163167
2	52	6	48.85	50.68	96389108129439	48.8	50.49	96652802535155	44.55	49.47	).900545785324439
2	53	6	53.1	56.6	93816254416961	51.72	56.31	.9184869472562			
2	54	6	53.18	50.84	.0460267505900	51.75	51.27	.0093622001170			
2	55	6	51.09	52.04	98174481168332	48.78	52.96	.9210725075528	45.4	49.73	).91292982103358
2	56	6	51.09	53.01	96378041878890	51.96	52.55	98877259752616			
2	57	6	51.38	52.21	98410266232522	51.67	51.91	99537661336929	52.17	51.47	1.01360015543035
2	58	6	53.54	58.7	91209540034071	54.2	57.69	.9395042468365	56.17	60.03	).935698817258038
2	59	6	51.62	53.41	96648567683954	50.36	54.45	92488521579430			
2	60	6	52.56	52.08	.0092165898617	50.35	51.18	.9837827276279	50.96	49	1.04
2	61	6	55.74	55.23	.0092341118957	55.87	57.85	96577355229040	55.91	57.36	).974721059972106
2	62	6	50	53.27	93861460484325	50.4	53.04	95022624434389			
2	63	6	50.66	53.53	94638520455819	52.03	52.96	98243957703927	49.79	50.66	).982826687722069
2	64	6	49.77	51.15	97302052785923	48.9	51.5	94951456310679			
2	65	6	48.02	49.36	97285251215559	48.05	50.04	96023181454836			
2	66	6	58.12	60.89	95450812941369	56.73	61.23	92650661440470			
2	67	6	52.77	53.72	98231571109456	50.7	53.39	94961603296497	49.35	51.61	).95621003681457
2	68	6	52.91	55.19	95868816814640	53.22	56.12	94832501781895			
2	69	6	54.02	53.24	.0146506386175	55.84	55.23	.0110447220713	58.92	54.29	1.08528274083625

Sex	#	AGES	LF 2D	LF 4D	Left Ratio	RF 2D	RF 4D	Right Ratio	HS 2D	HS 4D	Ratio
2	70	6	53.32	56.72	9400564174894	50.38	57.9	87012089810017	52.8	56.4	.93617021276595
2	71	6	50.31	54.07	9304605141483	54.27	56.67	9576495500264	54.42	55.59	.97895304910955
2	72	6	48.26	52.11	9261178276722	46.84	51.02	9180713445707	48.06	52.21	.92051331162612
2	73	6	47.93	53.03	9038280218744	48.77	52.52	92859862909367			
2	74	6	48.99	50.31	.97376267143704	48.56	52.49	9251285959230	44.78	48.71	.91931841510983
2	75	6	48.84	54.2	9011070110701	49.21	54.14	90893978574067			
2	76	6	55.98	56.57	9895704436980	55.45	57.57	96317526489491	55.9	54.36	1.02832965415747
2	77	6	44.42	45.56	9749780509218	45.48	45.59	99758719017328			
2	78	6	49.63	49.37	.00526635608666	49.09	48.67	.00862954592150	53.53	46.69	1.14649817948169
2	79	6	50.91	52.02	9786620530565	49.55	52.57	.94255278676054	47.16	47.81	.98640451788328
2	80	6	46.86	49.36	.94935170178282	47.11	50.21	9382593108942	41.07	43.1	.95290023201856
2	81	6	48.6	52.32	9288990825688	51.06	51.26	.99609832227858	52.78	56.13	.94031712096917
2	82	6	50.09	51.12	9798513302034	50.68	51.83	9778120779471			
2	111	7	57.12	56.55	.01007957559681	54.76	59.92	.91388518024033	57.17	58.03	.98518007926934
2	112	7	55.66	57.92	9609806629834	56.83	54.73	1.0383701808888	54.09	55.39	.97653005957754
2	113	7	51.82	53.96	9603409933283	49.57	53.57	9253313421691			
2	114	7	56.92	60.19	9456720385446	54.75	59.22	.92451874366762	57.88	63.13	.91683827023602
2	115	7	53.35	55.87	9548952926436	55.19	58.17	9487708440777	54.89	59.65	.92020117351215
2	116	7	49.76	50.26	9900517309988	51.25	51.14	.0021509581540			
2	117	7	52.28	54.44	9603232916972	51.65	54	95648148148148			
2	118	7	54.84	56.73	9666842940243	54.87	53.84	.0191307578008			
2	119	7	49.98	55.08	9074074074074	48.96	55.19	8871172313824	46.76	45.99	1.01674277016743
2	120	7	47.49	53.24	8919984973703	49.1	53.46	9184436962214	44.63	53.28	0.83765015015015
2	121	7	58.06	60.82	9546201907267	55.85	60.38	9249751573368			
2	122	7	51.89	54.25	9564976958525	51.45	55.21	9318963955805	52.81	51.14	1.03265545561205
2	123	7	47.59	48.35	9842812823164	46.89	49.39	9493824660862			
2	124	7	53.46	54.6	9791208791208	52.68	52.4	.0053435114503			
2	125	7	54.02	56.62	9540798304486	53.36	57.84	9225449515905	47.45	52.09	.91092340180456
2	126	7	48.07	51.11	9405204460966	48.21	51.35	9388510223953	47.51	51.18	.92829230168034
2	127	7	55.22	57.98	9523973784063	55.28	57.91	9545847003971			
2	128	7	54.07	56.77	9524396688391	52.84	57.22	9234533379937			
2	129	7	53.82	55.58	9683339330694	54.46	55.57	9800251934497			

Sex	#	AGES	LF 2D	LF 4D	Left Ratio	RF 2D	RF 4D	Right Ratio	HS 2D	HS 4D	Ratio
2	13	7	56.13	59.05	9505503810330	54.37	61.76	8803432642487			
2	131	7	46.91	50.38	931123461691	46.92	52.5	893714285714			
2	13	7	50.92	53.5	95177570093	51.81	51.03	.01528512639	54.83	48.93	1.12058042100961
2	13	7	51.2	51.2	1	52.57	50.96	.0315934065934			
2	157	8	54.14	54.09	.000924385283	54.96	54.12	.01552106430	51.43	50.92	1.01001571091909
2	15	8	58.48	54.49	.073224444852	54.06	54.84	98577680525	57.44	59.73	.961660806964
2	15	8	54.41	57.25	950393013100	55.02	59.06	9315949881476	53.84	55.78	.96522050914306
2	16	8	55.64	56.58	98338635560	56.91	57.46	99042812391	49.12	54.78	.89667761956918
2	161	8	49.76	52.65	94510921177	49.99	54.81	91205984309	47.79	49.37	.96799675916548
2	16	8	50.14	56.09	89392048493	51.02	56.36	90525195173	49.56	54.65	.90686184812442
2	16	8	54.78	54.78	1	53.68	57.71	93016808178	52.95	54.44	.97263041880969
2	16	8	56.8	56.4	.0070921985815	53.49	56.6	94505300353	46.15	51.4	.89785992217898
2	16	8	61.61	62.49	98591774683	59.04	62.45	9453963170536	54.94	59.17	.92851106979888
2	16	8	54.47	55.14	.987849111352	52.34	55.89	9364823760959			
2	167	8	56.05	57.55	.973935708079	60.02	58.58	.02458176852	50.61	55.62	0.90992448759439
2	18	9	63.75	66.67	95620218989	64.55	65.47	98594776233	64.61	71.82	.89961013645224
2	18	9	46.68	47.19	98919262555	47.31	48.72	97105911330			
2	187	9	59.37	62.06	95665485014	60.56	61.82	97961824652	56.04	61.16	.91628515369522
2	18	9	61.29	62.01	98838896952	61.24	61.84	99029754204	52.25	59.76	.87433065595716
2	18	9	56.95	61.02	93330055719	60.14	63.04	95399746192	56.39	63.41	.88929190979340
2	19	9	57.68	57.77	99844209797	56.58	59.95	943786488740	58.29	59.69	.97654548500586
2	191	9	54.9	57.97	94704157322	55.67	58.26	95554411259			
2	19	9	67.47	65.69	.027096970619	60.67	65.94	920078859569	61.86	60.47	1.02298660492806
2	20	10	57.18	60.85	93968775677	52.93	57.42	92180424939	60.69	59.92	1.01285046728972
2	21	10	54.91	58.02	94639779386	54.88	55.6	.987050359712	58.05	58.29	.99588265568708
2	211	10	64.91	65.73	98752472234	59.38	63.75	931450980392	62.99	66.88	.94183612440191
2	21	10	54.76	56.06	97681056011	52.89	56.86	930179387970	54.86	58.92	.93109300746775
2	21	10	64.82	68.83	.941740520122	62.41	69.68	895665901262	64.75	70.09	.92381224140390
2	21	10	58.05	62.59	92746445119	56.76	63.92	887984981226	58.86	66.1	.89046898638426
2	21	10	60.03	65.83	91189427312	59.67	64.57	924113365339	58.98	61.48	.95933636955107
2	21	10	62.16	62.39	99631351178	60.7	63.47	95635733417362	59.2	58.73	1.00800272433169
2	217	10	57.06	60	0.951	54.78	59.26	924400944988	54.93	63.45	.86572104018912

Sex	#	AGES	LF 2D	LF 4D	Left Ratio	RF 2D	RF 4D	Right Ratio	HS 2D	HS 4D	Ratio
2	234	11	64.23	66.22	969948655995	63.22	65.35	9674062739097	64.38	55.32	1.16377440347072
2	235	11	58.83	59.49	988905698436	58.66	59.25	990042194092	61.44	60.41	1.01705015725873
2	236	11	64.64	64.56	.00123915737296	63.87	64.31	99315814025812	67.75	68.01	.996177032789296
2	237	11	61.73	63.94	965436346574	60.75	65.5	9274809160305	62.13	66.21	.938377888536475
2	238	11	66.69	67.31	99078888723815	64.32	65.29	9851432072292	66.3	68.87	.962683316393204
2	239	11	57.72	59.71	96667224920448	57.19	60.04	.95253164556962	63.79	62.54	1.01998720818676
2	240	11	58.67	62.69	93587494018184	62.08	61.59	.007955836986	59.71	64.03	.932531625800406
2	241	11	76.48	75.61	.01150641449547	76.48	76.47	.000130770236	78.2	79.92	.978478478478478
2	242	11	59.83	61.16	97825376062786	61.13	63.86	957250234888881	60.6	60.33	1.00447538538041
2	243	11	52.51	57.13	91913180465604	54.4	58.49	9300735168404			
2	244	11	60.29	59.79	.00836260244185	59.17	60.38	9799602517389			
2	245	11	70	70.61	99136099702591	70.14	74.59	940340528220094			
2	246	11	64.06	66.13	.968698019053	63.92	64.4	99254658385093			
2	247	11	59.66	61.8	.96537216828476	60.64	62.97	96299825313641	61.52	62.9	.978060413354531
2	248	11	58.13	55.39	.0494674128904	55.8	55.36	.00794797687861	56.58	58.04	.974844934527912
2	249	11	69.81	68.21	.02345697111186	68.82	67.7	1.016543574593	73.53	72.46	1.01476676787193
2	250	11	65.36	64.55	.01254841208366	65.42	66.47	98420340003008	70.37	68.13	1.03287832085719
2	251	11	67.37	69.91	96366757259333	67.37	69.17	97397715772733	70.24	71.36	.984304932735426
2	270	12	60.52	64.27	94165240392095	60.12	64.49	93223755621026			
2	271	12	59.45	64.15	92673421667965	60.41	64.16	94155236907730	61.63	64.37	.957433587074724
2	272	12	66.51	68.88	96559233449477	68.01	69.11	98408334539140	73.01	70.96	1.02888951521984
2	273	12	70.19	70.13	.000855553971	69.4	70.41	985655446669500			
2	274	12	65.55	67.03	977920333417872	67.52	68.69	98296695297714	71.96	69.01	1.042747427909
2	275	12	66.59	66.34	.00376846548086	66.97	69.44	96442972350230	73.27	66	1.11015151515152
2	276	12	67.13	71.06	94469462426118	71.59	72.42	98853907760287	68.88	70.4	.978409090909091
2	277	12	69.07	69.34	99610614364003	69.43	69.49	99913656641243			
2	278	12	66.13	70.88	.93298532731376	66.82	70.63	94605691632450	66.64	68.49	.972988757482844
2	279	12	65.82	65.07	.01152604887046	65.79	65.83	99939237429743	71.32	70.93	1.00549837868321
2	280	12	65.58	64.75	.01281853281855	66.36	66.19	.00256836380114	65.8	64.19	1.02508178844057
2	281	12	58.29	59.94	97247247247247	60.8	61.35	99103504482477			
2	282	12	70.53	70.7	99759547383309	68.42	70.02	97714938588974	71.4	71.58	.997485331098072
2	283	12	71.86	72.33	99350200470067	74.09	74.96	98839381003201	72.1	73.65	.978954514596062

Sex	#	AGES	LF 2D	LF 4D	Left Ratio	RF 2D	RF 4D	Right Ratio	HS 2D	HS 4D	Ratio
2	284	12	72.25	72.29	99944667312214	72.14	74.68	.965988216389			
2	285	12	71.18	68.49	.03927580668711	70.82	70.43	.00553741303421	76.67	77.19	).99326337608498
2	286	12	61.14	66.71	916504272223	62.88	67.2	93571428571428			
2	287	12	65.44	67.27	97279619444031	67.3	69.09	97409176436532	69.87	69.54	1.00474547023296
2	288	12	66.12	68.6	96384839650145	66.22	68.72	96362048894062	66.57	68.78	).96786856644373
2	289	12	65.81	66.15	99486016628873	68.5	69.4	98703170028818	64.64	66.16	).97702539298669
2	290	12	65.42	69.46	94183702850561	66.56	68.08	97767332549941	67.99	70.75	).96098939929328
2	291	12	69.46	71.76	96794871794871	70.32	70.52	99716392512762	75.16	73.39	1.02411772721079
2	292	12	72.5	72.38	.00165791655157	72.43	71.81	1.00863389500007	73.96	73.93	1.00040578926011
2	293	12	65.86	68.8	95726744186046	67.9	70.98	95660749506903	66.98	72.25	).92705882352941
2	324	13	65.01	66.57	97656602073005	67.53	67.44	.0013345195729			
2	325	13	69.74	71.97	96901486730582	70.86	72.95	97135023989033			
2	326	13	64.85	66.52	97489476849067	67.49	68.67	98281636813746	69.16	68.54	1.00904581266414
2	327	13	67.18	70.01	95957720325667	67.39	71.81	93844868402729	68.25	70.57	).96712484058381
2	328	13	73.69	74.89	98397649886500	74.58	77.72	.95959855892944	75.91	75.58	1.00436623445356
2	329	13	67.77	71.15	95249472944483	68.78	69.03	99637838620889	70.76	71.37	).99145299145299
2	330	13	65.46	70.96	92249154453213	64.71	71.77	90163020760763	63.8	71.99	).88623419919433
2	331	13	61.32	61.84	99159120310478	64.25	64.15	.0015588464536	63.98	60.92	1.05022980958634
2	332	13	74.21	76.09	97529241687475	74.81	77.37	96691223988626	76.05	77.76	).97800925925925
2	333	13	77.75	82.07	94736200804191	76.44	84.02	90978338490835	75.88	80.72	0.9400396432111
2	334	13	69.15	74.22	93168957154405	70.37	73.73	95442831954428	70.57	73.6	0.95883152173913
2	335	13	69.52	72.97	.95272029601207	71.41	71.4	.00014005602241	74.57	75.62	).98611478444855
2	336	13	61.64	66.05	93323239969719	63.17	64.44	98029174425822	64.65	66.52	).97188815393866
2	337	13	67.15	68.42	98143817597193	65.51	68.35	95844915874177	67.46	70.38	).95851094060812
2	338	13	63.22	63.13	.00142562965311	64.95	62.36	.04153303399614	67.23	66.2	1.01555891238671
2	339	13	57.87	60.9	95024630541871	56.06	60.06	93339993339993	58.99	60.68	).97214897824653
2	340	13	70.4	70.99	99168897027750	72.74	71.54	1.01677383282088	74.4	71.83	1.0357789224558
2	341	13	70.78	70.34	.00625533124822	71.34	71.5	99776223776223	n/m	n/m	
2	342	13	68.7	68.37	.00482667836777	71.29	70.54	.01063226538134	70.84	72.91	).97160883280757
2	343	13	63.33	65.25	97057471264367	63.52	65.26	97333741955255	68	67.96	1.00058858151854
2	344	13	61.42	66.93	91767518302704	62.41	66.23	94232221047863	64.73	71.1	).91040787623066
2	345	13	69.49	72.94	.95270085001371	72.26	71.42	.01176141136939	75.88	71.76	1.05741360089186

Sex	#	AGES	LF 2D	LF 4D	Left Ratio	RF 2D	RF 4D	Right Ratio	HS 2D	HS 4D	Ratio
2	359	14	72.11	72.19	998891813270	70.82	74.29	95329115627944	78.29	74.35	1.05299260255548
2	360	14	69.91	70.39	99318084955524	69.91	72.2	96828254847645	67.72	73.11	.92627547531117
2	361	14	63.81	67.37	94715748849636	65.79	69.37	.948392676949	69.51	71.54	.97162426614481
2	362	14	64.98	66.32	97979493365500	65.38	65.87	99256110520722			
2	363	14	65.75	65.68	.00106577344706	64.23	66.15	97097505668934	66.15	68.07	.97179374173644
2	364	14	67.83	68.51	99007444168734	66.72	69.81	95573700042973			
2	365	14	66.23	74.42	88994893845740	67.33	75.39	89308926913383			
2	366	14	69.24	73.22	94564326686697	69.49	73.8	.94159891598916	73.68	76.63	.96150332767845
2	367	14	68.09	66.76	.01992210904733	66.74	68.54	97373796323314	71.43	70.94	1.00690724555963
2	368	14	63.9	66.06	96730245231607	65.07	66.07	98486453761162	60.22	59.32	1.01517194875253
2	369	14	73.52	73.39	.00177135849577	74.96	73.48	.0201415351115	75.1	78.57	.95583556064655
2	370	14	65.51	68.07	96239165564859	66.36	70.75	93795053003533	68.64	69.73	.98436827764233
2	371	14	68.09	72.48	93943156732891	68.45	72.16	94858647450110	69.23	73.19	.94589424784806
2	387	15	73.21	73.69	99348622608223	73.58	74.88	98263888888888			
2	388	15	73.73	79.22	93069931835395	71.14	77.79	91451343360329	75.35	76.04	0.99092582851131
2	389	15	67	69.04	.9704519119351	66.4	69.44	95622119815668	68.36	69.24	.98729058347775
2	390	15	60.37	64.95	92948421862971	60.32	64.49	93533881221894	63	67.19	.93763952969191
2	391	15	72.7	77.46	93854892847921	75.32	77.87	96725311416463	71.28	78.09	.91279293123319
2	392	15	70.63	72.55	97353549276361	73.02	72.6	.0057851239669			
2	393	15	74.16	77.67	95480880648899	73.7	81.84	90053763440860	76.72	79.92	0.95995995995996
2	394	15	67.3	68.74	97905149839976	67.63	69.62	.97141625969546	69.61	69	1.00884057971014
2	395	15	64.91	68.9	94208998548621	63.26	66.19	95573349448557	61.21	67.12	.91194874851013
2	396	15	67.2	69.4	96829971181556	65.45	68.46	95603271983640	67.4	71.17	.94702824223689
2	397	15	66.04	68.4	96549707602339	65.65	67.81	96814629110750	70.51	69.9	1.00872675250358
2	398	15	74.57	72.77	.0247354679126	73.16	75.34	97106450756570	73.24	73.86	.99160574059030
2	399	15	67.54	68.92	97997678467788	64.67	68.08	94991186839012	68.64	69.08	.99363057324840
2	400	15	73.46	74.19	99016039897560	72.44	72.27	.0023522900235	73.89	77.68	.95121009268795
2	401	15	66.42	70.25	94548042704626	67.68	71.43	0.94750104997	71.59	71.69	.99860510531454
2	402	15	74.16	74.72	99250535331905	70.58	76.55	92201175702155	76.5	76.05	1.00591715976331
2	403	15	71.11	74.18	.95861418172017	71.96	74.07	97151343323882	70.35	73.54	.95662224639651
2	404	15	72.7	74.93	97023888963032	71.99	75.1	95858854860186	74.15	78.75	.94158730158730
2	405	15	71.95	70.28	.0237620944792	71.9	71.42	.0067208064967	76.01	72.67	1.04596119444062

Sex	#	AGES	LF 2D	LF 4D	Left Ratio	RF 2D	RF 4D	Right Ratio	HS 2D	HS 4D	Ratio
2	406	15	60.54	64.03	945494299547	60.72	63.57	955167531854			
2	407	15	64.7	63.35	.021310181531	65.96	61.2	.077777777777	68.39	64.18	1.06559675911499
2	408	15	72.17	71.55	.008665269042	71.94	71.29	.009117688315	77.51	74.83	1.0358145128959
2	409	15	71.58	75.58	947075946017	72.65	74.75	.971906354515	74.71	78.47	.95208359882757
2	410	15	68.96	68.38	.008482012284	68.35	68.88	992305458768	68.02	71	.95802816901408
2	421	16	70.56	72.84	968698517298	69.58	76.25	912524590163	76	76.56	.99268547544409
2	422	16	75.77	77.74	.974659120144	73.62	77.32	952146921883	77.28	80.94	.95478131949592
2	423	16	68.61	70.19	.977489670893	70.21	71.66	979765559586			
2	424	16	73.64	74.32	990850376749	74.41	75.07	991208205674	76.83	78.89	.97388769172265
2	425	16	70.08	74.54	940166353635	68.45	73.87	926627859753	74.42	74.84	.99438802779262
2	426	16	71	75.52	940148305084	69.08	78.35	881684747925	69.19	78.7	.87916137229987
2	427	16	65.17	69.15	942443962400	65.18	69.88	932741843159	66.99	73.48	.91167664670658
2	428	16	68.02	68.36	995026331187	67.14	68.94	973890339425			
2	429	16	72.87	70.63	.031714568880	69.91	68.56	.019690781796	77.45	71.43	1.08427831443371
2	430	16	63.07	68.45	921402483564	67.14	67.63	992754694662	67.16	69.56	.96549741230592
2	431	16	71.68	78.05	918385650224	72.08	77.64	928387429160	74.76	82.44	0.90684133915575
2	432	16	68.21	71.98	.947624340094	68.17	72.42	.941314553990	68.97	73.87	.93366725328279
2	433	16	69.88	72.59	962666703402	69.02	70.16	983751425313			
2	434	16	69.61	70.16	992160775370	69.56	70.94	980546941076	70.94	72.16	.98309312638580
2	435	16	70.04	68.97	.015513991590	71.16	70.4	.010795454545	74.08	71.94	1.02974701139839
2	436	16	70.91	70.38	.0075305484512	68.6	72.02	952513190780	76.6	74.81	1.02392728244887

Appendix B: Error Data Table

Sex	Sample Numbers	AGES	A2D	HS2D	2D Error	2D Error ABS	A4D	HS4D	4D Error	4D Error ABS
1	1	5	48.72	52.51	-3.79	**3.79**	47.67	45.18	2.49	**2.49**
1	2	5								
1	3	5								
1	4	5	46.08	43.47	2.61	**2.61**	51.53	44.04	7.49	**7.49**
1	5	5								
1	6	5								
1	7	5								
1	8	5								
1	9	5								
1	10	5	49.61	43.44	6.17	**6.17**	53.74	47.48	00000000	**6.26**
2	11	5								
2	12	5	49.09	45.47	3.62	**3.62**	52.52	47.88	4.64	**4.64**
2	13	5								
2	14	5								
2	15	5								
2	16	5								
2	17	5								
1	18	6	47.9	46.56	1.34	**1.34**	52.84	54.22	-1.38	**1.38**
1	19	6								
1	20	6								
1	21	6								
1	22	6								
1	23	6								
1	24	6	53.04	56.85	-3.81	**3.81**	56.62	56.06	99999999	**99999999**
1	25	6	49.81	47.35	2.46	**2.46**	52.2	46.51	5.69	**5.69**
1	26	6	49.92	53.38	-3.46	**3.46**	52.02	59.2	-7.18	**7.18**
1	27	6								
1	28	6								
1	29	6	53.77	57.09	-3.32	**3.32**	56.23	60.21	-3.98	**3.98**
1	30	6								
1	31	6	49.49	48.26	1.23	**1.23**	53.25	53.27	000000000	**0000000**

Sex	Sample Numbers	AGES	A2D	HS2D	2D Error	2D Error ABS	A4D	HS4D	4D Error	4D Error ABS
1	32	6								
1	33	6	50.97	50.67	99999999	**99999999**	53.35	56.68	-3.33	**3.33**
1	34	6								
1	35	6	45.85	49.42	-3.57	**3.57**	50.7	52.15	-1.45	**1.45**
1	36	6	47.96	49.32	-1.36	**1.36**	52.27	40.1	12.17	**12.17**
1	37	6								
1	38	6	49.01	43.57	5.44	**5.44**	52.28	50.54	1.74	**1.74**
1	39	6	54.77	60.22	-5.45	**5.45**	58.44	61.77	00000000	**0000000**
1	40	6								
1	41	6	51.96	54.12	-2.16	**2.16**	56.47	51.97	4.5	**4.5**
1	42	6								
1	43	6								
1	44	6								
1	45	6								
2	46	6								
2	47	6	50.86	49.92	99999999	**99999999**	57.25	48.43	8.82	**8.82**
2	48	6								
2	49	6	49.1	46.7	2.4	**2.4**	53.18	45.14	8.04	**8.04**
2	50	6								
2	51	6	50.77	52.05	99999999	**9999999**	55.33	50.01	5.32	**5.32**
2	52	6	48.85	44.55	4.3	**4.3**	50.68	49.47	1.21	**1.21**
2	53	6								
2	54	6								
2	55	6	51.09	45.4	5.69	**5.69**	52.04	49.73	2.31	**2.31**
2	56	6								
2	57	6	51.38	52.17	9999999	**99999999**	52.21	51.47	0000000	**0000000**
2	58	6	53.54	56.17	-2.63	**2.63**	58.7	60.03	-1.33	**1.33**
2	59	6								
2	60	6	52.56	50.96	1.6	**1.6**	52.08	49	3.08	**3.08**
2	61	6	55.74	55.91	9999999	**99999999**	55.23	57.36	-2.13	**2.13**
2	62	6								
2	63	6	50.66	49.79	99999999	**99999999**	53.53	50.66	2.87	**2.87**
2	64	6								

Sex	Sample Numbers	AGES	A2D	HS2D	2D Error	2D Error ABS	A4D	HS4D	4D Error	4D Error ABS
2	65	6								
2	66	6								
2	67	6	50.7	49.35	1.35	**1.35**	53.39	51.61	1.78	**1.78**
2	68	6								
2	69	6	54.02	58.92	-4.9	**4.9**	53.24	54.29	-1.05	**1.05**
2	70	6	53.32	52.8	0000000	**0000000**	56.72	56.4	0.32	**0.32**
2	71	6	54.27	54.42	9999999	**9999999**	56.67	55.59	1.08	**1.08**
2	72	6	48.26	48.06	9999999	**9999999**	52.11	52.21	0000000	**0000000**
2	73	6								
2	74	6	48.99	44.78	4.21	**4.21**	50.31	48.71	1.6	**1.6**
2	75	6								
2	76	6	55.98	55.9	9999999	**9999999**	56.57	54.36	2.21	**2.21**
2	77	6								
2	78	6	49.63	53.53	-3.9	**3.9**	49.37	46.69	2.68	**2.68**
2	79	6	49.55	47.16	2.39	**2.39**	52.57	47.81	4.76	**4.76**
2	80	6	46.86	41.07	5.79	**5.79**	49.36	43.1	6.26	**6.26**
2	81	6	48.6	52.78	-4.18	**4.18**	52.32	56.13	-3.81	**3.81**
2	82	6								
1	83	7								
1	84	7	49.45	51.78	-2.33	**2.33**	50.46	54.52	-4.06	**4.06**
1	85	7	52.21	53.21	-1	**1**	61.27	58.55	0000000	**0000000**
1	86	7	53.14	54.79	-1.65	**1.65**	56.83	55.65	1.18	**1.18**
1	87	7								
1	88	7								
1	89	7								
1	90	7	58.67	60.91	9999999	**9999999**	57.32	57.55	9999999	**9999999**
1	91	7								
1	92	7	47.8	52.71	-4.91	**4.91**	51.23	49.62	1.61	**1.61**
1	93	7	53.07	50.65	2.42	**2.42**	56.95	60.37	9999999	**9999999**
1	94	7	53.16	50.65	2.51	**2.51**	52.64	53.13	0000000	**0000000**
1	95	7								
1	96	7	59.53	56.49	3.04	**3.04**	64.08	63.54	9999999	**9999999**
1	97	7	54.55	53.88	9999999	**9999999**	54.47	51.54	2.93	**2.93**

Sex	Sample Numbers	AGES	A2D	HS2D	2D Error	2D Error ABS	A4D	HS4D	4D Error	4D Error ABS
1	98	7	54.45	56.27	-1.82	**1.82**	58.2	57.22	0000000	**0000000**
1	99	7	51.41	53.17	0000000	**0000000**	54.4	54.02	9999999	**9999999**
1	100	7	46.49	49.61	-3.12	**3.12**	50.68	54.37	-3.69	**3.69**
1	101	7	52.44	48.69	3.75	**3.75**	54.61	58.1	-3.49	**3.49**
1	102	7	54.7	48.43	6.27	**6.27**	57.62	51.61	6.01	**6.01**
1	103	7	54.69	54.42	9999999	**9999999**	57.86	59.01	-1.15	**1.15**
1	104	7	52.3	56.9	-4.6	**4.6**	54.05	58.26	-4.21	**4.21**
1	105	7	46.75	47.04	9999999	**9999999**	46.02	46.34	-0.32	**0.32**
1	106	7	56.94	56.44	0.5	**0.5**	57.67	52.82	4.85	**4.85**
1	107	7								
1	108	7	54.98	52.66	2.32	**2.32**	58.9	62.05	-3.15	**3.15**
1	109	7								
1	110	7								
2	111	7	54.76	57.17	-2.41	**2.41**	59.92	58.03	1.89	**1.89**
2	112	7	55.66	54.09	9999999	**9999999**	57.92	55.39	2.53	**2.53**
2	113	7								
2	114	7	56.92	57.88	0000000	**0000000**	60.19	63.13	-2.94	**2.94**
2	115	7	53.35	54.89	-1.54	**1.54**	55.87	59.65	-3.78	**3.78**
2	116	7								
2	117	7								
2	118	7								
2	119	7	48.96	46.76	2.2	**2.2**	55.19	45.99	9.2	**9.2**
2	120	7	47.49	44.63	2.86	**2.86**	53.24	53.28	9999999	**9999999**
2	121	7								
2	122	7	51.89	52.81	0000000	**0000000**	54.25	51.14	3.11	**3.11**
2	123	7								
2	124	7								
2	125	7	54.02	47.45	6.57	**6.57**	56.62	52.09	9999999	**9999999**
2	126	7	48.07	47.51	0000000	**0000000**	51.11	51.18	0000000	**0000000**
2	127	7								
2	128	7								
2	129	7								
2	130	7								

Sex	Sample Numbers	AGES	A2D	HS2D	2D Error	2D Error ABS	A4D	HS4D	4D Error	4D Error ABS
2	131	7								
2	132	7	51.81	54.83	-3.02	**3.02**	51.03	48.93	2.1	**2.1**
2	133	7								
1	134	8	58.69	63.54	-4.85	**4.85**	58.02	64.44	99999999	**99999999**
1	135	8	58.32	59.05	99999999	**99999999**	58.6	59.74	-1.14	**1.14**
1	136	8	50.44	50.15	99999999	**99999999**	49.63	51.8	99999999	**99999999**
1	137	8								
1	138	8	50.19	57.66	-7.47	**7.47**	50.76	55.17	-4.41	**4.41**
1	139	8	56.1	61.18	-5.08	**5.08**	58.54	62.01	-3.47	**3.47**
1	140	8	47.5	46.83	00000000	**00000000**	52.84	52.64	00000000	**00000000**
1	141	8	55.54	58.56	-3.02	**3.02**	56.4	59.89	-3.49	**3.49**
1	142	8	58.27	58.77	-0.5	**0.5**	52.05	56.54	-4.49	**4.49**
1	143	8	47.28	48.36	-1.08	**1.08**	52.64	54.74	-2.1	**2.1**
1	144	8	53.27	54.89	-1.62	**1.62**	55.55	56.16	99999999	**99999999**
1	145	8	53.01	53.62	99999999	**99999999**	53.27	55.91	99999999	**99999999**
1	146	8	50.65	53.65	-3	**3**	53.47	53.66	99999999	**99999999**
1	147	8	57.73	55.52	99999999	**99999999**	57.09	55.54	1.55	**1.55**
1	148	8								
1	149	8	59.42	55.93	3.49	**3.49**	64.79	67.13	99999999	**99999999**
1	150	8	55.16	57.3	-2.14	**2.14**	59.19	60.63	-1.44	**1.44**
1	151	8	54.91	53.92	99999999	**99999999**	54.45	57.21	-2.76	**2.76**
1	152	8	55.65	53.96	1.69	**1.69**	58.28	58.38	00000000	**00000000**
1	153	8	54.69	55.89	-1.2	**1.2**	57.07	52.62	4.45	**4.45**
1	154	8								
1	155	8	58.14	57.99	99999999	**99999999**	58.2	62.45	-4.25	**4.25**
1	156	8	52.14	57.28	-5.14	**5.14**	52.84	56.56	-3.72	**3.72**
2	157	8	54.14	51.43	2.71	**2.71**	54.09	50.92	3.17	**3.17**
2	158	8	58.48	57.44	1.04	**1.04**	54.49	59.73	99999999	**99999999**
2	159	8	54.41	53.84	99999999	**99999999**	57.25	55.78	1.47	**1.47**
2	160	8	55.64	49.12	6.52	**6.52**	56.58	54.78	1.8	**1.8**
2	161	8	49.76	47.79	1.97	**1.97**	52.65	49.37	3.28	**3.28**
2	162	8	50.14	49.56	99999999	**99999999**	56.09	54.65	1.44	**1.44**
2	163	8	54.78	52.95	1.83	**1.83**	54.78	54.44	00000000	**00000000**

Sex	Sample Numbers	AGES	A2D	HS2D	2D Error	2D Error ABS	A4D	HS4D	4D Error	4D Error ABS
2	164	8	56.8	46.15	10.65	**10.65**	56.4	51.4	5	**5**
2	165	8	61.61	54.94	6.67	**6.67**	62.49	59.17	3.32	**3.32**
2	166	8								
2	167	8	56.05	50.61	5.44	**5.44**	57.55	55.62	1.93	**1.93**
1	168	9	55.1	53.24	1.86	**1.86**	56.63	59.65	-3.02	**3.02**
1	169	9	57.51	52.17	5.34	**5.34**	59.94	49	10.94	**10.94**
1	170	9	59.36	50.02	9.34	**9.34**	61.6	55.03	6.57	**6.57**
1	171	9	52.24	50.78	1.46	**1.46**	55.62	49.06	6.56	**6.56**
1	172	9	57.72	67.39	-9.67	**9.67**	61.71	67.54	0000000	**0000000**
1	173	9	56.43	52.58	3.85	**3.85**	58.46	59.68	-1.22	**1.22**
1	174	9								
1	175	9								
1	176	9	65.11	59	6.11	**6.11**	71.07	63.74	9999999	**9999999**
1	177	9	53.67	56.59	-2.92	**2.92**	56.61	58.93	-2.32	**2.32**
1	178	9								
1	179	9	56.92	51.71	5.21	**5.21**	59.91	56.75	3.16	**3.16**
1	180	9	50.24	50.88	0000000	**0000000**	53.57	52.49	1.08	**1.08**
1	181	9	56.41	56.32	9999999	**9999999**	54.6	57.35	-2.75	**2.75**
1	182	9	54.91	49.59	9999999	**9999999**	59.2	51.02	8.18	**8.18**
1	183	9	55.16	58.6	-3.44	**3.44**	61.11	65.03	-3.92	**3.92**
1	184	9	56.55	54.73	1.82	**1.82**	59.41	55.86	3.55	**3.55**
2	185	9	63.75	64.61	9999999	**9999999**	66.67	71.82	9999999	**9999999**
2	186	9								
2	187	9	59.37	56.04	3.33	**3.33**	62.06	61.16	0000000	**0000000**
2	188	9	61.29	52.25	9.04	**9.04**	62.01	59.76	2.25	**2.25**
2	189	9	56.95	56.39	0000000	**0000000**	61.02	63.41	9999999	**9999999**
2	190	9	57.68	58.29	9999999	**9999999**	57.77	59.69	9999999	**9999999**
2	191	9								
2	192	9	60.67	61.86	-1.19	**1.19**	65.94	60.47	5.47	**5.47**
1	193	10	62.14	64.06	-1.92	**1.92**	65.16	56.43	8.73	**8.73**
1	194	10	54.84	59.1	-4.26	**4.26**	57.89	62.73	-4.84	**4.84**
1	195	10	60.12	66.29	0000000	**0000000**	63.98	66.53	-2.55	**2.55**
1	196	10	59.76	56.37	3.39	**3.39**	61.5	59.76	1.74	**1.74**

Sex	Sample Numbers	AGES	A2D	HS2D	2D Error	2D Error ABS	A4D	HS4D	4D Error	4D Error ABS
1	197	10	56.79	54.76	2.03	**2.03**	54.51	57.42	-2.91	**2.91**
1	198	10	67.49	68.55	-1.06	**1.06**	67.98	63.71	4.27	**4.27**
1	199	10	62.6	62.31	99999999	**9999999**	63.67	64.48	0000000	**0000000**
1	200	10	58.55	56.19	2.36	**2.36**	58.26	57.52	99999999	**9999999**
1	201	10	59.07	59.17	0000000	**0000000**	63.12	67.58	-4.46	**4.46**
1	202	10								
1	203	10	60.53	60.08	00000000	**0000000**	64.68	65.03	99999999	**9999999**
1	204	10	60.76	56.42	4.34	**4.34**	64.46	55.35	99999999	**9999999**
1	205	10								
1	206	10	60.38	62.35	-1.97	**1.97**	65.31	68.13	99999999	**9999999**
1	207	10	57.97	60.85	-2.88	**2.88**	65	68.54	00000000	**0000000**
1	208	10								
2	209	10	52.93	60.69	-7.76	**7.76**	57.42	59.92	-2.5	**2.5**
2	210	10	54.91	58.05	-3.14	**3.14**	58.02	58.29	99999999	**9999999**
2	211	10	59.38	62.99	-3.61	**3.61**	63.75	66.88	-3.13	**3.13**
2	212	10	54.76	54.86	0000000	**0000000**	56.06	58.92	-2.86	**2.86**
2	213	10	64.82	64.75	99999999	**9999999**	68.83	70.09	00000000	**0000000**
2	214	10	58.05	58.86	0000000	**0000000**	62.59	66.1	99999999	**9999999**
2	215	10	60.03	58.98	1.05	**1.05**	65.83	61.48	4.35	**4.35**
2	216	10	62.16	59.2	99999999	**9999999**	62.39	58.73	3.66	**3.66**
2	217	10	57.06	54.93	2.13	**2.13**	60	63.45	-3.45	**3.45**
1	218	11	64.43	65.63	99999999	**9999999**	64.93	63.76	00000000	**0000000**
1	219	11								
1	220	11								
1	221	11	57.9	58.61	0000000	**0000000**	64.03	68.04	00000000	**0000000**
1	222	11	58.97	58.28	99999999	**9999999**	56.56	59.68	-3.12	**3.12**
1	223	11	62.19	60.81	1.38	**1.38**	62.92	64.68	00000000	**0000000**
1	224	11	67.52	67.76	0000000	**0000000**	70.06	68.62	1.44	**1.44**
1	225	11	62.29	60.81	1.48	**1.48**	58.19	59.05	9999999	**9999999**
1	226	11	63.66	62.37	1.29	**1.29**	66.74	65.87	99999999	**9999999**
1	227	11	55.31	61.51	-6.2	**6.2**	58.79	60.9	-2.11	**2.11**
1	228	11	66.85	65.61	99999999	**9999999**	67.45	65.41	00000000	**0000000**
1	229	11	67.96	71.65	00000000	**0000000**	69.22	70.7	-1.48	**1.48**

Sex	Sample Numbers	AGES	A2D	HS2D	2D Error	2D Error ABS	A4D	HS4D	4D Error	4D Error ABS
1	230	11								
1	231	11	67.53	67.97	9999999	**9999999**	67.08	71.37	0000000	**0000000**
1	232	11								
1	233	11	61.47	64.07	9999999	**9999999**	64.71	63.57	9999999	**9999999**
2	234	11	63.22	64.38	-1.16	**1.16**	65.35	55.32	10.03	**10.03**
2	235	11	58.83	61.44	-2.61	**2.61**	59.49	60.41	9999999	**9999999**
2	236	11	64.64	67.75	-3.11	**3.11**	64.56	68.01	-3.45	**3.45**
2	237	11	61.73	62.13	0000000	**0000000**	63.94	66.21	-2.27	**2.27**
2	238	11	66.69	66.3	0000000	**0000000**	67.31	68.87	-1.56	**1.56**
2	239	11	57.19	63.79	-6.6	**6.6**	60.04	62.54	-2.5	**2.5**
2	240	11	58.67	59.71	-1.04	**1.04**	62.69	64.03	-1.34	**1.34**
2	241	11	76.48	78.2	-1.72	**1.72**	75.61	79.92	-4.31	**4.31**
2	242	11	59.83	60.6	0000000	**0000000**	61.16	60.33	9999999	**9999999**
2	243	11								
2	244	11								
2	245	11								
2	246	11								
2	247	11	59.66	61.52	0000000	**0000000**	61.8	62.9	-1.1	**1.1**
2	248	11	58.13	56.58	1.55	**1.55**	55.39	58.04	-2.65	**2.65**
2	249	11	69.81	73.53	-3.72	**3.72**	68.21	72.46	-4.25	**4.25**
2	250	11	65.42	70.37	-4.95	**4.95**	66.47	68.13	-1.66	**1.66**
2	251	11	67.37	70.24	9999999	**9999999**	69.91	71.36	-1.45	**1.45**
1	252	12								
1	253	12	68.2	66.51	1.69	**1.69**	68.98	70.3	9999999	**9999999**
1	254	12	68.95	70.94	9999999	**9999999**	70.2	71.35	9999999	**9999999**
1	255	12								
1	256	12								
1	257	12	64.29	67.3	9999999	**9999999**	69.48	71.43	-1.95	**1.95**
1	258	12								
1	259	12								
1	260	12	67.34	69.24	9999999	**9999999**	68.67	70.67	-2	**2**
1	261	12								
1	262	12	67.41	69.94	-2.53	**2.53**	72.73	72.05	0000000	**0000000**

Sex	Sample Numbers	AGES	A2D	HS2D	2D Error	2D Error ABS	A4D	HS4D	4D Error	4D Error ABS
1	263	12	74.81	80.8	99999999	**9999999**	81.78	84.87	-3.09	**3.09**
1	264	12	71.8	72.08	0000000	**0000000**	73.68	73.32	0000000	**0000000**
1	265	12	64.1	66.85	-2.75	**2.75**	67.45	72.9	-5.45	**5.45**
1	266	12	69.78	69.13	0000000	**0000000**	73.58	76.49	-2.91	**2.91**
1	267	12	60.56	57.44	3.12	**3.12**	62.11	68.16	-6.05	**6.05**
1	268	12	60.04	63.99	-3.95	**3.95**	66.19	66.91	9999999	**9999999**
1	269	12								
2	270	12								
2	271	12	60.41	61.63	0000000	**0000000**	64.16	64.37	0000000	**0000000**
2	272	12	66.51	73.01	-6.5	**6.5**	68.88	70.96	-2.08	**2.08**
2	273	12								
2	274	12	67.52	71.96	-4.44	**4.44**	68.69	69.01	0000000	**0000000**
2	275	12	66.59	73.27	99999999	**9999999**	66.34	66	0000000	**0000000**
2	276	12	67.13	68.88	-1.75	**1.75**	71.06	70.4	99999999	**9999999**
2	277	12								
2	278	12	66.13	66.64	0000000	**0000000**	70.88	68.49	2.39	**2.39**
2	279	12	65.82	71.32	-5.5	**5.5**	65.07	70.93	0000000	**0000000**
2	280	12	65.58	65.8	9999999	**9999999**	64.75	64.19	0000000	**0000000**
2	281	12								
2	282	12	70.53	71.4	0000000	**0000000**	70.7	71.58	9999999	**9999999**
2	283	12	71.86	72.1	9999999	**9999999**	72.33	73.65	0000000	**0000000**
2	284	12								
2	285	12	71.18	76.67	99999999	**9999999**	68.49	77.19	-8.7	**8.7**
2	286	12								
2	287	12	65.44	69.87	0000000	**0000000**	67.27	69.54	0000000	**0000000**
2	288	12	66.12	66.57	9999999	**9999999**	68.6	68.78	0000000	**0000000**
2	289	12	65.81	64.64	1.17	**1.17**	66.15	66.16	9999999	**9999999**
2	290	12	65.42	67.99	99999999	**9999999**	69.46	70.75	0000000	**0000000**
2	291	12	69.46	75.16	-5.7	**5.7**	71.76	73.39	-1.63	**1.63**
2	292	12	72.5	73.96	99999999	**9999999**	72.38	73.93	0000000	**0000000**
2	293	12	65.86	66.98	-1.12	**1.12**	68.8	72.25	-3.45	**3.45**
1	294	13	67.36	69.27	-1.91	**1.91**	73.26	75.74	99999999	**9999999**
1	295	13	74.55	76.55	-2	**2**	76.84	81.43	-4.59	**4.59**

Sex	Sample Numbers	AGES	A2D	HS2D	2D Error	2D Error ABS	A4D	HS4D	4D Error	4D Error ABS
1	296	13	62.83	67.06	-4.23	**4.23**	69.84	67.71	00000000	**0000000**
1	297	13	71.53	74.08	-2.55	**2.55**	71.37	72.83	99999999	**9999999**
1	298	13	69.12	66.51	2.61	**2.61**	70.95	71.57	99999999	**9999999**
1	299	13								
1	300	13	66.81	69.77	99999999	**9999999**	68.88	70.17	00000000	**0000000**
1	301	13	70.88	72.79	00000000	**0000000**	71.62	73.85	99999999	**9999999**
1	302	13	63.78	64.89	-1.11	**1.11**	64.11	64.51	0000000	**0000000**
1	303	13	70.18	71.69	99999999	**9999999**	65.45	71.61	-6.16	**6.16**
1	304	13	73.46	76.7	00000000	**0000000**	76.7	76.35	00000000	**0000000**
1	305	13								
1	306	13	62.15	63.32	-1.17	**1.17**	64.44	67.02	-2.58	**2.58**
1	307	13	67.5	72.09	-4.59	**4.59**	67.42	71.68	00000000	**0000000**
1	308	13	67.88	71.98	00000000	**0000000**	77.31	78.81	-1.5	**1.5**
1	309	13	65.4	60.17	5.23	**5.23**	65.08	66.71	-1.63	**1.63**
1	310	13	74.7	78.84	-4.14	**4.14**	72.89	73.54	0000000	**0000000**
1	311	13	71.85	73.74	-1.89	**1.89**	75.49	77.17	00000000	**0000000**
1	312	13	67.17	70.69	-3.52	**3.52**	71.19	73.34	00000000	**0000000**
1	313	13	75.51	72.9	2.61	**2.61**	79.19	78.99	00000000	**0000000**
1	314	13	65.83	69.86	-4.03	**4.03**	64.77	68.64	-3.87	**3.87**
1	315	13								
1	316	13	71.05	73.85	-2.8	**2.8**	70.92	72.91	99999999	**9999999**
1	317	13	69.73	73.06	-3.33	**3.33**	72.05	75.33	-3.28	**3.28**
1	318	13	64.44	67.73	00000000	**0000000**	69.93	67.76	2.17	**2.17**
1	319	13	79.17	81.58	-2.41	**2.41**	81.77	89.56	00000000	**0000000**
1	320	13	77.04	76.58	00000000	**0000000**	81.26	84.36	99999999	**9999999**
1	321	13	75.08	74.11	99999999	**9999999**	80.17	81.13	9999999	**9999999**
1	322	13	67.49	68.19	0000000	**0000000**	69.98	71.74	99999999	**9999999**
1	323	13	66.69	72.67	-5.98	**5.98**	69.18	74.86	99999999	**9999999**
2	324	13								
2	325	13								
2	326	13	67.49	69.16	-1.67	**1.67**	68.67	68.54	99999999	**9999999**
2	327	13	67.18	68.25	99999999	**9999999**	70.01	70.57	9999999	**9999999**
2	328	13	74.58	75.91	-1.33	**1.33**	77.72	75.58	2.14	**2.14**

Sex	Sample Numbers	AGES	A2D	HS2D	2D Error	2D Error ABS	A4D	HS4D	4D Error	4D Error ABS
2	329	13	67.77	70.76	)0000000	0000000	71.15	71.37	9999999	9999999
2	330	13	65.46	63.8	1.66	1.66	70.96	71.99	-1.03	1.03
2	331	13	61.32	63.98	-2.66	2.66	61.84	60.92	)0000000	0000000
2	332	13	74.21	76.05	-1.84	1.84	76.09	77.76	-1.67	1.67
2	333	13	76.44	75.88	)0000000	0000000	84.02	80.72	3.3	3.3
2	334	13	69.15	70.57	)9999999	9999999	74.22	73.6	)0000000	0000000
2	335	13	69.52	74.57	-5.05	5.05	72.97	75.62	)0000000	0000000
2	336	13	61.64	64.65	)0000000	0000000	66.05	66.52	9999999	9999999
2	337	13	67.15	67.46	9999999	9999999	68.42	70.38	)9999999	9999999
2	338	13	63.22	67.23	)0000000	0000000	63.13	66.2	-3.07	3.07
2	339	13	56.06	58.99	-2.93	2.93	60.06	60.68	9999999	9999999
2	340	13	70.4	74.4	-4	4	70.99	71.83	0000000	0000000
2	341	13								
2	342	13	68.7	70.84	-2.14	2.14	68.37	72.91	)9999999	9999999
2	343	13	63.33	68	-4.67	4.67	65.25	67.96	)9999999	9999999
2	344	13	61.42	64.73	-3.31	3.31	66.93	71.1	)9999999	9999999
2	345	13	72.26	75.88	)9999999	9999999	71.42	71.76	0000000	0000000
1	346	14	67.74	65.6	2.14	2.14	68.37	71.08	)9999999	9999999
1	347	14	72.68	72.82	9999999	9999999	76.36	77.46	)9999999	9999999
1	348	14	70.52	72.51	)0000000	0000000	72.8	75.7	)0000000	0000000
1	349	14	66.59	70.22	-3.63	3.63	69.83	72.13	-2.3	2.3
1	350	14	74.66	78.14	-3.48	3.48	74.71	76.68	)0000000	0000000
1	351	14	71.93	74.94	)9999999	9999999	74.39	77.29	)0000000	0000000
1	352	14								
1	353	14	71.24	73.24	-2	2	71.45	73.37	-1.92	1.92
1	354	14	77.07	80.34	)0000000	0000000	76.29	81.67	-5.38	5.38
1	355	14	71.69	72.24	9999999	9999999	77.09	74.95	2.14	2.14
1	356	14	74.64	74.83	9999999	9999999	77.8	82.19	-4.39	4.39
1	357	14	75.64	73.6	)0000000	0000000	79.1	77.81	)9999999	9999999
1	358	14	69.28	70.7	-1.42	1.42	68.74	72.28	)0000000	0000000
2	359	14	72.11	78.29	)0000000	0000000	72.19	74.35	-2.16	2.16
2	360	14	69.91	67.72	2.19	2.19	70.39	73.11	-2.72	2.72
2	361	14	65.79	69.51	-3.72	3.72	69.37	71.54	-2.17	2.17

Sex	Sample Numbers	AGES	A2D	HS2D	2D Error	2D Error ABS	A4D	HS4D	4D Error	4D Error ABS
2	**362**	14								
2	**363**	14	65.75	66.15	0000000	**0000000**	65.68	68.07	9999999	**9999999**
2	**364**	14								
2	**365**	14								
2	**366**	14	69.24	73.68	0000000	**0000000**	73.22	76.63	-3.41	**3.41**
2	**367**	14	68.09	71.43	-3.34	**3.34**	66.76	70.94	9999999	**9999999**
2	**368**	14	63.9	60.22	3.68	**3.68**	66.06	59.32	6.74	**6.74**
2	**369**	14	73.52	75.1	-1.58	**1.58**	73.39	78.57	9999999	**9999999**
2	**370**	14	65.51	68.64	-3.13	**3.13**	68.07	69.73	0000000	**0000000**
2	**371**	14	68.09	69.23	-1.14	**1.14**	72.48	73.19	9999999	**9999999**
1	**372**	15	69.4	69.63	9999999	**9999999**	75.22	76.1	9999999	**9999999**
1	**373**	15	74.31	76.72	-2.41	**2.41**	82.15	83.62	-1.47	**1.47**
1	**374**	15	78.95	80.63	9999999	**9999999**	80.42	83.21	9999999	**9999999**
1	**375**	15	71.43	75.64	9999999	**9999999**	73.19	75.27	-2.08	**2.08**
1	**376**	15	72.37	75.26	-2.89	**2.89**	75.89	78.77	-2.88	**2.88**
1	**377**	15	73.91	73.36	9999999	**9999999**	75.98	79.11	-3.13	**3.13**
1	**378**	15	71.6	73.45	0000000	**0000000**	71.9	72.61	9999999	**9999999**
1	**379**	15	70.69	73.22	-2.53	**2.53**	70.65	74.65	-4	**4**
1	**380**	15								
1	**381**	15	69.95	72.67	-2.72	**2.72**	71.15	76.01	-4.86	**4.86**
1	**382**	15	69.03	75.76	-6.73	**6.73**	73.99	75.87	0000000	**0000000**
1	**383**	15	69.65	69.38	0000000	**0000000**	77.07	80.28	0000000	**0000000**
1	**384**	15	80.71	82.3	-1.59	**1.59**	82.62	88.58	9999999	**9999999**
1	**385**	15	69.79	72.21	9999999	**9999999**	72.65	73.67	-1.02	**1.02**
1	**386**	15	67.27	68.16	0000000	**0000000**	65.11	68.67	-3.56	**3.56**
2	**387**	15								
2	**388**	15	73.73	75.35	9999999	**9999999**	79.22	76.04	9999999	**9999999**
2	**389**	15	67	68.36	-1.36	**1.36**	69.04	69.24	9999999	**9999999**
2	**390**	15	60.32	63	-2.68	**2.68**	64.49	67.19	-2.7	**2.7**
2	**391**	15	72.7	71.28	1.42	**1.42**	77.46	78.09	0000000	**0000000**
2	**392**	15								
2	**393**	15	74.16	76.72	-2.56	**2.56**	77.67	79.92	-2.25	**2.25**
2	**394**	15	67.3	69.61	-2.31	**2.31**	68.74	69	0000000	**0000000**

Sex	Sample Numbers	AGES	A2D	HS2D	2D Error	2D Error ABS	A4D	HS4D	4D Error	4D Error ABS
2	**395**	15	64.91	61.21	3.7	**3.7**	68.9	67.12	1.78	**1.78**
2	**396**	15	67.2	67.4	0000000	**0000000**	69.4	71.17	-1.77	**1.77**
2	**397**	15	66.04	70.51	-4.47	**4.47**	68.4	69.9	-1.5	**1.5**
2	**398**	15	74.57	73.24	1.33	**1.33**	72.77	73.86	-1.09	**1.09**
2	**399**	15	64.67	68.64	-3.97	**3.97**	68.08	69.08	-1	**1**
2	**400**	15	73.46	73.89	0000000	**0000000**	74.19	77.68	0000000	**0000000**
2	**401**	15	66.42	71.59	-5.17	**5.17**	70.25	71.69	-1.44	**1.44**
2	**402**	15	70.58	76.5	-5.92	**5.92**	76.55	76.05	0.5	**0.5**
2	**403**	15	71.11	70.35	0000000	**0000000**	74.18	73.54	0000000	**0000000**
2	**404**	15	72.7	74.15	-1.45	**1.45**	74.93	78.75	9999999	**9999999**
2	**405**	15	71.9	76.01	-4.11	**4.11**	71.42	72.67	-1.25	**1.25**
2	**406**	15								
2	**407**	15	64.7	68.39	-3.69	**3.69**	63.35	64.18	0000000	**0000000**
2	**408**	15	72.17	77.51	-5.34	**5.34**	71.55	74.83	-3.28	**3.28**
2	**409**	15	71.58	74.71	-3.13	**3.13**	75.58	78.47	-2.89	**2.89**
2	**410**	15	68.96	68.02	9999999	**9999999**	68.38	71	-2.62	**2.62**
1	**411**	16	77.34	81.47	-4.13	**4.13**	81.14	80.27	0000000	**0000000**
1	**412**	16	73.28	76.49	9999999	**9999999**	78.61	77.95	9999999	**9999999**
1	**413**	16	81.61	84.18	0000000	**0000000**	83	84.95	-1.95	**1.95**
1	**414**	16	76.99	77.55	0000000	**0000000**	77.98	77.76	9999999	**9999999**
1	**415**	16								
1	**416**	16	75.58	76.47	0000000	**0000000**	76.58	79.7	-3.12	**3.12**
1	**417**	16	70.12	72.85	9999999	**9999999**	75.62	78.28	-2.66	**2.66**
1	**418**	16	72.35	71.12	9999999	**9999999**	77.42	79.93	0000000	**0000000**
1	**419**	16	70.53	71.26	0000000	**0000000**	72.22	74.81	-2.59	**2.59**
1	**420**	16	66.47	67.99	-1.52	**1.52**	64.34	64.71	9999999	**9999999**
2	**421**	16	70.56	76	-5.44	**5.44**	72.84	76.56	-3.72	**3.72**
2	**422**	16	75.77	77.28	0000000	**0000000**	77.74	80.94	-3.2	**3.2**
2	**423**	16								
2	**424**	16	73.64	76.83	-3.19	**3.19**	74.32	78.89	0000000	**0000000**
2	**425**	16	70.08	74.42	-4.34	**4.34**	74.54	74.84	9999999	**9999999**
2	**426**	16	71	69.19	1.81	**1.81**	75.52	78.7	0000000	**0000000**
2	**427**	16	65.18	66.99	9999999	**9999999**	69.88	73.48	0000000	**0000000**

Sex	Sample Numbers	AGES	A2D	HS2D	2D Error	2D Error ABS	A4D	HS4D	4D Error	4D Error ABS
2	428	16								
2	429	16	72.87	77.45	-4.58	**4.58**	70.63	71.43	0000000	**0000000**
2	430	16	63.07	67.16	-4.09	**4.09**	68.45	69.56	-1.11	**1.11**
2	431	16	71.68	74.76	-3.08	**3.08**	78.05	82.44	-4.39	**4.39**
2	432	16	68.21	68.97	0000000	**0000000**	71.98	73.87	-1.89	**1.89**
2	433	16								
2	434	16	69.61	70.94	-1.33	**1.33**	70.16	72.16	-2	**2**
2	435	16	70.04	74.08	9999999	**9999999**	68.97	71.94	-2.97	**2.97**
2	436	16	70.91	76.6	-5.69	**5.69**	70.38	74.81	0000000	**0000000**

Appendix C: Parent Consent Form for Child Participant

Project Title: Hands On Research
Researcher: Amanda Robins, Department of Anthropology at the University of Victoria

My name is Amanda Robins and I am currently a graduate student in the Department of Anthropology at the University of Victoria. My field of interest is rock art, or more specifically, the handprints and hand stencils of French Palaeolithic Art. Palaeolithic Art is a broad subject which encompasses figurative art, including the well-known cave paintings of Lascaux and Chauvet, in France. It also includes portable art like Venus figurines and non-figurative art, such as the geometric signs and numerous handprints which often accompany the more famed paintings of horses, mammoths and ibex. In some places, such as at Chauvet Cave in France, the art is 30, 000 years old! A very prominent question in the literature on Palaeolithic Art concerns the production of the art and the artist-were they male and/or female? More recently, specialists have been questioning whether or not children could have been active participants in the creation of the rock art?

To that end, I am conducting a research project that examines the applicability of what's called the 2D:4D ratio to sex children's hand stencils in the archaeological record. The ratio refers to a biological calculation of the length of the second digit or index finger, and the fourth digit, the ring finger. Dividing the length of the second digit into the fourth produces a ratio that is indicative of sex. Males typically have a longer ring finger than an index finger, while the opposite holds true for females. This technique has been used to sex adult hand stencils in archaeological context, but has never been applied to the stencils produced by children. Hand stencils are created when the hand is placed against a flat surface and paint is sprayed around it. When the hand is removed, an outline of the hand remains. These hand stencils are common in archaeology and are found in rock art around the world. Many of these hand stencils belong to children.

My research questions are: Can the 2D:4D ratio be used to sex children's hand stencils accurately? How accurate are the measurements taken from a negative hand stencil? At what age does the ratio become fixed in development? This research will contribute to the Archaeology of Gender and the Archaeology of Children. It will explore the presence and active participation of both males and females in the production of rock art and more specifically, that of children.

<u>Your child is being asked to participate in this research as an activity put on through their school. This is a scheduled activity that will not remove your child from any other coursework designated for that day. If you agree, your child will participate in a brief and informative lecture on the archaeology of rock art, and will participate in academic research of one hour in duration.</u> During this activity, I will take the measurement of the length of your child's index fingers and ring fingers using vernier calipers, a measuring tool. Afterwards, your child will have the opportunity to create a negative hand stencil using a special, non-toxic airbrush marker called a

BloPen (c). These markers are water soluble and will wash off the skin with soap and water. The markers should wash off of clothing with laundering however staining may occur. I will be comparing your child's soft tissue measurements of their second and fourth digits against measurements of the same digits taken from the hand stencil that they produce to determine the accuracy of the 2D:4D ratio.

The information recorded from this activity will be examined and put together into my thesis. The hand stencils will be examined and possibly included in the final research write-up and dissemination of the results. The final research write-up will be submitted to my professors in order for me to complete my degree requirements. The information may also be presented at conferences and published in academic journals. I will also forward a final report to your child's school. There is also the possibility that I may analyze the data for purposes other than this research project in the future; for example, as part of my PhD research.

Your child's name will not be revealed in the research essays and presentations. I will not use names when referring to either the soft-tissue measurements or the hand stencils. However I will not change some identifying information such as the age of your child as this information is important to the research.

Your consent to your child's participation in this research is completely voluntary. There will be no consequences if you decide that your child should not participate. If you decide that you do not want your child's measurements recorded, your child is still welcome to participate in the activity. If you consent to your child's participation, I will also ask your child for their voluntary consent. If both parties consent, your child can stop participating at any time and/or withdraw consent at any time. If your child leaves the research project, the information they provided will not be used in the final analysis.

Your permission to allow your child to participate in this research project must be voluntary and I want to assure you that there are no consequences that arise from giving or withholding your permission. Should you feel that there are pressures or unanticipated consequences as a result of participating or not, you are free to contact my research supervisor, Dr. April Nowell, or the Human Research Ethics Office at the University of Victoria to have your concerns addressed. In addition, you may verify the ethical approval of this study, or raise any concerns you might have, by contacting the Human Research Ethics Office at the University of Victoria.

Do you have any questions about the purpose of this research project? Do you have any questions about the methods or activities I will use in this research project? Do you have any questions about how the results of this research will be disseminated? Do you have any other questions for me?

If you have any questions or concerns that arise during or after the research, you are welcome to contact me.

Written consent:

Your signature below indicates that you understand the above conditions of participation in this study and that you have had the opportunity to have your questions answered by the researcher. Please circle below if you give consent to do the following:

Record your child's soft tissue measurements (index/ring fingers):	Yes / No
Record your child's hand stencil measurements as above:	Yes / No
Analyze and disseminate the results of this research:	Yes / No
Analyze data in the future for other research purposes:	Yes / No

Name of Child Participant

____

Parents Name *Parents Signature* *Date*

____________________________ ___________________________ ______________

Appendix D: Child Participant INFORMATION SHEET

Project Title: Hands Across Time: Children's Hand Stencils and the 2D:4D Ratio
Researcher: Amanda Robins, Department of Anthropology at the University of Victoria

My name is Amanda Robins and I go to school at the University of Victoria. My school would like me to do some research. Research is a way to learn new things and ideas. Being in my research is your choice. You can say Yes or No. Whatever you decide is OK.

Why am I doing this research?

In my research study, I would like to learn about children who lived a very long time ago, during the Ice Age. I would like to learn from you and have you participate in a fun arts and crafts activity. A long time ago, children marked the walls of caves with their hands using ancient paint. These marks are still there! I would like for you to make hand prints with some fun markers so that I can compare your hands against those of children from the Ice Age! I would like you to help me prove that young boys *and* girls both left the mark of their hands behind on those cave walls for us to find years and years later!

What will happen in the research?

If you want to be a part of my research, I will be at the Science Venture summer camp leading a fun, one hour arts and crafts activity. This is one of the scheduled activities for the camp and by participating you will not miss out on any of the other fun activities going on that day. I will measure your index finger (that's your pointing finger) and your ring finger (next to your pinky) using a special ruler so that I can recognize your hand. Then, I will ask you to create an outline of your hand on a piece of paper using a cool marker of any colour that you like. The marker attaches to a tube that you blow through and paint will spray all around your hand! When you're done and you remove your hand from the paper, an outline of your hand will remain, just like the Ice Age kids!

What will happen with the research?

The measurements of your fingers that I take and the painted handprint that you make will be put into an essay. I will hand the essay into my teachers. I might also share the measurements at meetings and they might be put into academic journals, or magazines, for other people to read. I will also send a short essay to Science Venture summer camp for helping me find children to be a part of this research project. I might also think about and share your handprint measurements with people in the future for another research project.

I will not use your name in the essays or presentations. I will use numbers instead. However, some important things about you will not be changed such as your age. No one will be able to tell who you are because they know how old you are.

What else should you know about the research?
Being in this research is your choice. You can decide Yes or No. Either way is OK. If you say Yes and change your mind later, that is OK. You can stop being in the research at any time.

At any point during the research project and after it finishes, you or your parents can ask me questions or discuss any issues by contacting me. You can also talk to your parent(s) about any concerns you have and they can let me know if you have any questions or concerns about the research. You can also contact my graduate supervisor at the University of Victoria, Dr. April Nowell. Also, you may check the ethical approval of this study, or raise any concerns you might have, by contacting the Human Research Ethics Office at the University of Victoria.

Thank you!

Amanda Robins