# The glue that binds us together

## A cognitive comparison of anatomically modern humans and Neandertals through Palaeolithic adhesive making

Miriam Amé Hiltemann

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# Chapter 1. Introduction

## *1.1 Background and research questions*

The workings of the human mind as well as the evolution of mankind itself are areas that remain greatly unexplored. As a psychologist and an archaeologist, they are both of great interest to me. The combination of these two fields of research in the fairly recent practice of cognitive archaeology might not seem very logical however. What can a study focusing on living subjects and their neurological and behavioural actions and responses contribute to one focusing on the remains of people living thousands of years ago? The obvious second question is of course *why* we would want to go into this line of research. Can cognitive research truly contribute to the archaeological field of study, and is it worth studying? Because of this seemingly weak link, the importance of cognitive research, and its relevance to the archaeological field need to be underlined before moving on to further research and results that are based on the interaction between these two disciplines.

Archaeology in itself is limited by several interpretative constraints. Problems of preservation and discontinuity play a major role in the interpretation of archaeological data. Despite being limited by these constraints, its interests are broad, and include the reconstruction of not just past human behaviour, but society as a whole and all its influencing factors, including the cognitive processes underlying behaviour. When looking at the evolution of mankind, it is not only our physical and cultural qualities that are part of this evolution, but also our cognitive capabilities. Archaeology is not capable of dealing with these matters on its own however. Archaeological data might be able to provide a time line and background to the evolution of our cognitive capacities, but it cannot explain the reasons behind the behavioural changes seen in the record or the questions they raise concerning their bases in changes in cognitive and neural characteristics. These can only be answered through the incorporation of modern cognition studies. Archaeology has thus through necessity become more interdisciplinary throughout the years, incorporating psychological and neurological research and theory into its repertoire in the process. This had led to the introduction of cognitive archaeology.

Through the incorporation of these cognitive sciences, the field of cognitive archaeology tries to reconstruct the nature of the prehistoric mind, in an attempt to explain the behaviour reflected by the material remains in the archaeological record.

The application of this cognitive research to archaeology has led to further problems however. The models and theories of cognitive science were not made with archaeology in mind, nor were archaeological models made with cognition in mind. Because of this separation, most of these theories are not especially well suited to the other respective field, and their application often does not live up to the standards of both fields.

Regardless of these problems, there have been several attempts within archaeology to comment on the evolution of human cognition. In order to do so within archaeology, we must necessarily look at the material remains of past human behaviour, and try to link this behaviour to aspects of cognition. Because much of the research is focused on finding out when humans evolved the cognitive skillset we posses today, this has led to the discussion of which behaviours are and which are not representative of modern day cognition.

Within this discussion, terms such as “modern” and “complex” behaviour and cognition are often used, in order to distinguish between behavioural and cognitive capabilities on a level with that of modern day people, and earlier forms of behaviour and cognition that do not meet this level. The problem with these terms is that there is no agreed upon definition of their exact meaning. They are used in several different forms and with several different meanings throughout the archaeological field. By some for instance, “modern” behaviour has been related to behaviours specifically tied to the emergence of anatomically modern humans (AMH) (Mellars 2005; Bickerton 2007). Others classify it as a range of traits which appear in the behaviour of AMH as the result of a neurological change after having shared a previous behavioural repertoire with earlier hominins (Chase 2003; Klein 2008). Still others view it as the distinguishing characteristic that sets AMH apart from other species, searching for that which makes us human, by many researchers often tied to symbolic behaviour (Noble & Davidson 1991, 1996; Stringer & Gamble 1993; Wadley 2001; Henshilwood & Marean 2003; Marean et al. 2007; Soffer 2009).

The same is true for the term “modern cognition”. There is no agreed upon set of constructs which constitute “modern”cognition. The term is often used to imply different cognitive constructs that are thought to reflect hallmark aspects of current cognitive sophistication, such as syntactical language, symbol-use, enhanced working memory, or multiple intelligences (Nowell 2010).

A further point of confusion is that the term “modern behaviour” is not always used in connection with cognition. Not all researchers are of the opinion that the changes in behaviour seen through the archaeological record reflect changes in cognition. Some believe rather that these changes reflect social, demographic, historical, or cultural factors (Nowell 2010). Chase (2006) argues for instance that symbolic behaviour was present in humans long before it became detectable, and only became visible in the archaeological record after it started to influence social behaviour.

As the purpose of this thesis is to evaluate certain aspects of cognition however, I will be focusing on cognitive explanations of behaviour. I will be using the term “sophisticated” cognition, to indicate aspects of cognition which are thought to represent modern-day cognitive capabilities. The term “modern” will be used only to describe other authors' opinion on the subject of behavioural and cognitive modernity, as used by them.

Despite all these issues, several theories have been put forth by different authors on how, when and where modern humans developed the cognitive capacities they possess today (McBrearty and Brooks 2000; d'Errico 2003; Bar-Josef 2003; Klein and Edgar 2002; Wynn and Coolidge 2009). Some have argued for a relatively sudden onset of modern behaviour and cognition around 50.000 years ago (Bar-Yosef 2003; Klein and Edgar 2002; Wynn and Coolidge 2009), while others have posited that this was the result of a much more gradual development, with characteristics of cognitive sophistication having been assembled over a period of over 200.000 years over several different continents (McBrearty and Brooks 2000). Still others have suggested a parallel and gradual development of aspects of cognition in different regions throughout the world, by different groups of hominins (d'Errico 2003).

While these theories consider the timing and placement of human cognitive and behavioural evolution, they generally do not explicitly mention what these cognitive changes precisely entail. There have been some theories in which this has been attempted. These can be generally divided into three main categories. The first focuses on symbolism and language (*e.g.* Henshilwood 2004). The second focuses on Theory of Mind, the ability to attribute mental states such as beliefs, intents and desires to oneself and to others (*e.g.* Barnard 2010). The third focuses on modularity; the division of the mind into closed-off, domain specific modules; and working memory, a cognitive construct that is responsible for holding information in active memory for further processing (*e.g.* Mithen 1996; Wynn and Coolidge 2009). Especially the symbolic approach has been very popular within cognitive archaeology. Research into this field has unfortunately not always taken the modern views of cognitive science into account, and has often failed to be specific about the cognitive abilities under discussion, or whether these abilities are recognized by cognitive science (Wynn and Coolidge 2009).

Studies incorporating more recent lines of cognitive theory, have gradually moved away from this symbolic approach, and have underlined the importance of probabilistic (non-symbolic) reasoning and information processing as one of the underlying factors in cognitive sophistication (Doya *et al.* 2007; Chater and Oaksford 2009; Clark 2008). This suggests that we should be more rigorous in carrying out cognitive archaeology and consider non-symbolic explanations along with the other theories that have been put forth.

So far, all the theories that have been mentioned have focused on the cognitive development of anatomically modern humans (AMH). Very few attempts have been made to accurately determine cognition for other hominin species throughout history, whose cognitive abilities are often viewed as simply “not human”, and therefore less impressive or less interesting. The focus on anatomically modern humans is not completely surprising, as much of what drives cognition research is the interest in how our particular cognition developed throughout time, and the ability to possibly help answer current cognitive questions.

Nonetheless, research into the cognition of different hominin species could still provide important information. Wynn and Coolidge (2009) have argued that aspects of cognitive capacities evolved in different stages throughout evolution. They  point out that as some of these aspects are shared with other primates, in order to understand human cognition we cannot look at *Homo sapien* cognition alone. Determining similarities and differences between primates and modern humans for instance can help answer questions of when certain aspects of cognition may have developed. Research into this area can also aid in explaining the extinction and survival of groups of hominins, by looking for evidence of cognitive abilities that would have aided or limited their survival. It can also be helpful in determining questions of relatedness with other species, alongside evidence from fossil morphology and DNA.

All these issues are relevant to our own evolution. Of course from an archaeological perspective, it has equally as much value in itself, without necessarily informing us about anatomically modern humans. By looking at the evolution of cognition of hominins in general, it can provide valuable information regarding all sorts of questions concerning the archaeological record, and why specific traces are found or lacking in it.

Specifically research into Neandertal cognition, being our closest relative in time, could provide great insight into our evolutionary history. There have been a few attempts made at determining the cognitive sophistication of Neanderthals (*e.g.* Wynn and Coolidge 2004; Mithen 1996). These have been mostly based on interpretations of Neanderthal behaviour as seen through the archeological remains.

For a long time before the arrival of AMH, from around 200 to 30 ka (Wynn and Coolidge 2011) Neandertals ruled throughout Europe, adapting to the constantly changing climatic conditions. Studies have shown Neandertals to have adapted to these changing circumstances very well, allowing them to dominate in Europe for thousands of years. Neandertals have often been left behind in the discussions concerning technological, behavioural and cognitive capabilities though. While often thought to be less advanced and less capable than AMH, research has shown them to probably have employed a range of behaviours listed by different authors as aspects of “modernity”. These behaviours include range expansion, similar resource exploitation, planning behaviour, adaptation to numerous and diverse ecosystems, symbolic behaviour, and language (Deacon 1997; McBrearty and Brooks 2000; Adler *et al*. 2006; Tattersall 2009).

Evidence for range expansion for instance comes from recent research (Krause *et al.* 2007) showing Neandertals to have expanded their range even further than previously thought. Evidence has been found of their presence at the sites of Teshik Tash, Uzbekistan; where the remains of a human child were found to carry Neandertal mtDNA; and Okladnikov cave, Siberia; where the remains of an adult and sub-adult individual were found to have belonged to a population related to European and Western Asian Neandertals (*ibid*.). This evidence shows Neandertals to have traveled some 2000 kilometers further east than previously thought, and to clearly have been capable of adapting to differing climatic circumstances(*ibid*.)

Indications of long-term planning come from evidence of hunting behaviours that are very similar to that of AMH, with the two being equally skilled at exploiting a range of different ecological zones (Adler *et al.* 2006).

Evidence from sites such as the Grotte du Renne, Caune de Belvis, Saint-C´esaire and Quinçay also indicate Neandertal production of ornaments and bone tools, seen through the presence of re-fittings and by-products (d'Errico 1998; d'Errico and Zilhao 1999; Zilhao 2007). Though this is disputed by certain authors (Higham *et al.* 2010), claiming intrusion of symbolic artefacts from overlying Protoaurignacian layers, other authors (Caron *et al.* 2011) deny this statement, arguing for stratigraphic integrity. If stratigraphic integrity is indeed maintained, this could indicate the use of symbolism by Neandertals, on which as we have seen many indications of cognitive complexity for AMH have been based (Deacon 1996, 1997; McBrearty and Brooks 2000; Henshilwood 2004; Tattersall 2009)

Analysis of Neanderthal anatomy indicates that they were also probably capable of speech, though the precise level of speech is not known (Wynn and Coolidge 2011). Evidence from fossil endocasts of Neandertal skulls, indicating an expanded Broca's area (a region in the brain used to control speech production) supports this idea (*ibid*.)

Having occupied the same area for several thousand years in the Upper and possibly Middle Palaeolithic, recent DNA research has further shown interbreeding to have taken place between Neandertals and anatomically modern humans (Green *et al*..

2010). This has raised questions of phylogenetic relatedness of our two species.

These behaviours are all very similar to those seen in AMH, but have not led to similar inferences on their possible cognitive capabilities. If such areas of cultural, technological and subsistence overlap between Neandertals and modern humans indeed existed, and there were enough physical and genetic similarities to allow for successful interbreeding, the possibility of there having been cognitive similarities as well is not so far-fetched. Even though the link between Neandertals and specific cognitive capabilities might be difficult to make, it seems that it has remained disproportionately unresearched.

The link between modern humans and their cognitive evolution is clearly a fragile one. However, the evidence that has been accepted as implying sophisticated cognitive capabilities for AMH should be applied to the Neandertal record with equal validity if similar evidence is found. Most research seems to rather easily set aside the possibility of Neandertal cognitive sophistication to work on AMH cognition, often assuming it to be less complex than our own and possibly not worth much effort. This is of course very much in line with, and possibly influenced by, the general and popular view of Neandertals being merely simple cavemen, of not especially high intelligence.

This corresponds to Roebroeks and Corbey's (2001) suggestion of a double standard being used when it comes to interpretations of archaeological evidence from the Upper Palaeolithic period and AMH, and the Middle and Lower Palaeolithic periods and earlier hominin species. This double standard is illustrated by the authors through an example concerning the interpretation of evidence for purposeful burial by Neandertals. While the criteria set up for intentional burial (Gargett 1988) are applied very strictly to the Neandertal context, leaving the record with no remaining intentional burials by Neandertals, these criteria are applied much more loosely to the Upper Palaeolithic period for AMH burials. The authors note that should these criteria be equally strictly applied to the Upper Palaeolithic period, most (22 out of 28) of these so-called burials would also not live up to the proposed standards (Villa 1989) of intentional burial. This illustrates the tendency of many researchers to view evidence of Neandertal behaviour in a different light than that of AMH, leading to obvious biases in interpretation.

This thesis will attempt to address the issues of unequal research and double standards in this area through a specific case study. The aim of this thesis will be to compare specific findings from the Neandertal record with similar findings from the AMH record that have been used to imply cognitive sophistication for AMH. This comparison will then be used to comment on Neandertal cognition. Through a comparison of a generally well-accepted source of evidence for AMH cognitive sophistication at Sibudu Cave, South Africa (Wadley *et al.* 2010), and several sources from the European Neandertal record (Koller *et al.* 2001, Pawlik and Thissen 2011 ), I will attempt to comment on the level of cognitive sophistication of the Neandertal mind. I will use the evidence from Sibudu Cave, South Africa (Wadley *et al.* 2010) as a starting point for this comparison. This research shows modern humans to have manufactured a compound adhesive used to attach stone points to shafts to create spears. These adhesives date to around 70 ka (*ibid*.). Through a very well documented replication of the adhesive production process, it has been argued that creating this adhesive required several cognitive skills equally advanced as those modern humans possess today, namely enhanced working memory (Wynn and Coolidge 2009), fourth-order abstraction (Barnard 2010), multi-level operations and non-routine thought (Amati and Shallice 2007), mental rotation (Kane 2004), embedded recursion (Reuland 2010), and cognitive fluidity (Mithen 1996).

My reasons for using this specific research are twofold. The first is that the cognitive implications that are made are based on technical procedures and knowledge rather than indications of symbolism. Where the weight and meaning of symbolic behaviour has been greatly disputed in archaeological as well as cognitive interpretations, this is less so for tool manufacture. The second reason is that similar examples of adhesive production can be found in the European record associated with Neandertals (Koller *et al.* 2001; Mazza *et al.* 2006; Pawlik and Thissen 2011), thus allowing for an optimum comparison between the two species.

Specifically, I will focus on two German sites. First, the site of Königsaue, where adhesives have been found to date to approximately 80 ka (Koller *et al*. 2001), and have been clearly linked to the Neandertals. Second, the equally well-documented site of Inden-Altdorf, also linked to Neandertals (Pawlik and Thissen 2011). These adhesives have been described by many however as merely “simple” adhesives (Wadley *et al.* 2009), that do not involve much effort to create, and certainly do not imply any advanced cognitive abilities. They have therefore not been linked to any cognitive theories, nor have any attempts been made to draw any conclusions as to the cognitive capabilities of Neandertals from them.

Though an analysis of the cognitive implications made by Wadley for the adhesive production at Sibudu Cave has already been made (Wynn 2009), in order to accurately compare this case with examples from the Neandertal record, a more in-depth analysis is required as a basis for a cognitive comparison.

*1.2 Methods and data*

The main research question for this thesis will be whether it is possible to comment on Neandertal cognition through the study of AMH and Neandertal adhesive production. This research question will be divided into several  subquestions. The first question will be whether the inferences on AMH cognition, based on the evidence for adhesive production are convincing and well-founded. The second will be whether the adhesive production processes of AMH and Neandertals under review are can be reliably compared. The third question will be whether the cognitive capacities that have been linked to AMH, and found to be valid, can be linked to Neandertals as well. The fourth and final question will be whether alternative cognitive explanations can be found to account for the adhesive production of Neandertals and AMH other than the constructs of cognitive sophistication that have been suggested.

These questions will be investigated by looking at the adhesive production process for AMH at Sibudu Cave as well as the accompanying cognitive inferences, which will be evaluated with respect to their validity. The production process of the two German Neandertal sites will then be inspected and compared to that of Sibudu Cave, and possible cognitive implications based on this process will be considered.

A number of researchers have developed criteria for the what constitutes a valid argument in cognitive archaeology (Botha 2008; Wynn and Coolidge 2009). Two of these sets of criteria will provide a framework for the thesis and will be discussed in more detail below. The two sets of guidelines that will be used for this evaluation will be Botha's (2008) concepts of groundedness and warantedness, and Wynn and Coolidge's (2009) strict standard. These two guidelines can be used simultaneously because they have similar requirements. Wynn and Coolidge's strict standard (2009), made up of the criteria of archaeological and cognitive validity, correspond broadly to Botha's (2008) requirements of groundedness and warantedness, respectively. These criteria will be applied by looking at the archaeological data, assessing whether the methods that were used are in line with current archaeological approaches for this type of evidence, and evaluating the cognitive/psychological evidence for the inferred constructs and relating this to cognitive validity.

The data for this study will consist of published material on Palaeolithic adhesives from Sibudu Cave, South Africa (Wadley 2010); Königsaue, Germany (Koller *et al*. 2001), and Inden-Altdorf (Pawlik and Thissen 2011), also in Germany. In addition, I will use literature on experimental and cognitive studies (Wynn and Coolidge 2009,Barnard 2010, Amati and Shallice 2007; Kane 2004; Haidle 2010; Reuland 2010, and Mithen 1996) which are used as a basis for evaluating the cognitive inferences of the adhesive production process at Sibudu Cave.

I have chosen the site of Sibudu Cave because it is a generally well-accepted source of evidence for modern human cognitive sophistication, for which a very elaborate description is available of the production process of the adhesive created there by early humans. The elaborate nature of the description of the production process, including detailed accounts of the production sequence, chemical investigations, use-wear studies, and microscopic analysis, will allow for a thorough analysis of the production process itself as well as the interpretations of cognition based on that process.

The two German sites have been selected because they represent well-documented evidence of Neandertal adhesive production, including detailed accounts of use wear, mircoscopic analyses, and chemical investigations. The similar industry and clear stratigraphy of these sites make for a good match, while the dating of these sites at around 80 (Koller *et al.* 2001) and 120 ka (Pawlik and Thissen 2011), for Königsaue and Inden-Altdorf respectively, places them clearly within the Neandertal period. The relative closeness in age of these samples compared to those at Sibudu Cave (~70 ka) (Wadley 2010) also makes for a good comparison. I have chosen to use two sites for this analysis because it will provide a larger sample and thereby a better foundation for my conclusions of Neandertal cognition being comparable in certain aspects to that of anatomically modern humans.

### *1.3 Chapter outline*

Following the introduction, the second chapter will underline  the importance of cognitive research in archaeology. Beginning with a detailed description of the problems one encounters when applying cognitive theory to the archaeological setting, and possible ways to circumvent these, this will be followed by a more elaborate description of the cognitive theories that have been applied to the archaeological setting within the field of cognitive archaeology. I will analyse their strong and weak points, and discuss the more recent influences coming from the field of cognitive science regarding these theories, as well as  the manner in which they might be applied to the archaeological setting. Wynn and Coolidge's (2009) strict standard, and Botha's (2008) criteria of groundedness and warantedness will be discussed as guidelines for the structuring of a valid argument in cognitive archaeology, which will then be applied to the following chapters.

This overview will aid in my analysis of the models used by Wadley (2010) for Sibudu Cave, help me to critique them, and suggest possible alternative models that could be applied to the evidence for adhesive production

Chapter 3 will entail a description and analysis of the production process of the hafting material used at Sibudu Cave as described by Wadley in her 2010 article (Lombard 2005, 2006; Delagne *et al*. 2006; Shae 2006). This will involve several steps. The first step will be to analyse the evidence for hafting given by Wadley. In order to reach the criteria for archaeological validity according to Wynn and Coolidge (2009) and Botha (2008), the inference of hafting has to be shown to be grounded in archaeological evidence before any conclusions can be drawn based on that evidence. This evidence will be gathered through the reproduction experiments performed and described by Wadley, an analysis of the compound adhesive ingredients and manufacture, and evidence from use-wear studies, residue analyses, and microscopic analysis, which have provided identifying markers to indicate hafting (Rots 2002). This information will come from Wadley's current analysis as well as from earlier work (Lombard 2005, 2006; Delagne *et al*. 2006; Shae 2006; Wadley 2006). This analysis will be used to summarize the key procedures and knowledge shown in the production process.

This will be followed by an analysis of the cognitive inferences made by Wadley in the article. The link between the procedures and knowledge that are used, and the cognitive abilities that are inferred from them, will be analysed. In order to do this, I will evaluate the cognitive models on which Wadley bases her claims for cognitive sophistication, and comment on their relevance, strong and weak points, and their validity and acceptance within the field of cognitive science. The inferences themselves will be critiqued on their archaeological and cognitive validity according to Wynn and Coolidge's strict standard (Wynn and Coolidge 2009), as well as Botha's arguments for groundedness and warantedness (Botha 2008).

On the basis of this analysis a guideline will be set up for the knowledge and procedures required for these cognitive inferences. In order for these inferences on cognition to live up to the criteria for archaeological validity, they must be clearly indicated in the archaeological record. For cognitive validity, the procedures and skills must be shown to be necessary for the production process, and have support from cognitive science. These guidelines will then be connected to the actual procedures and/or skills described in the production process. This guideline will then be employed in the next chapter in order to comment on the cognitive sophistication of Neandertals, and to see which inferences might be made with regard to the local adhesive production process.

I will then attempt to link the procedures and knowledge argued by Wadley to be required for the adhesive production to possible alternative cognitive explanations. The information for this section will come from my review of cognitive archaeology in the previous section as well as other literature from the field of cognitive science and cognitive archaeology. This will be done in an attempt to see if there are other cognitive explanations possible that might be responsible for the adhesive production other than the ones proposed by Wadley. If simpler explanations can be provided, a good case can be made that these would have been responsible for the production process, rather than the more advanced ones (Wynn and Coolidge 2009).

Chapter 4 will entail an analysis of the two German sites. This will again involve the description and analysis of the hafting procedure at the sites of Königsaue, and Inden-Altdorf, Germany, based on residue analysis, use-wear studies and microscopic analysis (Koller *et al*. 2001; Pawlik and Thissen 2011). The same careful evaluation will be applied to these sites as was applied to Sibudu Cave in the previous chapter. The validity of the claim of adhesive and tool production will be looked into first, again with respect to its archaeological validity (Wynn and Coolidge 2009), and Botha's (2008) requirement of groundedness. A description will be given of the possible adhesive manufacturing process at the sites, along with an evaluation of the ingredients and techniques that are used in this sequence.

As there have been no former attempts to link the production sequences at these sites to cognition for Neandertals, this will be the goal of the following section. Careful evaluation of the production process will determine precisely which actions and/or skills were required to produce the adhesives at these sites. I will then determine which cognitive inferences might be made based on these actions that can satisfy the criteria for cognitive validity (Wynn and Coolidge 2009) and warantedness (Botha 2008). I will further attempt to find  possible alternative cognitive explanations that might be applied to the Neandertal context, once again drawing from my earlier analysis and other sources of cognitive science.

Chapter 5 will conclude and discuss the findings of this thesis, the effectiveness of the methods that were employed, the implications that these findings may have put forth for broader issues in human origin research, and possibilities for further research.

## Chapter 2. Approaches to cognitive research in archaeology: a critical review

### *2.1 Chapter introduction*

The goal of this thesis is to compare AMH and Neandertal cognitive abilities involved in adhesive making. In order to do this, I must first give an overview of the different models and theories used in cognitive archaeology to make this kind of comparison. In order to gain a better understanding of the intellectual background of this field, and where its research has brought us so far, this chapter will serve to outline the different approaches that are used, their successfulness and current standing within cognitive science, and their usefulness for this thesis. It will outline the difficulties in such cognitive applications to archaeology and provide guidelines for overcoming these difficulties. This will aid me in my analysis of Wadley's research by identifying the cognitive background of the inferences made by her, and help me to evaluate them more accurately. It will also help me identify alternative approaches that might be applicable to Wadley's research.

Before the main theories are explained more fully, it is necessary to acknowledge some of the main problems in applying cognitive research to the archaeological field, and the ways in which we might overcome these problems. There have been a few researchers who have set up guidelines for carrying out sound cognitive archaeology (Botha 2008; Wynn and Coolidge 2009). These will be discussed currently.

### *2.2 Problems and ways forward*

One of the main problems in cognitive archaeology is that cognitive models are created for application to living subjects. Archaeology unfortunately does not have any living subjects to work with, making the application of cognitive models that much more difficult. All archaeologists can do is make inferences about past actions from the remains found in the record. The record unfortunately does not give a continuous overview of all past actions, but merely shows the effects of some of those actions. Because of the nature of archaeology, often working through excavation, this means that results unfortunately cannot be replicated as in laboratory circumstances. A lot of material can only be analysed a limited amount of times, and it is impossible to go back and document items in their original state again once they've been removed. Everything needs to be documented correctly the first time, or risk biasing all future interpretations based on that documentation.

A second problem is that of preservation. Material remains that are found are necessarily biased, as some materials survive more than others in the archaeological record, and many do not survive at all. This is why stone tools are by far the largest group of artifacts found in the record. Some environments, such as very dry or cold areas, preserve material much better than for instance tropical areas (Wynn 2002), causing a definite skew in the apparent location of finds. One area can appear to be a highly favoured location for past hominin visitation, due to its high find density, whereas another produces no finds at all. These areas might be labeled as unfavourable, when in reality the difference is merely due to different levels of preservation. Colder areas might seem more behaviourally diverse than warmer ones for instance, because more material has survived there. Age is another influencing factor, for the further back in time we go, the less we find, giving a misleadingly progressive appearance to the record (Wynn 2002). This will tend to make more recent behaviour seem more varied, and lead to the interpretation of increasingly complex cognition, when this is not necessarily the case.

Wynn, having studied these issues intensely for quite some time (Wynn 1979;1985;1991;2002; 2010) has boiled these problems and biases in the record down to two concrete questions concerning cognitive implications that are based on this record. The first question is “if traces of actions can reliably inform us about aspects of cognition”(Wynn 2002, 389). The second is “if archaeologists can overcome the methodological problems accompanying these issues” (Wynn 2002, 389).

Looking at the first question, Wynn immediately notes that psychologists also make inferences from traces of actions (Wynn 2002). Psychologists however have the advantage of being able to talk to their subjects. Is it possible then, to make inferences on cognition without the subject in question being there to study? According to Wynn, it might be, but the links to cognition that are made need to be that much stronger. If there should be any doubt, or possible alternative explanations, there is no test subject to fall back on to strengthen your theoretical arguments. Archaeologists need to provide highly reliable evidence of the cognitive meaning of archaeological finds. This is of course not very easy, partly due to the fact that cognitive models were not created with the archaeological setting in mind, nor archaeological models with cognition in mind. Looking at archaeological approaches for instance, the technocultural taxonomy used in archaeological classifications is an organizational system that was defined based purely on tool types and manufacturing techniques, and did not have cognition in mind when it was created (Wynn and Coolidge 2009). These periodizations can affect interpretations of behaviour and cognition (Roebroeks and Corbey 2001).

Wynn and Coolidge have argued that many researchers have approached cognitive archaeology the wrong way around. They start with archaeological remains, and try to build a cognitive argument from there, when instead they should be starting with a behaviour linked to an aspect of modern cognition, and try to identify archaeological indications of this behaviour (Wynn and Coolidge 2009).

In order to make sure cognitive implications based on archaeology are indeed reliable, Wynn and Coolidge have developed what they have called a “strict standard” for cognitive archaeology (Wynn and Coolidge 2009). This strict standard is made up of two main components: cognitive validity and archaeological validity. Cognitive validity requires that the cognitive ability that is argued is not only recognized by cognitive science, but is also necessary for the behaviour stated, and that this behaviour must be required for the archaeological traces implying this behaviour. Archaeological validity holds that the archaeological evidence in itself must be credible, and based on accepted scientific archaeological methods (*ibid.*).

In this strict standard, they argue that for a cognitive archaeological argument to be persuasive and to have cognitive validity, it needs to adhere to three methodological requirements. The first requirement listed by Wynn and Coolidge states that “it is necessary that the archaeologist understand the cognitive ability in question” (Wynn and Coolidge 2009, 118). They argue that without adequate background knowledge of modern cognition and its defining features, one cannot properly argue about modern cognition. The second requirement is that “the archaeologist must identify specific actions or sets of actions that are enabled by the ability in question”(*ibid.*, 118). Because the archaeological record consists of traces of actions, not traces of cognition, the link between the two must be explicit. The third and final argument states that “the archaeologist must then define a set of criteria (attributes), by which these actions can be reliably identified in the archaeological record”(*ibid.*,118). It is through adherence to this type of framework that archaeologists will be capable of making reliable cognitive inferences from traces of actions.

This brings us to the second question, whether archaeologists are able to overcome the methodological difficulties accompanying the inherent problems in archaeology. Wynn (2002) proposes that in order to overcome the obstacles of an incomplete record, and preservation and age biases, cognitive archaeologists should look from a more psychological perspective, instead of a purely archaeological one, and avoid using standard archaeological classifications of time periods and cultural complexes to comment on cognition. Rather than trying to define differences in cognition for certain industries or complexes, they should work from a more evolutionary scale, focusing on long-term patterns of change instead of specific changes in technology or cultural complexes (*ibid.*).

Another model insuring the validity of cognitive arguments in archaeology has been proposed by Botha (2008), in his critique of an archaeological argument for the use of syntactical language by people from Blombos Cave some 77.000 years ago. This argument, proposed by d'Errico (2003) discusses shell beads that were recovered by d’Errico and Henshilwood at Blombos cave in South Africa, dating to about 77 ka. These shell beads have been interpreted by them as evidence that the people who produced them had “fully syntactical language” (Henshilwood *et al.* 2004, 404). The line of reasoning for this argument is that the shells, which are perforated in a manner that is not naturally occurring, are similar in colour and form, and which show a use-wear pattern that is argued to be consistent with the shells rubbing against clothes, represent beads (*ibid.*). Beads are in turn seen as personal ornaments, and are thereby argued to be symbols (*ibid.*). In order to transmit the symbolic meaning of these beads, the authors have argued that fully syntactical language would have been required *(ibid.*).

Botha has argued however that the underlying arguments for this line of reasoning are not sound. He introduces the two concepts of groundedness and warantedness, which he applies to the arguments at hand. The first concept, that of groundedness, states that "inferences about (language) evolution need to be grounded in data or empirical assumptions about properties of phenomena that are well-understood" (Botha 2008, 200), in other words, they must have some evidential basis in order for them to be valid. The second concept, that of warantedness, states that "the inferential steps leading to conclusions about what (language) evolution involved need to be suitably warranted or licensed" (*ibid.* 200). In other words, there should be a good argument explaining how these different phenomena are connected, and how the inferential step can be made from one domain to another, also known as "bridge theory" (Botha 2003).

According to Botha however, the inferences involved in the case of the shell beads at Blombos cave lack suitable grounding and warranting on several levels (Botha 2008). He argues that in order for there to be evidence of fully syntactical language, there are several assumptions that are made which need to be better supported by evidence. For instance, what is the evidence that these beads are in fact symbols or representations at all, and if so why did the people who made them require a fully syntactical language to do so? Why couldn't they have had a less evolved language and still have made these beads, or have no language at all and still have used symbols (Botha 2008, 206-207)? The steps taken in the argument to link beads to language are made clear by use of a schematic overview (fig 1). According to Botha, some of the bridging arguments (steps D and F) lack suitable grounding and warranting to connect the inferences made through them; such as the beads representing symbols (C to E) or the symbols requiring syntactical language (E to G); to be considered scientifically valid.

For the "bead window" for instance, Henshillwood and colleagues argue that the beads are in fact symbols. They use definitions of the meaning of symbols to support there arguments. These state that "symbols are objects that have a meaning" (Botha 2008, 203), "The meaning of symbols is assigned by arbitrary social conventions, tacit agreements, or explicit codes" (*ibid.*, 203), and "Symbols make possible the storage and display of information external to the human brain” (*ibid*., 203). Botha argues however, that for their argument to be valid they need to provide evidence of these symbol properties. The specific meaning these beads had to the Blombos Cave inhabitants would need to be specified, the social conventions, agreements or codes on which the meaning of these symbols was based would need to be provided, and the information that was stored through these beads would need to be given, all of which they fail to do. This leaves the inference of beads being symbols ungrounded.

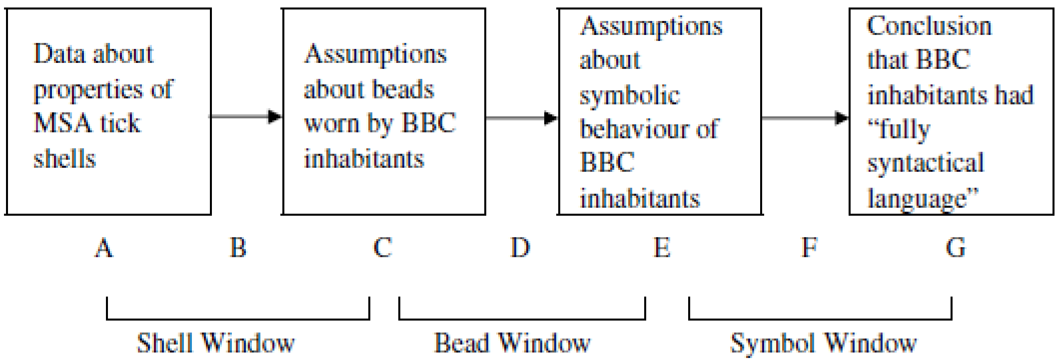


**Figure 1** Schematic overview of Henshilwood and d'Errico's argument (Botha 2008)

Both Wynn and Coolidge's strict standard and Botha's theory of groundedness and warantedness show the need for strong arguments and supporting evidence when making inferences on cognition. I believe that it is only through the application of such strict measures that we can make a truly sound cognitive argument in archaeology. I will therefore use these strict measures in my own analysis of the adhesive production process at Sibudu Cave, along with up to date and well-supported cognitive scientific theories, and apply them to the cognitive inferences that are made based on this production process. Archaeological validity will be assessed through an examination of the evidence given to support the inferences. These will be evaluated on whether they are up to date with current archaeological methods used to make these inferences. Cognitive validity will be assessed through several ways. An evaluating will be made of Wadley's understanding of the cognitive constructs she uses, based on their description and context use. The cognitive support for the constructs that are used will be analysed based on references on the coming background review. Lastly, the necessity of the cognitive construct for the related behaviour will be analysed. This will provide a framework for my analysis of the Sibudu Cave adhesive manufacture.

### *2.3 When did sophisticated cognition evolve?*

Despite all these problems, the question of how and when sophisticated human cognition evolved has been of interest to many researchers, and several attempts have been made to describe and trace human cognitive evolution throughout the past. These attempts have been based mainly on lists of traits seen in the archaeological record, originally those distinguishing Middle Palaeolithic (MP) and Upper Palaeolithic (UP) records in Europe. Some authors relate these traits to the appearance of certain types of behaviour (e.g. McBrearty and Brooks 2000). These behaviours are then used by some to imply changes in human cognition (*e.g.* McBrearty and Brooks 2000; Wynn and Coolidge 2009). The discussion in this area has gone mainly between people favouring a gradual evolution of “modern” behaviour and early cognitive change (McBrearty and Brooks 2000), and those that favour a more sudden and later onset (Bar-Josef 2003; Klein and Edgar 2002; Wynn and Coolidge 2009).

Those in favour of a more revolutionary type of change argue that the transition from the Middle to the Upper palaeolithic reflects such a change in specific behaviour and material types, that is is likely that this was also the transition to sophisticated cognition as we know it today. Bar-Josef (2003) for example, has taken the side of the “human revolution”, claiming that many of the distinctly modern traits seen in the Upper Palaeolithic, such as standardization and variability in tool types, the exploitation of certain raw materials for ritual purposes, the use of body decorations and long distance exchange networks, were not present in the same way in the late Middle Palaeolithic. According to these researchers (Bar-Josef 2003; Klein and Edgar 2002; Wynn and Coolidge 2009), the changes in the Upper Palaeolithic occurred at a much more rapid pace than those seen in the Middle Palaeolithic, and therefore indicate a revolutionary change.

Others have argued for a more gradual change in behaviour and cognition

(McBrearty and Brooks 2000). According to them these former “revolutionary” findings are based on an incomplete record, as there is much less evidence from parts of Asia and Africa than from the European record, giving a clear bias to the sample. McBrearty and Brooks argue instead that this “revolution” was not a revolution at all, but a gradual change over time. According to them, many of the traits that some would describe as not occurring until the Upper Palaeolithic, such as specialized hunting strategies (McBrearty and Brooks 2000, 510) can actually be seen in parts of Africa much earlier than they are seen in Europe. They suggest that this set of behaviours did not occur suddenly, but was assembled over a period of 200 ka (McBrearty and Brooks 2000, 458) in Africa, and only later dispersed to neighbouring regions such as Europe. It is their belief that Africa has been dismissed as the source of complex behaviour because researchers have focused on trying to find a “human revolution” similar to the one supposedly seen in Europe during the transition from the late Middle palaeolithic to the Upper palaeolithic. According to McBrearty and Brooks this transition has been unjustly equated with the African transitional period between the Middle Stone Age and the Late Stone Age, when the two should not be so compared. The lack of such a revolution in Africa has been interpreted as lack of evidence for these changes, when according to the authors this is merely because the changes were much more gradual.

Finds from Blombos cave in South Africa are used to support these claims of earlier “modern” behaviour in Africa. Two ochre fragments found at the site bear similarly engraved geometric patterns (Henshilwood *et al.* 2002), dated to around 77 ka, and according to d’Errico and colleagues suggest ritual use (d'Errico 2003). Recent evidence has shown a number of other MSA sites to also possess stone and ochre items with engraved pattern, supporting this claim (Henshilwood and Dubreuil 2011). McBrearty and Brooks make the valid argument that if this type of artifact is seen as evidence for “modern” behaviour in Europe, then the same interpretation must be made regarding the African finds. This would give the African record the earlier evidence of “modern” behaviour and cognition, as the dating on these fragments far precedes any found in European context.

Another theory supported by several researchers (d'Errico 2003, Conard 2007) is the parallel and gradual development of cognition in different regions throughout the world. They suggest that different groups of hominins may have reacted in a similar way to comparable ecological conditions or pressures (d'Errico 2003). Through the course of this thesis, I will analyse if cognitive inferences made for *Homo sapien* cognition can also be applied to Neandertal cognition, assessing whether, for these constructs, cognitive development was similar.

The arguments that have been discussed so far have focused on the chronology and geographical origin of “modern” human behaviour. Another question is how the changes in the record can be explained. Both cognitive change and other processes provide possible explanations. Explanations in terms of cognition can be roughly divided into those based on symbolism and language, those based on Theory of Mind, those on modularity and working memory, and some alternative approaches. These different approaches will be discussed below.

### *2.4 Symbolism and Language*

A heavy emphasis in much of the existing literature is placed on symbolism and language as a basis for sophisticated cognition and behaviour. Several researchers have argued that language and symbolism, though not equivalent, are nonetheless interconnected and are two of the main components of the evolution of the modern human mind (Deacon 1997, Tattersall 2009). Deacon (1996), for instance, has argued that the evolution of the human mind is mainly about the evolution of language, of which symbols are the essential element. He described symbols as “representations of social conventions, tacit agreement, or explicit codes that link to one another and are mediated by some formal or merely agreed upon link irrespective of any physical characteristics of either sign or object” (Deacon 1997, 70). He believes that the evolution of language can be explained through the acquisition and manipulation of these symbols and symbol-relations. Similarly, Tattersall (2009) has argued for the uniqueness of *Homo sapiens* in the natural world, specifically because of their possession and use of symbolic reasoning, while  other hominin species are argued have been far behind in this aspect.

One language construct that has been used to interpret archaeological data is that of recursion. Recursion is the repeating of items in a self-similar way. In language it is the method of combining and restructuring sentences, while keeping their inherent meaning. Recursion has been central to many theories of language, most prominently those of Noam Chomsky (1959). The link has been made from language to tool use, arguing that the manipulation of objects can show structural and cognitive parallels to language, including recursion and concepts such as past and future (Haidle 2010), which is discussed in more detail in the following chapter. Though the importance of recursion in language has been challenged by some (Everett 2005), claiming that not all people use a language in which recursion plays an essential role, it has recently been shown through neurolinguistic studies to be supported by neurobiological brain structures that deal specifically with recursive language, which are present in all humans (Kaan *et al.* 2002).

The focus on language and mainly symbolism in explaining archaeological phenomena brings about several problems. One problem with using so-called symbols found in the archaeological record, is that because of their connection with language, they are often used to make inferences on it. Several authors (McBrearty and Brooks 2000) have noted however, that it is highly unlikely that the first signs of symbolism in the archaeological record actually coincide with the beginning of language. Indeed, others suggest that language probably developed much earlier in humans than it was manifested in their material culture (Henshilwood and Marean 2003). Though this is important to remember, it a probably a generally unavoidable issue in cognitive archaeology.

A second problem is shown by Botha's (2008) critiques, namely the difficulty in extracting valid and scientifically founded conclusions from instances of so-called symbolism in the record, especially when attempting to make inferences on cognition. The bridging arguments for this line of reasoning need to be very strong and grounded in archaeological and cognitive evidence.

The problem with this emphasis on symbolism in archaeology and its relation to cognition is described in what Renfrew has termed “the sapient paradox” (Renfrew 2008). A heavy emphasis is placed on symbolism as being the distinguishing characteristic of modern humans, even though there is evidence of modern human anatomy from 200 ka, whereas there is only evidence of modern human symbolism from

77 ka at Blombos cave (Henshilwood 2004). If symbolism is truly the distinguishing characteristic of modern humans, and if, as Renfrew points out, it is indeed a genetic characteristic that is the cause of these changes to symbolic behaviour (Renfrew 2008), why then, do we not find earlier traces of it in the archaeological record? Though this might be a general problem in cognitive archaeology, related to the incomplete state of the archaeological record, it it still a valid point, and worth looking into.

Klein has suggested (Klein 2001), in line with Wynn and Coolidge (2009), that this might be due to a genetic mutation that was not accompanied by any physical changes. If this mutation took place after the transition to anatomical modernity, this would explain the delay in cognitive sophistication, implying that anatomical modernity does not refer to cognition. Others have suggested that it might not be due to a single genetic mutation or occurrence, but due the gradual development of an increasingly symbolic way of thinking (Renfrew 2007), which would be more in line with the gradual development of modern behaviour proposed by McBrearty and Brooks (2000).

These explanations all still imply that symbolic reasoning is fundamental for cognitive sophistication. This is where cognitive archaeology and cognitive science diverge. Whereas cognitive archaeology still very much relies on these explanations of symbolism, cognitive science has increasingly started questioning this connection (Thelen and Smith 1993; Ballard 1991), and has since moved on to different explanations of cognitive complexity.

According to cognitive science, the emphasis placed on symbolism relies on the belief that symbolism needs to be reflected in a physical or functional way through the use of material symbols, when that does not necessarily need to be the case (Thornton 2012). Even though symbolism was long thought to be critical to complex cognition and integration (Marr 1977; Boden 1977; Winston 1984), the necessary neurological foundation to support this theory has not been found. Neurological research has shown that there is no executive centre in charge of the performance of symbolic reasoning (Clark 1997). The executive centre in the brain, a theorized cognitive system in charge of other cognitive processes, is responsible for cognitive mechanisms such as working memory, planning, attention, problem solving, multi-tasking, and mental flexibility (Chan *et al.* 2008). These are all cognitive abilities that have been linked to modern cognitive sophistication (Coolidge and Wynn 2001, 2005, Wynn and Coolidge 2003). Symbolic reasoning has not been shown to have this type of neurological link to sophisticated cognition.

Research into artificial intelligence has shown that symbolic reasoning machines do not to have the same amount of power and fluidity as the modern human mind, even when capable of similar levels of symbolism (Clark 1997). This would imply that symbolism on its own is not a necessity for sophisticated cognition. Critics have made the point that approaches that focus on symbolic reasoning to explain cognition are philosophically flawed (Wheeler 2005). They are argued to be dependent on conceptual projection, i.e. requiring physical representations (Thornton 2012). Thornton makes the point that where a set of ideas is responsible for a certain behaviour, these ideas or behaviours do not need to have a physical representation (Thornton 2012; Wheeler 2005). Instead of looking purely at symbolism and its physical representations therefore, it is suggested that instead the focus should be on the underlying processes of symbolism.

More recent approaches in cognitive science underline the greater likelihood and neurological foundation of probabilistic (non-symbolic) forms of reasoning and information processing as the underlying factors in cognitive sophistication (Doya *et al.* 2007; Chater and Oaksford 2009; Clark 2008). Instead of an increasing use of symbolic processing and representation, it looks at “increasingly predictive, increasingly well-defined and increasingly broad generalizations” (Thornton 2012, 7), which allow for symbolism. Thornton argues that the concept of symbolism should be viewed differently, on a continuous scale, rather than as a static concept. He proposes that concepts can become more symbolic, and that as they do so, they become more abstract, well-defined and broad in generalization. When symbolism is then not directly linked to the use of material symbols, but merely seen as a product of the predictive, generalizing mind, it avoids the problem of having to explain the meaning of these symbols, which is one of the main problems when dealing with the idea of symbolism in cognitive archaeology. Thornton therefore underlines a definite need for reevaluation of cognitive archaeology's reliance on symbolic theory, a reevaluation of the concept of symbolism, and the incorporation of more up to date cognitive scientific theories through more interdisciplinary work between the two fields.

Though I agree with the need to reevaluate archaeology's reliance on symbolic theory, the problem with not linking symbolic ideas to actual physical representations of those ideas, but rather to abstract ideas, is that it would make it very hard to find any archaeological evidence to comment any further on the evolution of our cognition. Though it is necessary to stay up to date with cognitive science in order to create valid conclusions, the restriction inherent to the archaeological field might not allow us to follow al lines of modern cognitive science like these.

The above review has identified several issues when it comes to the use of symbolism and language in cognitive archaeology. Both concepts do not leave strong traces in the archaeological record, making them very hard to identify. Any traces that are found, are often so disputed that they need very strong evidence to back them up  in order to meet the criteria for archaeological validity. Especially when making inferences on cognition, these concepts need to be represented by exceptionally clear evidence for them to be warranted in inferring any cognitive capabilities. Though evidence of language use is hard to find archaeologically, it does have cognitive and neurological support for its importance as an aspect of sophisticated cognition. The same cannot be said for symbolism, which, though used frequently by archaeologists, had received more and more criticism from cognitive science as a construct for identifying cognitive sophistication. These issues often make any cognitive inferences made from language and symbolism speculative. I will therefore not be using these approaches in my analysis of adhesive production and comparison of cognitive capabilities of AMH and Neandertals.

There are some alternative approaches to cognitive evolution other than language and symbolism however, two prominent ones being Theory of Mind and Modularity, which will be discussed presently.

### *2.5 Theory of Mind*

A different approach to the evolution of human cognition can be found in theories focusing on the concept of “Theory of Mind”. This term was coined during the 1970s

(Premack and Woodruff 1978) and refers to the ability to attribute mental states such as beliefs, intentions, desires and knowledge, not only to oneself, but also to others. It includes the understanding that others may not share the same beliefs and ideas as we do. It is often equated with the term “meta-representation”, or the ability to represent mental representations. This ability is often listed as one of the cognitive capabilities specific to modern human cognition (Amati and Shallice 2007; Barnard 2010).

Research into chimpanzee behaviour has shown them also to have a partial Theory of Mind however. They have a basic understanding for instance of what others see and how this may influence their behaviour, though there is no evidence that they understand the beliefs of others, or concepts such as prior intentions, different perspectives, and attention (Tomasello *et al.* 2003). Though chimpanzee Theory of Mind may not be as developed as that of modern day humans, who do possess these aspects of Theory of Mind as well as the ones shared by chimpanzees, it does allow for the assumption that this reduced level of Theory of Mind was also present in our common ancestor (Kane 2004).

This has allowed theories based on Theory of Mind to suggest a development of the concept throughout our evolutionary history. One such theory proposes that human cognition developed from a basic model regulating sensory input and output to one with many different subsystems, that represents fully modern cognition with all its abilities, including conceptual planning, Theory of Mind, an aesthetic sense and an algorithmic capacity, that supports productivity and learning (Barnard 2010). This theory has been used to support the claims of cognitive sophistication based on hafting adhesives created at Sibudu Cave, which will be discussed in more detail later.

Another theory, proposed by Robin Dunbar (1998) has suggested that Theory of Mind developed throughout evolution as a means to integrate groups more effectively through the use of language. Without Theory of Mind there would be no language in the form that we know today, as people would not be able to fully understand another person's intentions, and build a language filled with words describing concepts such as “intention”, “belief”, “idea” etc. (Dunbar 1998). This “social brain” hypothesis (Barton and Dunbar 1997) emphasizes the social function of the primate brain rather than the ecological function, supported by the fact that primates appear more skilled at solving social problems than ecological ones (Cheney and Seyfarth 1990). Study has shown primates and humans to spend about 20% of their time in social interaction (*ibid*.). For primates this is done through grooming, and the time spent grooming has been shown to be correlated with their neocortex size and the size of their social group (Kudo *et al.* 1999). Because of mankind's evolution to a larger brainsize, and thereby a larger neocortex size, this would increase human group size as well as their time spent grooming. The group size and grooming time of primates was therefore used to predict grooming time for humans with their increased neocortex and group size. This turned out to be around 40% of their time, much in excess of what would be possible in order to stay alive (Dunbar 1998). Dunbar suggests that Theory of Mind and language developed as mechanisms to deal more effectively with this increase in group- and brainsize, and that grooming was gradually replaced by “vocal-grooming-at-a-distance”, to allow for better time management (Aiello and Dunbar 1993). Dunbar proposes a date of 250 ka as the point in time where this change in grooming mechanism would have taken place, corresponding broadly with the emergence of our own species (Dunbar 1998). This theory would correspond with the findings of human having a more advanced Theory of Mind than chimpanzees (Tomasello *et al.* 2003).

This capacity is one that is well-defined and researched as well as supported by cognitive science. Though chimpanzee research would indicate that it is not a matter of presence or absence of Theory of Mind for Neandertals and AMH, the question can be raised if their levels of Theory of Mind were as advanced as those of modern day people. Though the concept could prove difficult for archaeologists to work with directly, as ideas, beliefs and intentions are unlikely to be clearly visible in the archaeological record, primate research could be very useful in determining the levels of Theory of Mind of past hominin species, adding to our knowledge of their cognitive capacities.

### *2.6 Modularity and Working Memory*

Other theories regarding the evolution of human cognition have been based on a concept called modularity. This term was first used by Fodor in 1983 in his “modularity of mind” theory, and refers to the idea that the mind is composed of independent, closed, domain-specific processing modules.

Cognitive fluidity is a term coined by Mithen (1996) in the nineties, and used in his model for human intelligence, based on the principal of modularity, where it represents the interaction of different forms of intelligence, allowing for original and creative thought, problem solving, information storage, abstract thought, metaphor, analogy and more (*ibid.*) This model is based on human a intelligence evolving through 3 different phases, which Mithen (*ibid*.) compares to the structure of a cathedral. Phase one involves the basic framework of general intelligence, or the outer structure of the cathedral dome as described by Mithen(*ibid*.) This phase is evident in chimpanzees, and therefore most likely mirrors the intelligence of our common ancestor (*ibid*.). Phase two involves the evolution of different domains of intelligence surrounding the general intelligence, described by Mithen (*ibid*.) as separate alcoves in a cathedral, yet still not in direct contact with one another. These domains represent different forms of intelligence, namely: social intelligence, which deals with the interaction with other humans; technical intelligence, concerning the production and use of tools; natural history intelligence, to due with elements of the natural world relevant to us; and language intelligence (*ibid*.). Phase two can be seen, or at least inferred from the archaeological context, in early humans. In this phase, and according to Mithen (*ibid*.), early humans therefore did not have cognitive fluidity. This conclusion is based on analyses of environmental evidence, settlement patterns, hunting strategies and analyses of social, technical and linguistic accounts. It is only in phase three that the different domains come into contact with each other, and interaction between different forms of intelligence, known as cognitive fluidity, becomes possible. This phase, according to Mithen (*ibid*.), is seen only in anatomically modern humans, and can be witnessed through the combination of natural history intelligence and technical intelligence culminating in rock art, cave paintings, multi-component tools and such. Other examples are ornaments, created through the combination of social and technical intelligence. As these are all elements seen mainly from around 50 kya onwards (*ibid*.), they have been subsequently associated with only anatomically modern humans AMH, thereby also linking cognitive fluidity with anatomically modern humans.

This is contradicted however, by the wooden spears found in Schöningen, dating to 300.000 to 400.000 ka BP (Thieme 1999, 2005). As these spears have been found to require a specific woodworking technique (whittling), according to Mithens (1996) theory this should be a clear case of the crossing of domains (natural history and technical intelligence) (Haidle 2012). This would contradict Mithen's (1996) idea of cognitive fluidity only being present from around 50 ka BP onward.

Further criticism of Mithen's (1996) theory has been aimed at the lack of compelling evidence to support it. Critiques have regarded a lack of explanation as to why modularity should suddenly have broken down, and what the benefit was for the individual to no longer have a modular mind, especially after millions of years of it being assumingly beneficial to earlier hominin species (Sambrook 1999). Also questioned, is the storage of information in the modules and their lack of interaction up to phase three. A disregard for the possibility of knowledge being stored in more than one module is suggested. Bone, for example, could be stored in the natural history module, being part of an animal, and in the technical module, being a raw material for tool manufacture (*ibid*.). Further critique is aimed at the lack of any supporting evidence from neurological science. There has been no support found for any structures or regions on the brain being responsible for domain specific aspects of intelligence (McDermott 1997). Without this support, it remains an untested theory.

Another concept which has been explored within the evolution of cognition is that of working memory. Coined in the 1960's by Miller, Galanter and Pribram (1960), it was first used in theories comparing the mind to a computer. The multi-component model of working memory as we now know it was proposed by Baddeley and Hitch in 1974. The construct of working memory is made up of 4 main components; a central executive component called the panmodal controller, a memory interface called the episodic buffer, a component for phonological storage, and a visual subsystem called the visuospatial sketch pad; it is a mental construct that refers to a general cognitive ability underlying important behaviours such as attention, intelligence, language acquisition, learning, memory, and several others (Wynn and Coolidge 2009, 216). Many of these cognitive concepts have been linked to modern cognitive sophistication through executive function (Coolidge and Wynn 2001, 2005, Wynn and Coolidge 2003). Some researchers have created theories and models of cognitive evolution around the concept of working memory and how the many cognitive constructs involved in it came into being (Wynn and Coolidge 2009). Wynn and Coolidge for instance have proposed that a neural mutation led to an increase in working memory capacity, which in turn led to the development of these aspects of modern cognition and behaviour listed above (Wynn and Coolidge 2009). They argue that this is not at all a strange suggestion, as humans are in fact the products of a long history of genetic mutations and natural selection. They propose that it was not the single genetic event was the cause of instant changes to modern cognition but that it acted on a preexisting set of cognitive abilities that resulted in a marked change in behaviour towards what we now call “modern” behaviour. A less sophisticated cognitive technique suggested by Wynn and Coolidge (2007b) that may have been employed before this change in behaviour and cognition, is that of expertise through apprenticeship and learning, which will be discussed below.

Though executive functions play an important role in many theories of cognitive sophistication, the working memory model used by Wynn and Coolidge has been called into question by several cognitive psychologists (Barnard 2010; Beaman 2010; Engle 2010; Martin-Loeches 2010). These critics focus mainly on the fact that there has been no convincing evidence tying cognitive indicators of modern cognition to an extension of working memory (Haidle 2010). Haidle (2010) underlines the fact that the evolution of working memory cannot be studied in the same manner as is used usually applied for neurological studies on living subjects however. She argues that in order to trace the development of executive brain functions such as working memory, archaeological material must be found in the record to support this, which is already limited (Haidle 2007). A further problem is that the features of “modern” behaviour and cognition often named by archaeologists, that need to be tied to this extension, are too narrow and static to allow for proper tracking of these constructs on an evolutionary scale (*ibid*.).

Instead, Haidle (2010) suggests that a better way to measure the development of executive functions for the course of human evolution, namely that of measuring cognitive complexity, flexibility and decision making through the concept of problem-solution distance (Haidle 2010). She poses that tool behaviour, which has been recognized as an extension of indirect thinking (Kohler 1926), can be seen as an indication of the problem-solution distance (Haidle 2010). When tools are employed to solve a problem, the ultimate goal of for instance obtaining an item of food, must be temporarily set aside in favour of a temporary goal of finding a tool with which to accomplish this ultimate goal of finding food. According to Haidle (*ibid.*) this problem-solution distance yields information on the cognitive flexibility of a species. Here she gives the example of a comparison between different animal species. Where some species are known to use tools for very specific purposes, such as birds using sticks to build a nest, others use tools for very varied purposes and in many different ways. Chimpanzees for instance, use a range of tools such as sticks, stones, leaves, twigs, and branches in order to obtain food, investigate their surroundings, to communicate, play, defend themselves, and more (*ibid*.). The more flexibility that is shown within this problem-solution paradigm, the more decisions therefore need to be made on how to reach the desired goal (*ibid.*).

According to Haidle (*ibid.*) this problem-solution distance is reflective of several general aspects of the executive functions of working memory such as planning, attention, decision making, flexibility, and the integration, comparing, processing and rehearsal of information. She argues that a similar comparison can be made for humans by looking at operational sequences of tools. More complex problem-solution units, such as are required for composite tools, are then reflective of further developed executive functions of working memory (*ibid*.).

Though evidence of an extension of working memory has not been found, Haidle's (2010) problem-solution paradigm could provide an alternative to future research on tracking the development of human cognitive functions. By comparing operational sequences of archaeological objects for different hominin species, one might be able to comment on the difference in problem-solution distance and accompanying levels of executive function and working memory. This approach will be kept in mind for the analysis of the AMH and Neandertal adhesive production processes in the coming chapters.

2.7 *Apprenticeship and Learning*

An alternative model recently proposed by Wynn and Coolidge (2007b) as possibly having played a large part the history of tool proficiency, is that of apprenticeship and learning *(ibid.*). This model is based on the performance of certain actions through the construct of expertise. Expertise is described here as being "based on patterns and procedures that are held in long-term memory and that can be accessed quickly and deployed with a minimum of attention" (*ibid.*, 45). Still one of the main problem-solving strategies used by people today, it is responsible for many learned behaviours, such as driving, playing a musical instrument (well), cooking, and many other actions that require practice. The main difference between expertise and other forms of problem solving is that it is learned through apprenticeship. Wynn and Coolidge have identified the main elements in apprenticeship to be procedural memories, which require great amounts of practice to learn fully (*ibid*.). These procedural memories are stored in what is known as long term working memory (LTWM) (*ibid.*).

Unlike regular working memory, LTWM can hold information in storage for a longer period of time (*ibid.*). Using retrieval cues (items of knowledge linked to longer encodings of knowledge) (Ericsson and Kintsch 1995) people are able to encode and retrieve information very rapidly into LTWM. This type of information storage is only used by people within their areas of expertise though, and is not easily required. Ericsson (1995) has estimated a time span of around a decade to adequately learn the required technique in any field, not just to master the basic skills, but also to be able to handle any changes in circumstances that might occur during the process by drawing on a large store of internalized procedures and routines. Though this is a very flexible and powerful way of thinking, it a rather narrow domain, being limited to a person's area of expertise only (Wynn and Coolidge 2004).

Wynn and Coolidge (2004) illustrate this by looking at the practice of blacksmithing through a study performed by Kellar and Kellar (1996), which has been shown to rely on a roughly similar construction. In this study three main concepts are used, namely “stock of knowledge”, “umbrella plan”, and “constellation” (Kellar 1996). Stock of knowledge refers to the entirety of knowledge held by the smith on materials, procedures, results, and visual and tactile information, as well as semantic knowledge(Wynn and Coolidge 2004). This, according to Wynn and Coolidge is comparable to the information stored in LTWM (*ibid*.). “Umbrella plan” is the smith's mental representation of the production process and final goal, including the exact procedures required to achieve that goal (*ibid*.). Umbrella plans include knowledge of materials, time, costs, as well as visual and tactile information (*ibid.*). Wynn and Coolidge (*ibid.*) have suggested that this umbrella plan also relies on retrieval cues, as they are formed according to the task at hand. The concept of “constellation” represents the “configurations of ideas, implements, and materials” (Keller and Keller 1996, 91) which account for the completion of one step in the production process. It includes the actual tools and materials required to reach this stage. According to Wynn and Coolidge (2004) these constellations are retrieval structures linked to tools and materials, which can access the required images and procudures, and can encode new knowledge into long term memory (*ibid.*)

Ethnographic work by Dietrich Stout (2002) on the adze makers of Langda, Indonesia gives a good example of the use of apprenticeship in modern times. It has shown people to be capable of creating well-shaped and extensively worked core forms through the application of apprenticeship and expertise. These tools are comparable to Acheulean handaxes and cleavers known from sites such as Kalambo Falls, Zambia (Clark 1969, 1974), Bodo, Ethiopia (Schick and Clark 2000), Lion Spring, Jordan (Copeland 1991), as well as Middle Stone Age core axes like those from the Central African “Lupemban” industry (Stout 2002). The making of these adzes is learned through a long-term process of apprenticeship, and requires not only fine perceptual-motor and strategic skills, but also an extensive knowledge of raw materials (*ibid.*). Obtaining these raw materials can be very difficult, as several different kinds are required, and are often difficult to identify to the un-apprenticed eye (*ibid.*). The knowledge of these raw materials and procedures can be equated to Ericsson's (1995) concept of “stock of knowledge”, whereas the strategic and perceptal-motor skills as well as the known procedures can be seen as the “umbrella plan” or reliant on retrieval cues as suggested by Wynn and Coolidge (2004). Stout's work provides insights into the learning process, the duration of apprenticeship, and the social context of axe production for contemporary humans. These are all issues which are not easily retrieved from the archaeological record, and therefore can give us useful information which we are otherwise lacking.

Wynn and Coolidge (2009) have also identified Levallois stone tool reduction to show similar elements, such as a stock of knowledge, skill acquired through an extended period of practice, and elements comparable to an umbrella plan an constellation (*ibid.*).

Looking at the evolution of this problem-solving mechanism, primate studies have shown certain apes to also apply this technique (Toth and Schick 2009; Boesch and Boesch-Achermann 2000). Research into Bonobo tool proficiency has shown them to be capable of manufacturing stone tools through observation of human tool production (Toth and Schick 2009). Though they do not reach the skill of early human tool manufacturers, they are capable of limited stone tool production (*ibid*.). Further research into West-African Taï chimpanzees has shown them to undergo a prolonged period of apprenticeship in order to gain the skill to crack open certain edible nuts (Boesch and Boesch-Achermann 2000). The learning period for this nut cracking skill ranges from 4 to 7 years and is started during a very early age, when they observe their mothers cracking nuts with either stone or wooden hammers. They do not gain the required skill to crack the nuts until they have undergone several years of practice (*ibid.*).

Though this form of expertise and apprenticeship is perhaps not similar to that described by Wynn and Coolidge (2004) to be employed by skilled human experts of a craft, it does indicate the inherently human nature of the technique of apprenticeship itself. If this technique is used by bonobos, then is can be presumed to have been used by our common ancestor as well as later hominins species.

Whereas the evolution of AMH cognition has been linked by some (*e.g.* Wynn and Coolidge 2004) to the development of executive functions such as working memory, long-term planning, problem solving, mental flexibility and multi-tasking, Neandertal cognition has not. Though they are thought to have possessed flexible minds that were capable of responding adequately to changing conditions, the lack of development in tool types, or indications of long-term planning or innovativeness have led Wynn and Coolidge to believe that Neandertals relied solely on the problem solving technique of expertise (*ibid.*). AMH on the other hand, are thought by these authors to have benefited from an enhanced form of working memory through a neural mutation (*ibid.*). According to them (*ibid.*) this mutation acted on their existing behavioural and cognitive abilities, leading to what we now call "modern" cognitive capacities. However, expertise has been shown to remain intact even when enhanced working memory capacity is removed (*ibid*.), showing that it does not rely on an equal amount of executive control.

Though this technique is still the most employed  problem-solving technique used today, and has been shown to be capable of producing items such as hafted spears (Wynn and Coolidge 2007b), it is not often called upon as a possible explanations for modern human behaviour in archaeological considerations. Though we now know modern humans to have at some point developed more sophisticated cognitive abilities, Occam's razor states that where two explanations are capable of producing a similar outcome, it is likely the simpler one that is responsible. As expertise has been shown not to be reliant on enhanced working memory (Wynn and Coolidge 2004), and its accompanying features of sophisticated cognition, it can be seen to count as the simpler explanation. This means that even though anatomically modern humans may have had more sophisticated cognitive abilities, we cannot assume they used them for the creation of certain archaeological artifacts. The possibility that expertise was used must be kept in mind as a possible explanation, as it will be for the course of this thesis.

### 2.8 *Chapter conclusions*

The above review has outlines several broad approaches to explain the evolution of human cognition and behaviour. Symbolism and language, though used in many of these explanations, was not only shown to be very hard to link to the archaeological record validly, but also to lack supporting evidence from cognitive and neurological science  in being critical to the development of cognitive sophistication.

The Theory of Mind model was shown to also be difficult to detect aspects of archaeologically. Though it does not appear to be question of whether past hominin species had a Theory of Mind, research could contribute to our knowledge of the extent of their mental capacities and Theory of Mind, through for instance primate research.

Modularity and working memory were shown to have different results. Mithen's (1996) model of modularity has received many critiques, including not having any support from cognitive neurological science, and not being in line with archaeological evidence. Explanatory models based on working memory have are supported by cognitive science, which recognizes working memory as a crucial construct to cognitive sophistication. Though Wynn and Coolidge's (2009) model of enhanced working memory has not received the required cognitive support tying cognitive sophistication to an enhancement of working memory, it has been suggested (Haidle 2010) that this is due to archaeologists' concepts for recognizing “modern”cognition being too static and narrow to accurately trace the development of concepts like working memory on an evolutionary scale.

An alternative explanatory model could be found in Wynn and Coolidge's (2004; 2007b) theory of expertise through apprenticeship and learning. It is a construct which has been shown to be employed as a problem-solving technique in modern day society as well as by bonobos and chimpanzees. This has the implication that past hominin species would have been capable of using this strategy as well, including AMH and Neandertals.

A range of different capacities and models are used to interpret the evidence of Sibudu Cave hafting and adhesive production. These models and capacities fit within the broad approaches listed by this review. This chapter has provided a broad context and relevant information about the underlying cognitive constructs of these models and capacities, which will help me evaluate them more accurately.

## Chapter 3. Sibudu Cave, South Africa: a case study

### *3.1 Chapter introduction*

Having outlined some of the broad approaches used to explain the evolution of human behaviour and cognition, it is now time to look at the specific case study for which these approaches will form a background, namely that of AMH adhesive making at Sibudu Cave, South Africa. An analysis will be made of the hafting and adhesive making process performed at Sibudu Cave. The evidence for hafting and adhesive making as well as the cognitive inferences that are made based on this evidence will be checked for archaeological and cognitive validity. The key knowledge and procedures required for these inferred cognitive concepts will be outlined, to form a basis for later comparison with the Neandertal adhesive making process. Alternative approaches for explaining these key procedures and elements of knowledge will also be considered in the analysis.

### *3.2. Key trends and research questions in MSA South Africa*

The South African Middle Stone Age (MSA) encompasses a period of some 250.000 years, from 280 ka to around 50 to 25 ka (McBrearty and Brooks 2000). It is characterized by flake and blade tool industries that are distinguished by the presence of prepared core technology and unifacial and bifacial projectile points, and the absence of handaxes and microliths, the latter of which characterizes the subsequent Late Stone Age period (McBrearty and Brooks 2000). Though not as well researched as many European periods, it is represented by several noteworthy sites such as Blombos Cave, Pinnacle Point, the Klasies River Caves, and Sibudu Cave. The later periods of the South African MSA, ranging from around 80.000 BP to 26.000 BP (Wadley and Jacobs 2004), have been especially noteworthy in recent research. They have provided much information regarding the behavioural and cognitive sophistication of the people that inhabited them. Evidence such as early use of ochre (Watts 2002), bone tool production (Klein 2000), and compound glue manufacture (Wadley 2010) have contributed greatly to recent discussions on the origins of modern behaviour, language, and cognition sophistication.

Once thought to be approximately equivalent to the European Middle Palaeolithic, several finds from South African sites, such as the ones from Blombos Cave (Henshilwood 2002), have caused a reconsideration of that idea (McBrearty and Brooks 2000). Many now consider the African MSA to represent the world's first symbolic culture and visual art forms. This has in turn been linked to the first indication of language by modern humans (Henshilwood *et al.* 2004); however, as we have seen (Botha 2008) not everyone is in agreement on this issue.

Due to the controversy surrounding the meaning and importance of symbolism with regard to cognition in recent research, some researchers have shifted their focus from symbolic indications to indications of complex technological behaviour to imply sophisticated cognition (*e.g.* Wadley 2010). A good example of this type of complex technological behaviour can be found at Sibudu Cave, in the Kwazulu-Natal region of South Africa. Extensive research on this site has been performed by Lynn Wadley since 1998; specifically, and most important for the content of this thesis, she has tried to connect the indications of compound glue manufacture at the site, to a level of cognitive sophistication in its creators which is similar to that of modern humans. Though no human remains have been found at Sibudu Cave, the similarity of the tool assemblage to other sites in the regions such as Blombos Cave and Hollow rock shelter (Wadley 2007), some of which have been linked to AMH through human remains (Grine and Henshilwood 2002), clearly indicate that the creators of the Sibudu Cave adhesives were also *Homo sapiens*.

### *3.3 Site description*

The site of Sibudu Cave is located in the northern part of the Kwazulu-Natal region of South Africa (fig 2). About 15 kilometers inland from the Indian ocean, it is situated on a cliff top overlooking the Tongati river. The cave itself is about 55 meters long and 18 meters wide, and was formed by the river eroding the sandstone cliff now situated above it, during a lowering of its channel some 160 to 140 ka BP (Maud 2000).

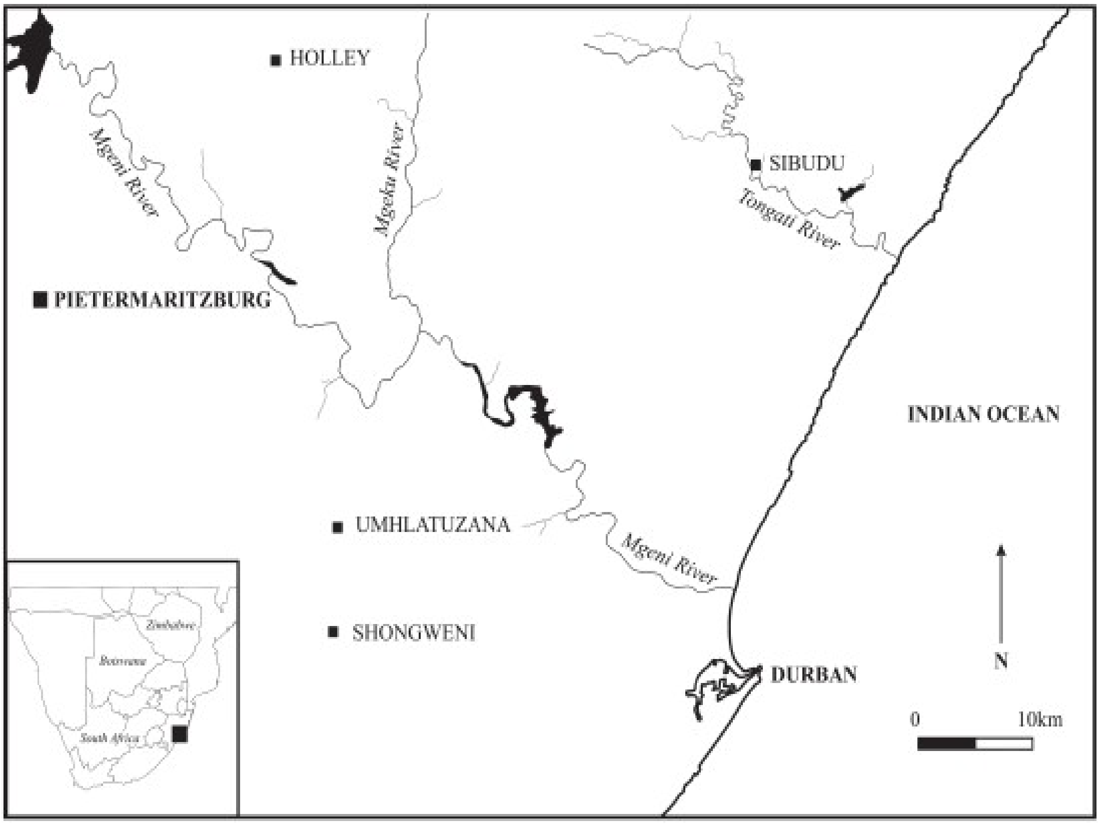


**Figure 2** The location of Sibudu Cave (Wadley 2006)

Clear stratigraphy and good organic preservation of bone, seeds and charcoal in the layers have allowed for optimal analysis through environmental reconstruction and techniques such as optically stimulated luminescence (OSL) dating (Wadley and Jacobs 2004).

The site has shown a range of MSA occupational phases (fig 3), from a Pre Still Bay phase coming up from the rock base (lacking bifacial points), to a Still bay industry (>70 ka, mainly bifacial points), a Howiesons Poort phase (>60 ka, backed tools and segments), and even late and final MSA industries (Wadley 2004), with research still being conducted. These analyses have shown the cave site to have been occupied throughout a large part of the MSA, with inhabitants of the cave being skilled hunters in an area with a very diverse animal population (Plug 2004).

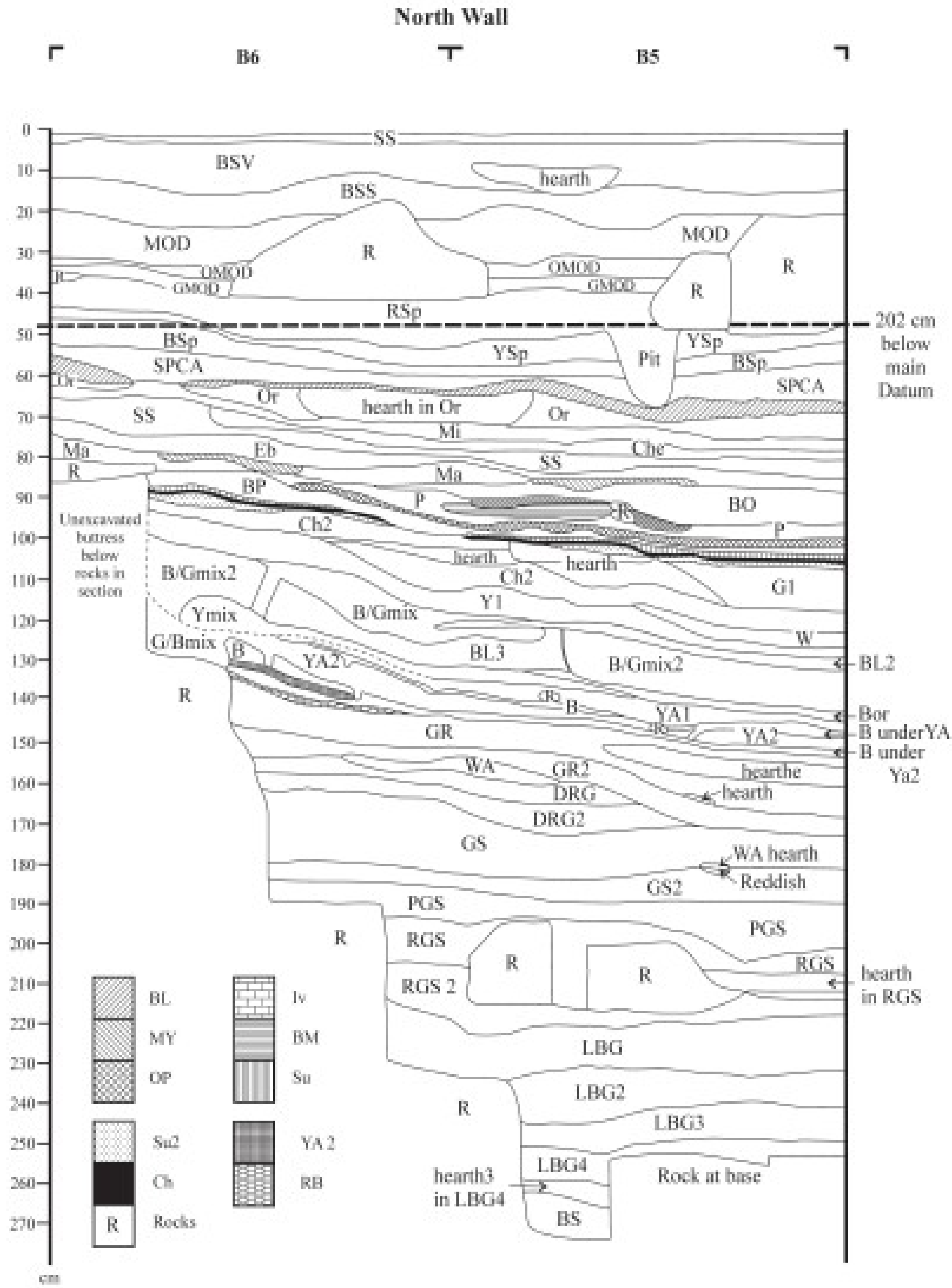


**Figure 3** Diagram of the stratigraphy on the Northern wall of the Sibudu Cave test pit (Wadley 2006).

The time period under discussion for this particular case study lies around 70 ka BP, and places the current discussion most likely in the Still Bay or Howiesons Poort period. Figure 3 shows the occupational layers seen through the north wall of the test pit at Sibudu Cave. The layers under discussion for this thesis (60 ka and older) are represented in figure 3 by layers BS up to, and including, GR. Early OSL dates for the Sibudu Cave Still Bay sequence seems to place it on a line with the Blombos cave Still Bay industry (Jacobs *et al.* 2006). For Sibudu Cave, this is represented by a stone tool industry with many bifacial points, and some backed tools (Wadley 2010). The assemblages consists mainly of flakes rather than blades, of which there are far less, and only has a few worked cores. This is in contrast with the succeeding Howiesons Poort period, which is represented by many backed tools and segments, but lacks points (Wadley 2007). The good bone preservation has shown the presence of mainly smaller animals such as birds, reptiles and rodents, but also marine products such as mussels, and some larger bovids are represented (Wadley 2007).

Analysis of the tools found at Sibudu Cave indicate that hafting took place during several different phases of occupation. Plant gum residue found on several of the tools have led the researchers  to conclude that adhesive was manufactured as one of the methods for hafting these tools. According to McBrearty and Brooks (2000) hafting was probably routinely used in MSA contexts. They point out that MSA points are often deliberately modified to facilitate hafting through thinning at the butt or the fabrication of tangs.

Indications of the use of adhesives are not new to the archaeological record. Traces of adhesives used for hafting have been found dating to around 200 ka Campitello Quarry, Italy (Mazza *et al.* 2006), 120 ka at Inden-Altdorf, Germany (Pawlik and Thissen 2011), 80 ka in Königsaue, Germany (Koller, Baumer and Mania 2001), and 40 ka at the site of Umm el Tlel in Syria (Boeda 1996).

Wadley has argued however, that these finds are examples of the use of “simple, 1-component” adhesives (Wadley 2009, 9590), whereas the adhesives used at Sibudu Cave can be considered to be compound adhesives, which require a more sophisticated production process. This adhesive production process calls for certain cognitive skills that are unique to the modern human mind, and thus points to the cognitive sophistication of the Sibudu inhabitants. Along these lines, she has suggested that the creators of these adhesives had modern cognitive sophistication. In order to analyse this assumption properly we must first look at the evidence for adhesive manufacture at Sibudu Cave and its production process.

*3.4 Evidence of hafting*

Macrofracture analysis performed through low-power microscopy, along with microscopic analysis of use-wear patterns, was performed on tools from the Still Bay, Howiesons Poort and post Howiesons Poort complexes at Sibudu Cave (Lombard 2005). Five main categories of microscopic traces have been shown to be relevant to identifying hafting on lithic tools: polish, edge damage, edge-rounding, striations and bright spots (Rots 2002). These categories were used as markers in the analysis of the Sibudu Cave stone tools. Residue analysis for similar samples were performed through optical residue recognition (Lombard 2005).

A small sample of tools (n=11) was analysed to interpret the evidence for hafting for the Sibudu Still Bay industry (Lombard 2006). Two of these tools showed clear indications of having been hafted through signs of polish, edge rounding and striations. Ochre, resin, plant and fat residue on these tools were also seen to be clear indications of hafting. Several other of these tools showed similar adhesive residues and use-wear traces, but these were not as clear as the first two, and no definite conclusions as to hafting could be drawn. The preliminary interpretations drawn from these analyses is that at least the two tools with clear hafting signs were used as butchery implements.

Micro-residue analysis was performed on a small sample (n=8) of backed stone tools from the Howiesons Poort layers at Sibudu (Delagnes *et al.* 2006). Resin deposits were found at the end of several tools, along with small traces of ochre on three of the tools. Two of the tools showed further traces of wood and plant residue mixed with the resin. Retouch found on the back of several segments are also consistent with hafting procedures (Wadley 2010). Conclusions drawn from this analysis is that these backed stone tools were hafted with the aid of a resinous substance.

Analysis of the post Howiesons Poort tools also delivered several lines of evidence for the hafting of points at Sibudu Cave (Lombard 2005). A sample of 50 bifacial and unifacial points and point fragments was used for the analysis. Macro-fracture analysis showed signs of bending fractures and proximal crushing, regarded as signs of hafting, and indicated 42% of the examined tools to have diagnostic impact fractures consistent with hafting. Use-wear analysis showed further signs of edge-rounding, edge damage, polish and longitudinal striations on many of the tools, also suggestive of the point having been hafted. Residue analysis showed vegetal and plant fibre residue on many of the tools, leading to the suggestion that fibrous plant material was used as a binding agent for the hafting of these tools. Resin and wood residue was also found on most of the tools, almost all on the proximal ends, consistent with the use of resin as an adhesive material. Analysis of the position of the glue on the tools suggests that they may have been hafted in a variety of positions (Lombard 2007, 2008).

Wadley further argues the the link between stone point and hafting to be valid due to the wide acceptance of stone points being tips of spears in the African MSA and European and Middle Eastern palaeolithic (Shea 2006).

These analyses have led the authors to conclude that hafting was definitely being employed as a technique at Sibudu Cave, and that this was done not only through binding with fibrous material, but also through the use of resin based adhesives made up of several ingredients such as plant gum, ochre, fat, and beeswax (Wadley 2010).

These arguments have been analysed with respect to their validity as indications that the people living at Sibudu Cave were indeed employing the techniques of adhesive making and hafting (Wynn 2009). Borrowing from Wynn's adapted version of Botha's previously introduced schematic argument, the groundedness and warantedness of the above arguments are analysed. This places us in step B of the schematic overview (fig 4), leading to the question if the bridging argument B, in this case the evidence presented in the form of residue analysis, macrofracture patterns, and use-wear analysis, is valid in connecting A, the stone tools, to C, the conclusion of hafting having been used.

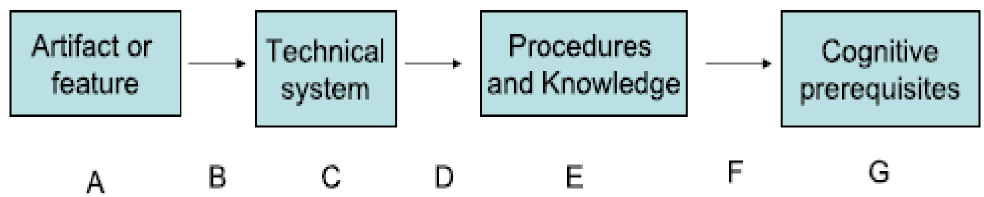


**Figure 4** Wynn's (2009) adapted form of Botha's (2008) schematic argument.

Wynn has analysed the argument for hafting at Sibudu Cave through the structure of Botha's critique. He has concluded that because the inference of hafting was based on analyses of macro-fractures, use-wear analysis and microscopic residue analyses, and the results corresponded with signs of hafting, that the argument was indeed grounded (Wynn 2009). The fact that the techniques that were used are well established archaeological methods for the indication of hafting, has led him to conclude that the argument is also clearly warranted (Wynn 2009). The multitude and depth of analyses performed on the Sibudu Cave tools leads me to agree that the argument for hafting is indeed well-founded and valid.

In his analysis Wynn states that the condition of equifinality must also be taken into account. This concept indicates that the same outcome can be produced through different methods. If this is the case, Wynn (2009) states that archaeologists should conclude that it was probably the one that is technically easiest that is most likely to have been used. If it could be demonstrated therefore that the residue and wear on the stone points could have been caused by a different, easier, technique that did not involve hafting, then a re-evaluation of the conclusions as to hafting would be necessary (Wynn 2009). However, it seems that the evidence for hafting is fairly strong in this case.

### *3.5 Production Process*

The information in the next four sections concerning the production sequence of the adhesives made at Sibudu Cave and their ingredients are taken from the published work of Wadley described in her recent articles (Wadley 2010; Wadley 2009; Wadley 2005b). This is based on the residue, macro-fracture and use-wear analyses discussed above and a series of experiments. An overview will be given of the required ingredients and the steps involved and described by Wadley for the production of these adhesives. Looking once again at Botha's diagram (fig 4), this places us at bridging argument D, leading to the question of whether the procedures and knowledge described in the coming section, are indeed required for the technical system employed, in this case hafting. This step is shown more clearly in figure 5 below.

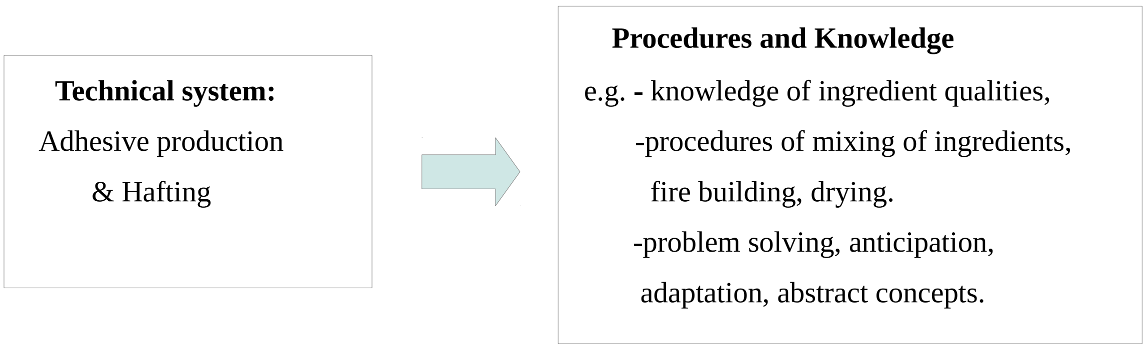


**Figure 5** Wadley's inferential step from technical system to procedures and knowledge, based on Wynn's (2009) adapted form of Botha's (2008) schematic argument.

*3.5.1 Ingredients*

The residue analysis performed on the Sibudu Cave points and segments revealed several different mixtures of adhesives that may have been used for hafting. These adhesives consisted of different ingredients, possibly used for different purposes. Besides the plant gum or resin, several of the MSA segments also had ochre stains on the backed edges, suggesting ochre may have been part of the adhesives. Traces of fat and wax were also found in some of the residues, which were also possibly a part of the mixture.

Different mixtures may have been used to produce different results. The use of mere plant gum or resin, without any extra ingredients, has been shown to create a brittle adhesive that cannot resist high pressures (Rots 2002). Points that are hafted onto shafts would break off on impact (Crombe *et al.* 2001). This could have been favourable if the end-product was used as a throwing spear, the tip would break off inside the animal, leaving the haft intact to be re-used, and causing more eventual damage to the animal.

More robust mixtures made up of a combination of several ingredients could have been used in spears that needed to be able to withstand high pressure impact, such as hand-held thrusting spears (Wadley 2010).

With the ingredients known, Wadley has attempted to recreate these adhesives, and has described the process in her 2010 publication. For her experimental approach she chose to carry out her experiments in a context that did not differ much from the (probable) original context, rather than in laboratory circumstances. Before starting the actual production process, she first gathers all the ingredients necessary to replicate these adhesives; firewood, wood for handles or shafts, rocks and a hammer stone for the knapping of the points, hematite nodules and some coarse grained flat rocks to grind ochre powder, tree resin from the Acacia karroo tree, and leaves for twine. Wadley underlines the large amount of time and planning involved in the gathering of all these different ingredients.

*3.5.2 Processing of ingredients*

Prior to creating the actual adhesive, the main ingredients need to be processed in order to be used in the adhesive production. For the stone, this was shown to involve the knapping of the stone to cut the wood into shafts and creating stone  inserts that could be hafted onto the shafts. The wood had to be cut into shafts while wet, and dried for a week before it was ready to use. The hematite nodules were ground into ochre powder on the coarse slab of rock. In the process of grinding, coarse particles of the stone are mixed with the ochre powder, giving it extra structure and lending strength to the final product.

*3.5.3 Simple adhesives*

The production process Wadley describes involved the making of several different mixtures of adhesives. A distinction is made between “simple” adhesives, made from just 1 component, and “compound adhesives”, made of 2 or more components. The simple adhesives are made using acacia gum alone. Not much information is given regarding the exact process of the making of this adhesive, but rather about its properties and workability.

The gum is shown to have variable consistency, drier ones being more easily workable, and runny ones being stickier and more difficult to work with. Dry gum needs no further processing besides air-drying, whereas sticky gum needs to be dried over a fire and rotated constantly to keep the adhesive from dripping off the haft or stick. When sufficiently dried so that it can be molded around a haft and tool, it still needs to be rotated every half minute while drying next to the fire to keep the stone tool from coming loose from the adhesive. Both the drier and more sticky variants result in a brittle product that is not resistant to high pressure, and can crumble on impact. Without any additives resin is also water-soluble, causing it to become stickier again in damp conditions and release the stone insert from the haft. Microscopic analysis also showed plant inclusions to be present in the adhesives, though this was probably caused while scraping the gum from the Acacia trees, and does not imply purposeful admixture of plant products (Wadley 2010).

This simple adhesive appears therefore to be quite easy to make, depending on the starting quality of the gum, and can be useful in certain circumstances (where the tip is meant to break off for instance), but is rather unreliable.

*3.5.4 Compound adhesives*

The compound adhesives are made using the ingredients identified in the residue analysis above, the main ingredient still being acacia gum, mixed with smaller amounts of ochre and in some cases beeswax. The added ochre works to bind the acacia gum into a more workable substance. The drier gum was shown to need less added ochre powder than the stickier kind. To increase the binding effect, the hematite nodules were ground on a rough sandstone, creating a mixture of fine ochre powder and coarser sandstone grains. Earlier experiments by Wadley have shown mixtures that did not have the mixed grain-size element to fail, making the grinding on rough slabs essential. These types of coarse sandstone slabs have also been found at Sibudu Cave. Of course this doesn't necessarily mean they used them for this purpose. Wadley states however, that if they did not in fact use them to grind the ochre for the adhesives, they would have needed to add sand to coarsen the mixture, or it would not have been strong enough to use as a hafting material.

The mixing of the ingredients is described by Wadley as requiring “complete, undivided attention”(Wadley 2010, 115). Evaluation of the qualities of the ingredients (how runny the resin is, how coarse the ochre particles etc) is needed in order to estimate the correct quantities and to adjust them correctly when required. The added advantage of adding ochre powder to the acacia gum, besides increasing the strength and workability of the mixture, is that the resulting adhesive is not water soluble. Unlike the simple adhesive, it will not re-soften in damp circumstances. This also means that the adhesive cannot be reheated and re-used, nor can the ingredients be separated once mixed. The process is, as Wadley (2010) states, irreversible.

A small amount of beeswax was added to some of the mixtures, giving the resulting adhesive a higher degree of plasticity. When too much beeswax was added however, the product shrank when it dried, releasing the stone tool from its haft in the process. To obtain the desired amount of plasticity, cohesiveness, and workability, only 15% of the total weight in beeswax was needed. The adding of ochre and/or beeswax lessens the time the mixture needs to dry and harden.

When making the adhesive, the quality of the wood, the fineness of the ochre powder when ground, the consistency of the beeswax, fat and acacia gum would all have varied with each production sequence. People would not have been able to rely on a fixed recipe to create this adhesive properly. Had they been able to use such a recipe, they would not need to have been mindful of the changes and adjustments required to produce a working adhesive. As these ingredients did all vary however, they would have had to pay close attention to changes in quality and quantity in order to produce a working adhesive. Besides natural differences in the raw materials, their own actions would also have required attention, and the quantities that were used and subsequent consistency of the adhesive mixture would have required adjustment if any of the products had not been used in the correct amount relative to its counterparts.

Wadley has emphasized the significance of the addition of these extra ingredients. Whereas acacia gum has natural adhesive-like qualities and can therefore be used as glue instinctively by people, the added materials of ochre, beeswax and fat have no such glue-like attributes. She argues that there would have been no obvious natural reason to add these ingredients to the mixture. Though fat and beeswax are both sticky, contradicting this statement, ochre is definitely not, and nonetheless did help to strengthen the adhesives along with the other ingredients. Not only did the people creating this adhesive have to know the right amounts and combinations however, they also had to alter the mixture chemically through fire.

The time it takes the adhesives to dry depends not only on the mixture itself however, but also on the method of drying itself. When dried by a fire, while being rotated approximately every 10 minutes, a tool could be used after 3 to 4 hours. At this point Wadley (2010) points out the necessity of careful judgement and attention to the task, though this was likely the case for the simple adhesives as well. She describes several attempts at drying the adhesives where the task failed and the end-product was not usable. Adhesives that are heated too rapidly can start to boil, causing cracks and weaknesses, so that the tool does not set securely. The mixture can also swell, causing the crust to char, and air bubbles to form under the surface. This also weakens the adhesive and can cause the tool to fall from its grip. Wadley (2010) describes this process as requiring "vigilance, keen judgement, and an understanding of the feel and appearance of the end product" (Wadley 2010, 115).

When air-dried, it takes 6 days for the adhesive to set and harden enough for the tool to be used without breaking. Drying the adhesive by a fire speeds up the process significantly. It was therefore shown to be possible to avoid the fire-drying stage of the adhesive production, but it certainly has major time advantages over air-drying.

The production process is well described in general. Ingredients are listed, different mixtures are shown, along with their advantages and disadvantages. Successful and failed attempts at creating a useful adhesive are described, as well as the general manner in which these attempts were performed. What it lacks however, is an exact description of the duration of the processes involved, and the exact steps taken to perform them. We get an overall description of the acts that are performed, but a more precise account would help in determining what exactly would have needed to be done by past people, and what the involved timespan would have been, in order to create these adhesives. The procedure involved in obtaining the resin used in the production process would have been useful for instance. Especially considering the implications that are tied to these production steps, they need to be very precisely specified.

*3.6 Key procedures and knowledge*

In order to allow for a better analysis of the cognitive concepts inferred by Wadley through the elements of the production process, it is necessary to list the key procedures and knowledge involved in this process. The key element of knowledge required for the adhesive making process include the following: 1. knowledge of the natural surrounding in order to find the different raw materials. 2. knowledge of the qualities of the raw materials themselves in order to know to use them in adhesive production and to be able to measure and adjust their quantities properly. 3. knowledge of the technical procedures of fire making and composite tool production. 4. knowledge of abstract concepts such as workability, plasticity, irreversibility, past, future. 5. Knowledge of the techniques of keeping and switching attention, anticipation, adapting to changing circumstances, and problem solving. The key procedures involved in the adhesive production process include the following: 1. Gathering the raw materials. 2. Processing and mixing of the raw materials into the adhesive mixture. 3. Working the adhesive onto tools. 4. Drying and chemically altering the adhesive over a fire. An overview of the procedural steps in the adhesive production process can be seen in figure 6 below.

All-in-all however, considering Botha's diagram once again, it does seem that the knowledge, preparation and procedures involved in the production of these adhesives is so elaborate, as shown by experimental reproduction, that without them, it would be very difficult indeed to haft stone tools with the use of compound glues such as the ones produced at Sibudu Cave. This type of hafting therefore does appear to require the procedures and knowledge specific to step E, making the bridging argument D grounded in evidence, and also warranted to imply the procedures and knowledge of step E.

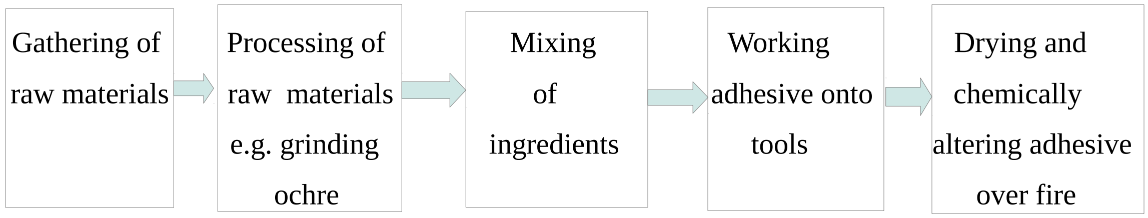


**Figure 6** Flow chart of the AMH adhesive making process

### *3.7 Cognitive prerequisites*

Wadley goes on to link the steps in this production sequence to elements of modern cognition. She argues that several of these steps require cognitive sophistication at a level equal to that of modern humans in order for them to be performed. Looking at Botha's diagram (fig 4), this places us at bridging argument F, linking the procedures and knowledge involved in producing the compound adhesives of step E, to the cognitive prerequisites of step G, as shown in figure 7 below. The cognitive processes or abilities that are suggested to be involved in the production sequence include enhanced working memory (Wynn and Coolidge 2005), fourth-order abstraction (Barnard 2010), multi-level operations and non-routine thought (Amati and Shallice 2007),mental rotation (Kane *et al.* 2004), embedded recursion (Haidle 2010, Reuland 2010), and cognitive fluidity (Mithen 1996). I will assess both the choice of cognitive models and whether they are supported by cognitive science, as well as how well Wadley's data on the procedures and knowledge involved in the production sequence can be shown to be connected to aspects of these cognitive models. Through the application of both Botha's (2008) structural argument and Wynn and Coolidge's (2009) strict standard I will attempt to comment on the groundedness, warantedness and cognitive and archaeological validity of these inferences.

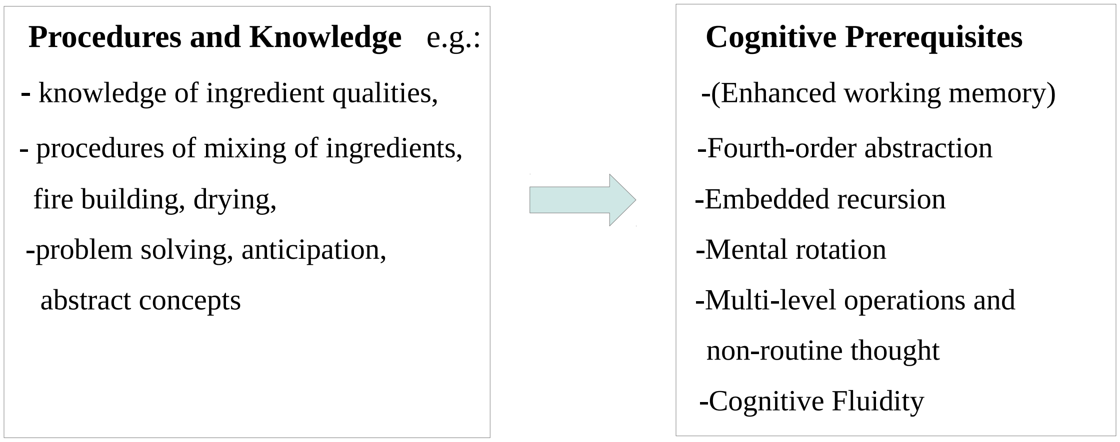


**Figure 7** Wadley's inferential step from procedures and knowledge, to cognitive prerequisites, based on Wynn's (2009) adapted form of Botha's (2008) schematic argument.

*3.7.1 Enhanced Working Memory*

The concept of enhanced working memory was proposed by Wynn and Coolidge (2005), and builds on the construct of working memory as proposed by Baddeley and Hitch (1974). As discussed in the previous chapter, the concepts of working memory is tied to executive functions of the brain, which in turn is an aspect of modern cognitive sophistication, and in charge of elements such as planning, attention, problem solving, multi-tasking and mental flexibility (Chan *et al.* 2008). Working memory itself is responsible for constructs such as attention, intelligence, language acquisition, learning and memory (Wynn and Coolidge 2009, 216). Wynn and Coolidge have proposed that a neural mutation in AMH led to an enhancement of working memory, which in turn led to the aspects of cognitive sophistication we know today.

Wadley's starting point for this argument lies in the qualities of the ingredients that are used for the production of the adhesive. She argues that the combining of these seemingly unrelated materials and the subsequent making of the adhesive can be equated with the practice of alloying metals or firing ceramics. She argues that the underlying cognitive processes involved in these two practices can also be equated. These practices require a similar process of collecting and combining raw, seemingly unrelated ingredients, and transforming them irreversibly into a useful end product. This irreversibility is significant because it implies that the makers of the adhesive could not correct their mistakes once the adhesive had been completed.

These practices have been shown by Wynn and Coolidge to be examples of techniques that depend on executive functions of the brain, which in turn depend on capabilities linked to frontal lobe activity (Wynn and Coolidge 2006, 2007). They have argued that these techniques are examples of technologies that provide evidence for remote action and contingency planning, employing the phonological loop and central executive aspects of working memory, thereby providing evidence for enhanced working memory (Wynn and Coolidge 2005).

Though Wadley (2010) does not make the specific inference that the makers of the Sibudu Cave adhesives had enhanced working memory, her equation of the production process with the techniques of alloying metals and firing ceramics, which in turn have been linked to enhanced working memory, makes a similar inference. Through this comparison Wadley argues that the process of adhesive making, also calling for problem anticipation, ideas about future actions, and prepared responses and adjustments; was equally representative of complex cognition as the techniques of alloying metals or firing ceramics.

Though this seems a valid equation, the are still several problems with the enhanced working memory theory itself that stand in the way of the bridging argument for this inference having cognitive validity. As discussed in the previous chapter, Wynn and Coolidge's (2005) enhanced working memory model has been called into question due to the fact that there has been no convincing evidence found to tie cognitive indicators of sophistication to an extension of working memory. This implies a lack of cognitive validity for the concept. Because working memory is a broad construct, responsible for elements such as attention, intelligence, language acquisition, learning and memory (Wynn and Coolidge 2009, 216), it is hard to provide archaeological validity for an advancement of such a construct. Elements of the construct such as attention can be successfully argued to have been present during adhesive production, but indications of the enhancement of such a construct would require evidence that these concepts are somehow more advanced than during a previous period, requiring a temporal comparison. As this does not fall within the scope of this thesis, archaeological validity cannot be proven to be intact.

Haidle's (2010) proposed problem-solution paradigm might present a way in which the development of working memory can nonetheless be investigated, as it does not rely on standard archaeological traits of cognitive sophistication. While perhaps not being able to comment directly on their level of working memory capacity, it might be able to provide information on the  possible differences in level between AMH and Neandertals working memory and executive function, through a comparison of the elaborateness of their adhesive production sequences. For AMH, the flow chart shown in figure 6 illustrates the steps taken in the production sequence and thereby the problem-solution distance for the creation of the adhesives made at Sibudu Cave. This operational sequence can be used in a comparison with that of Neandertals in the following chapter.

#### *3.7.2 Fourth-order abstraction*

The concept of fourth-order abstraction deals with the ability to employ meta-representation, or in other words the representation of mental representations. The term meta-representation is often used synonymously with Theory of Mind, and is used to describe the cognitive capability of attributing mental states such as knowledge, beliefs, intents, desires and thoughts to yourself and to others, with the knowledge that these mental states might vary per person, and may or may not correspond with the actual world itself. The idea of fourth-order abstraction derives from Barnard's (2010) model of working memory and cognition. This model describes the evolution of human cognition through the continuous adding of elements, or subsystems. It starts with a four subsystem model that deals with basic sensory input and output, and ends with a nine subsystem model that represents fully modern cognition with all its abilities; including conceptual planning and Theory of Mind, an aesthetic sense, and algorithmic capacity, and abstract thought; and supports productivity and learning (*ibid.*). The adding of elements thus represents steps in the evolution of human cognition through time. Fourth-order abstraction comes into play only after the ninth subsystem is in place, and is therefore also representative of fully developed cognitive sophistication (*ibid*.). Barnard has described these fourth-order abstractions as being comparable to feelings of intuition or wisdom (*ibid*., 51).

Wadley (2010) has proposed that fourth-order abstraction is shown to be present in the adhesive production process at Sibudu Cave. She argues that the combining of different materials, all having different qualities that need to be carefully considered before each adhesive production, and the consequent need for constant evaluation, anticipation, and adjustment, is unlikely to have been possible without a certain level of intuition, and abstractions to explain concepts such as stickiness, workability, consistency, viscosity, plasticity, temperature, shrinkage, past, future, and irreversibility.

It is quite hard to imagine creating an adhesive without the help of these terms, especially as anyone attempting to recreate the process today would have knowledge of the meaning of these concepts. People creating such adhesives would undoubtedly have benefited from the understanding and use of these abstractions, but there are nonetheless a few problems with this implication.

The main problem lies with a technical aspect of the subsystem model proposed by Barnard (2010). In order for the conclusion to be drawn that people at Sibudu Cave had a nine-subsystem mental architecture, thereby being equivalent to modern cognitive sophistication, fourth-order abstractions (the use of abstract ideas and  the ability to express them through language) had to have been used. Up till now however, bridging evidence for this conclusion is lacking. As suggested by Barnard, further research involving novices that are instructed with and without the help of abstract concepts could provide this evidence in the future (*ibid*.).

Going back to Botha's diagram therefore, it seems that the bridging argument F is lacking the power to connect the procedures and knowledge of E (switching of attention, evaluation, adjustment etc) to the cognitive prerequisites in G, in this case fourth order abstraction. It fails to meet the criteria for the requirement of warantedness, and as such does not have cognitive validity required for Wynn and Coolidge's strict standard (2008). Though Barnard's theory in itself has support from cognitive science, in order for it to have cognitive validity in this situation, it must be shown that abstract concepts were not only present for the production of these adhesives, but also necessary. For archaeological validity, there must be evidence of abstractions having been used during the process. As all we can say is that Wadley made use of these concepts during her attempt at reproducing the adhesive, but do not have direct evidence that they were used during the original attempt, the argument lacks suitable grounding as well as warranting.

### *3.7.3 Multi-level operations and non-routine thought*

Amati and Shallice (2007) have placed an emphasis on the concepts of multi-level operations and non-routine thought as being important indicators of sophisticated cognition. These concepts emerge from their computational model, dealing with the evolution of cognition, and the differences between species, and will be discussed below.

This model deals with so-called h-capacities, which are capacities specific to modern human cognition as compared to non-humans. These capacities include concepts such as language, abstract thought, Theory of Mind, anticipatory planning, organisation and more (*ibid*.). The model is loosely divided into three computational types that have developed over time to deal with routine operations and supervisory operations, which represent classifications of capacities used in the model (*ibid*.). Type one computations are the most basic, they deal with routine operations and are seen in many mammals (*ibid*.). Type two and three computations are already more limited species-wise, while type three computations are specific to modern humans, and allowing for novel strategy generation, open-ended goal setting and prospective memory (*ibid*.). Amati and Shallice (*ibid*.) have identified a concept specific to modern human cognition that they have termed “latching”, which is the driving force behind these capabilities. Latching is an adaptive strategy to deal with novel situations which is only found in type three computations. It is necessary for abstract projectuality, a distinctly human trait (*ibid*.). It is this capacity within type three computations that is responsible for fluent, non-routine thought, goal-directed strategy adaptation, and multi-level operations required for problem solving(*ibid*.).

Wadley has suggested that the adhesive production process, which as discussed above, calls for constant attention and adaptive problem solving, is an example of this type of non-routine thought. She argues that during the entire process people had to have been mindful of changes and problems that would have required adaptations in their strategy. It seems very likely that the production of the adhesive did indeed require non-routine thought and strategy adaptation, linking it directly to modern human cognitive sophistication.

Brain structures have been identified that are relevant to the operations central to type I and type II computations, dealing with the routine operations found in most mammals. The model proposed by Amati and Shallice (2007) has unfortunately not found any scientific evidence for brain structures controlling the concept of latching, and thus for type three computations. Though we are certainly capable of the abilities tied to this concept of latching, the lack of neurological support for an overarching construct responsible for these capabilities means it cannot (yet) be tied directly to anatomical modernity or its accompanying cognitive sophistication. This is consistent with the theory that no qualitative change has taken place in the human brain during the shift to so-called modern behaviour (Tattersall 2002). Amati and Shallice (2007) have proposed for instance that a basic functional architecture was possibly already in place in earlier humans such as *Homo erectus*, whereas cognitive ability did continue to evolve (*ibid*.).

As latching is introduced as a concept responsible for the h-capacities specific to modern humans, and the level of cognitive sophistication for AMH in the past is still under discussion, their cognitive complexity and possession of these h-capacities cannot simply be assumed. We therefore need to look to the archaeological evidence for clues as to the validity of this model.

Amati and Shallice (2007) have looked into this problem through their list of h-capacities. Most of these, such as Theory of Mind, abstract thought, dynamic concepts, and others, are pretty much impossible to find within archaeological contexts. The only h-capacities that are supported by archaeological or anthropological evidence are tool making, aesthetic sense, and visual representation. For tool production, the link to modernity is made through the appearance of mode 4 technology in Europe and Africa around 40 kya, bringing greater differentiation and standardization of forms, indicating “more clearly distinct mental objectives” (*ibid.*, 363). The other two capacities rely on evidence of markings and symbolism, arising in Africa and Europe around 75 kya. Though tool production makes a fair case, the other two capacities are speculative at best. There is often little proof of the exact meaning of symbols or signs that appear in the record. The importance of symbolism has also been pulled into discussion recently, as mentioned earlier. Wadley's (2010) argument would therefore be much stronger if there were more archaeological evidence available that could tie Amati and Shallice's (2007) construct of latching to the archaeological record directly.

Though it seems fairly clear that the adhesive production process did call on non-routine thought and strategy adaptation, the underlying framework of these concepts does not provide very strong evidence that this was a trait specific to anatomically modern humans. Once again going back to Botha's (2008) critique it is therefore not only not suitably grounded in archaeological evidence, but the lack of neurological support also makes it unwarranted. By Wynn and Coolidge's (2009) strict standard it is therefore lacking in both archaeological and cognitive validity.

#### *3.7.4 Mental rotation*

Mental rotation involves the ability to mentally rotate representations of two- or three-dimensional objects. It is often used in psychological tests to determine the cognitive development of infants, or the capacities of subjects with brain-lesions. Performance on spatial tasks such as complex span tasks, involving mental rotation of for instance blocks or letters, is linked to higher order cognitive capabilities such as executive function and complex reasoning (Kane 2004). Wadley (2010) has argued that the capacity for mental rotation is shown through the different placements of points and segments hafted onto the spears at Sibudu Cave. She suggests that people had to have been able to think abstractly about the placement of these inserts in order to determine their later functions as tools. It does seem rather strange if the different placements were all due to coincidences or random action, more likely people did indeed purposefully place the inserts a certain way, with a certain function in mind. Besides being obviously difficult to prove however, mental rotation is also not necessarily an ability reserved specifically for anatomically modern humans. Going back to Barnard's (2010) subsystem model of mental architecture, great apes have been shown to have a six-subsystem mental architecture that shows enough of a grasp of spatial-praxis organization that it consequently shows enhanced working memory (*ibid.*).

Research on chimpanzees has even shown them to have enhanced working memory for visually presented numerical stimuli that is even better than that of humans (Inoue and Matsuzawa 2007). Barnard is of the opinion that this spatial-praxis capability and sophisticated pattern recognition would support mental rotation and other complex spatial-praxis behaviours in great apes. Needless to say, if should this be the case, it follows that the capabilities were present not just for AMH, but for other hominin species as well. Further research would of course be required to settle this matter.

As the archaeological evidence supports the conclusion that the Sibudu inhabitants were capable of mental rotation, the argument seems to be grounded, showing archaeological validity. The lack of consensus as to whether mental rotation can be considered a strictly modern human trait means the argument cannot yet be named cognitively valid or completely warranted. This would require further investigation, perhaps into the extent of mental rotation capabilities of humans and primates.

### *3.7.5 Embedded recursion*

Recursion is the repeating of items in a similar way. Embedding is the process of containing some form of structure within another structure, thereby a form of recursion in itself. This can be understood most clearly through the example of language, where sentences can be combined and slightly restructured, yet keep their inherent meaning. Recursion has been central to many theories of language, most prominently those of Noam Chomsky (1960). Because of its repetitive nature, it is inherently linked to working memory development, from where it needs to be recalled in order to be repeated. With this concept, language could potentially have infinite combinability, as long as the initial product is held in mind. Though the importance of recursion in language has been challenged by Everett (2005), who claims that not all people use a language in which recursion plays an essential role, it has recently been shown through neurolinguistic studies to be supported by neurobiological brain structures that deal specifically with recursive language, which are present in all humans (Kaan *et al.* 2002). As discussed in the previous chapter, the link has been made from language to tool use, arguing that the manipulation of objects can show structural and cognitive parallels to language, including recursion and concepts such as past and future (Haidle 2010). It has been suggested that the creation of adhesives also employs these linguistic tools (Reuland 2010) through the need for constant attention, feedback, assessment and readjustment in order to produce a working product. The combinability also has the potential to be infinite, if the maker can keep in mind what has been done and what still needs to be done, and can adapt to changing circumstances.

Though neurological support is at hand for the construct of recursive language being present in all humans, there is of yet no supporting evidence that a technical recursive element in tool use or any other technical capacity is also specific to cognitive sophistication, or that it is directly connected with recursive language. While Wadley (2010) argues that cognitive sophistication is shown through a technical recursive element in the adhesive production process, there is no evidence that recursive language was used. While the production process does indicate recursive tactics to have been employed, giving the technical element of recursion archaeological validity, this technical recursive element unfortunately does not have any support from cognitive science, causing it to be unwarranted. While recursive language does have cognitive support, it has neither been shown to be present during the adhesive production process, nor necessary, leaving it ungrounded as well as unwarranted.

### *3.7.6 Cognitive fluidity*

Cognitive fluidity (Mithen 1996), as discussed in the previous chapter, refers to the interaction of different types of intelligence, which where previously separated in the closed-off domains of a modular mind. The ability of these different domains to interact with one another, is suggested to be specific to the modern human mind, indicating cognitive sophistication.

It is Wadleys (2010) argument that cognitive fluidity can be seen in the Sibudu Cave adhesive production process. Mithen (1996) describes how a mind with phase two intelligence would not be capable of combining social and technical intelligence, and would therefore leave no traces of for instance tool production in areas of social gathering. The need to be able to do and think several things at ones, such as mixing multiple ingredients, adjusting to changes, tending the fire, talking, mentally rotating segments and so on, according to Wadley (2010) shows cognitive fluidity. It does seem that there would have to have been some interplay between different forms of intelligence for the creation of this adhesive. While this is not  necessarily a social component, technical and natural history intelligence, as well as possibly language, would have to have interacted with one another. The knowledge of raw materials, where to find them, what uses they have and how these can be accomplished, necessary for the adhesive production, fall under natural history intelligence. The knowledge of how to deal with technical elements such as building a fire, combining the materials and drying the adhesive properly, fall under technical intelligence. The full production process would therefore require a combination of these different elements.

As discussed however, Mithen's (1996) theory of cognitive fluidity has received much criticism from cognitive science, making it unwarranted. Archaeological evidence discussed earlier, in the form of the Schöningen spears (Thieme 1999, 2005) has also shown this theory not to be properly grounded.

### *3.8 Apprenticeship and learning*

Though several of the above cognitive prerequisites proposed by Wadley  (2010) seem to have been involved in the production of the Sibudu adhesives, none of them haven proven to be able to live up to Wynn and Coolidge's (2009) strict standard completely, failing to provide either cognitive or archaeological validity. The same can be said of Botha's (2008) schematic argument. The bridging arguments linking the procedures and knowledge involved in the production sequence at Sibudu Cave lack either proper grounding or proper warranting for the cognitive inferences made from them.

An alternative to these cognitive models for the adhesive production process at Sibudu Cave can be found in Wynn and Coolidge's (2009) theory of apprenticeship and learning. Taking equifinality into account, when there are different ways of reaching a destination, or in this case a final product, Occams razor states that it is probably the simplest one that is responsible. With the models of cognition used by Wadley all implied to be connected to advanced cognitive sophistication and executive functions, the apprenticeship and learning model would qualify as the simpler route. This method differs from more innovative ones requiring executive function control (Wynn and Coolidge 2007b). Seeing as expertise has been shown to be capable of producing a hafted spear (Wynn and Coolidge 2007b, it would quite possibly also be capable of producing an adhesive like the ones produced at Sibudu Cave. This possibility will be discussed in more detail below.

The evidence discussed in the previous chapter, of apprenticeship and learning being used as a technique by bonobos and chimpanzees, as well as by people alive today, implies that our common ancestor could also have employed this technique for technical learning and manufacture, and by extension, so could the people of Sibudu Cave.

I would argue that the work of the Langda adze makers, through the obtaining and identifying of separate raw materials, as well as the production of extensively worked core forms, is comparable to the combining of raw materials in the production process of the adhesives created at Sibudu Cave. Combined with the ability of expertise through apprenticeship to be able to not only master the basic skills but also be able to adapt to changing circumstances in the production process (Wynn and Coolidge 2007b), I would argue that expertise may well have been able to account for the production of compound adhesives at Sibudu Cave. The skills now attributed to cognitive sophistication might well be explained by an accumulation of knowledge, stored in procedural memories, as proposed by Wynn and Coolidge (2007b), similar to the “stock of knowledge” (Kellar and Kellar 1996) concept. Years of apprenticeship could have allowed for the storage of procedures for a range of adaptations to problems and interference that might occur during the production process, allowing people to draw from these stored responses when necessary, similar to the “umbrella plan”(*ibid*.) concept.

The evidence from the Stout's work as well as Wynn and Coolidge's (2009) analysis of Levallois reduction would imply that this theory is archaeologically valid. The archaeological validity of this theory for adhesive making cannot be directly proven however, as we cannot provide irrefutable proof that this was the technique employed for the creation of the Sibudu Cave adhesives. The evidence from modern day ethnographic research as well as research into the behaviour of chimpanzees and bonobos however, indicates that the theory does have cognitive validity.

### *3.9 A guideline for cognitive inferences*

In order to get a better idea of exactly which procedures and knowledge are required to make grounded and warranted, archaeologically and cognitively valid arguments as to the cognitive inferences made by Wadley, I have compiled a list of necessary requirements for each of the cognitive constructs implied by Wadley, as shown in table 1 below. Archaeological validity is shown through the requirement of there being proof of a certain capability being present. Cognitive validity on the other hand requires two separate lines of evidence, namely proof that the capability was necessary for adhesive production, and support from cognitive science, which is outlined in the table.

This list will be used as a guideline in the coming chapter in order to examine the validity of inferences made on cognition in the Neandertal context. Table 2 describes the actual steps taken in the adhesive production process that correspond with each of the discussed constructs.

**Table 1** Guideline for the requirements necessary for cognitive inferences with archaeological and cognitive validity.

| **Mental constructs** | **Requirements for evidence of cognitive sophistication** | |
|---|---|---|
| | **Archaeological validity/ groundedness** | **Cognitive validity/ warrantedness** |
| **Enhanced Working Memory** | • Evidence that the Sibudu cave adhesive makers had enhanced working memory e.g. superior attention, language acquisition, intelligence, memory. | • Proof of the necessity of enhanced working memory to create the adhesives<br>• Cognitive/Neurological evidence of enhanced working memory being linked to cognitive sophistication. |

| | | |
|---|---|---|
| **Fourth-order Abstractions** | • Evidence of abstractions having been used in production sequence | • Proof of the necessity of abstract concepts to create the adhesives -eg reproduction with/without abstract guidance<br>• Cognitive/Neurological evidence of fourth-order abstractions being linked to cognitive sophistication. |
| **Multi-level operations and non-routine thought** | • Evidence of changing circumstances that require adaptation of procedures, switching of attention and anticipation of problems | • Proof of the necessity that successful production is not possible without the ability to adapt, switch attention, and anticipate problems<br>• Cognitive/Neurological evidence for "latching" or h-capacities linked to cognitive sophistication. |
| **Embedded Recursion** | • Evidence of use of language for production sequence<br>OR<br>• Evidence that technological recursion occurred during production sequence -eg attention, feedback, adjustment, concepts of past and future | • Evidence of necessity of language use during adhesive production -eg through reproduction with without verbal guidance<br>• Evidence of recursion in language being specific t cognitive sophistication.<br>OR<br>• Evidence of necessity of technical recursion elements for adhesive production<br>• Evidence linking recursion in technical capabilities to cognitive sophistication. |
| **Mental Rotation** | • Evidence of mental rotation of items -eg through differing placements of items | • Evidence of necessity of mental rotation for adhesive production<br>• Evidence that mental rotation is linked specifically to cognitive sophistication. |
| **Cognitive Fluidity** | • Evidence of combining of different forms of intelligence -eg social and technical intelligence | • Evidence of necessity of combining different forms of intelligence for adhesive production<br>• Cognitive/neurological evidence for theory of domain specific intelligences and cognitive fluidity for cognitive sophistication |

| | | |
|---|---|---|
| **Expertise through apprenticeship and learning** | • Evidence of expertise/apprenticeship being present/responsible for the adhesive production process<br>-eg stock of knowledge, umbrella plan, constellation present | • Evidence of the necessity of expertise/apprenticeship for the production of the adhesive<br>• Cognitive/Neurological evidence for the theory of expertise through apprenticeship and learning. |

**Table 2** Knowledge and Procedures shown in AMH adhesive production process that correspong to cognitive inferences.

| Cognitive construct | Steps of adhesive production process shown, corresponding to requirements of archaeological and cognitive validity |
|---|---|
| **Enhanced Working Memory** | • No elements identified. |
| **Fourth-order abstractions** | • Knowledge of required consistency of adhesive, knowledge of order of steps in the production procedure. |
| **Multi-level operations and non-routine thought** | • Keeping attention on drying adhesive to ensure working end-product<br>• Rotating adhesive over fire or moving it further from the fire when it threatens to overheat |
| **Embedded Recursion** | • Adding of certain ingredients, adjusting quantities, rotating the adhesive periodically over the fire |
| **Mental Rotation** | • Rotating the segments in one mind to envisage the different possible placements for tools |
| **Cognitive Fluidity** | • Knowledge of e.g. raw materials and fire making/tool making |
| **Expertise through Apprenticeship and Learning** | • Range of knowledge of raw materials, fire making, and composite tool production show stock of knowledge - adhesive mixing, fire building, adhesive application shows umbrella plan – toolsemployed: adhesive, grinding stone, fire, etc. show constellation |

*3.10 Chapter conclusions*

The cognitive concepts inferred by Wadley (2010) seem to be based on fairly strong evidence from the production process described for Sibudu Cave. It seems that the people making these adhesives very likely possessed a cognitive sophistication capable of problem solving, mental flexibility, and adaptation to changing circumstances. However, the problems with many of the implications lie with the models themselves. Amati and Shallice's (2007) theory, though convincing evidence was given by Wadley (2010) for non-routine thought, was shown to lack any neurological basis for their type three computations, as does Mithen's (1996) theory for cognitive fluidity, and Wynn and Coolidge's (2009) theory of enhanced working memory. This is not surprising considering the limited amount of data available in the archaeological record to support theories of cognitive evolution. Mental rotation was likely present, but was shown not necessarily to be specific for only anatomically modern humans. Barnard's (2010) meta-representation theory, though well-founded, has not yet proven the use of abstractions to be necessary for adhesive production. Recursion appears to be well founded scientifically, but as a language construct, not a technical ability. An alternative explanation may also be sufficient to account for these aspects of adhesive production, namely the method of expertise and learning proposed by Wynn and Coolidge (2007b).

Whether the inferences made in this chapter are also applicable to the Neandertal context will be shown in the next chapter, where comparisons will be made with the knowledge and procedures involved in the Neandertal adhesive production process. Archaeological and cognitive validity will be investigated, and the alternative theory of apprenticeship and learning will again be considered as an explanation of the adhesive production.

## Chapter 4. Neandertal adhesive making in palaeolithic Europe

### *4.1 Introduction*

Having studied all the different archaeological and cognitive aspects of AMH adhesive production at Sibudu Cave, it is now time to look more closely at these same aspects for Neandertal adhesive production. This will be done by examining evidence of hafting and adhesive production from the two German sites of Königsaue and Inden-Altdorf. The evidence for hafting and adhesive production will be described and analysed, and checked for archaeological and cognitive validity. The key knowledge and procedures involved in the production will be outlined, and the cognitive inferences implied for AMH adhesive production will be considered as possibilities for explaining these key aspects of knowledge and procedures. The theory of expertise through apprenticeship and learning will be considered as an alternative explanation. These cognitive models will be tested for groundedness and warantedness.

### *4.2 Background and Research context*

During the Middle Palaeolithic, great changes occurred throughout Europe. For the large part dominated by Neandertals, the later Middle Palaeolithic and early to middle Upper Palaeolithic saw not only the advent of anatomically modern humans spreading throughout Europe, but also a range of technological, climatic, behavioural, and possibly even cognitive changes. Changes were seen in tool types (Bar-Josef 2002), raw materials were gathered from further distances through long-distance exchange networks (McBrearty and Brooks 2000; Bar-Josef 2003), new materials such as bone and antler were exploited more (Bar-Yosef 2003) and expressions of symbolic or artistic behaviour were starting to be seen throughout Europe (Conard 2009; Zilhao 2010). For Europe these changes occurred during the early to middle Upper Palaeolithic, whereas the period under discussion for the coming section deals with the earlier Middle Palaeolithic period, before the presence of AMH.

During that period, from around 200 ka to 30 ka (Wynn and Coolidge 2011), Neandertals dominated throughout Europe. As discussed in the previous chapters, though often thought to have been less advanced than AMH, they have been shown to have employed a range of behaviours similar to that of AMH, including range expansion, planning behaviour, similar resource exploitation, adaptation to numerous and diverse ecosystems, symbolic behaviour, and probably language (Deacon 1997; McBrearty and Brooks 2000; Adler *et al.* 2006; Tattersall 2009).

One of the behaviours seen in both the AMH and Neandertal context is that of adhesive production. For AMH, adhesive making has been very clearly linked to certain cognitive capabilities. This is an excellent behaviour to use as a comparison for cognitive capabilities as there are several occurrences known from the European record of Neandertals creating adhesives, with which to compare them. Occurrences from two of these sites will be used for further analysis, namely the site of Königsaue, Germany, and that of Inden-Altdorf, also in Germany. The adhesives used at these two sites were both made from birch bark tar (Koller *et al.* 2001; Pawlik and Thissen 2011). Chemical investigations, usually through gas chromatography/mass spectrometry, have confirmed the widespread use of birch bark tar for adhesive production, sealants and waterproofing agents in prehistoric European context (Aveling and Heron 1999; Pollard and Heron 1999; Regert *et al.* 2006). Especially from the Neolithic period onwards, the use of birch bark tar seems to have become more and more common (Binder *et al.* 1991; Charters *et al.* 1993; Regert *et al.* 1996; Regert *et al.* 1998). Use of birch bark tar in earlier palaeolithic times has also been discovered at several sites (Koller *et al.* 2001; Grünberg 2002; Mazza *et al.* 2006; Modugno *et al.* 2006; Pawlik *et al.* 2011). Several attempts have been made to reproduce these adhesives in ways that would have been possible in Palaeolithic times, with corresponding technology and materials (Todtenhaupt *et al.* 2007; Todtenhaupt and Kurzweil 2007; Pomstra and Meijer 2010)

Examples of the adhesives found at Königsaue and Inden-Altdorf will be analysed, their production processes will be studied and compared to that of Sibudu Cave, and their cognitive implications will be looked at. The information concerning these sites will come mainly from the publications of Koller and colleagues (2001) for Königsaue, and Pawlik and Thissen (2011) for Inden-Altdorf. As these two sites share a similar research background as well as a similar adhesive type, the evidence for the production of the adhesives will be discussed for the two sites together. This production sequence will then be analysed to see whether any cognitive inferences on the makers of the adhesives might be made through it. Any inferences made will of course be guided by Botha's (2008) structured line of argument, Wynn and Coolidge's (2009) strict standard, and the guidelines for the requirements for evidence of modern cognitive sophistication set up in the previous chapter.

*4.3 Königsaue, Germany*

The first site that will be looked into is that of Königsaue, Germany. Situated at the shore of lake Asherleben, it lies in the province of Saxony-Anhalt, Eastern Germany (fig 8). It was first discovered by Dietrich Mania in 1963, after the lake had been drained, and mining into the lignite bed found near and underneath the lake had begun. The mining exposed several layers with Middle palaeolithic remains, including a great deal of flint objects. These vary from prepared cores to bifacial tools. Animal bones indicate mammoth, woolly rhino, red deer, horses and reindeer may have been hunted at the site. Among these finds were also two pieces of pitch, seen in figure 9. These pieces clearly show the marking of being man-made. Their shape, as well as indentations of a knife blade and wood-cell structures, and a partial fingerprint on one of the pieces are consistent with hafting. Analysis of the two pieces showed them to have characteristics specific to birch tar. The dating of the site has been determined through the stratigraphy of the Ascherleben lake deposits. These deposits give a very accurate climatic record up to 125.000 BP (Koller *et al.* 2001). The deposition sequence of the lake has been divided into fifteen sedimentation cycles with corresponding climatic zones. Within the third sedimentation cycle were three horizons that produced the Middle palaeolithic finds, labeled horizons A, B, and C, as shown in figure 10.

This sedimentation cycle was formed during the second interstadial of the Weichselian (Koller *et al.* 2001). These horizons have been Geo-stratigraphically dated to over 80.000 BP, corresponding to Oxygen Isotope Stage 5a (*ibid*.). The pitch pieces in these horizons have also been separately dated for further accuracy. AMS radiocarbon dating produced ages of 43.800 +- 2100 BP for the sample from the older horizon A and

48.400 +- 3700 BP for the one from the younger horizon B (Hedges *et al.*1998).

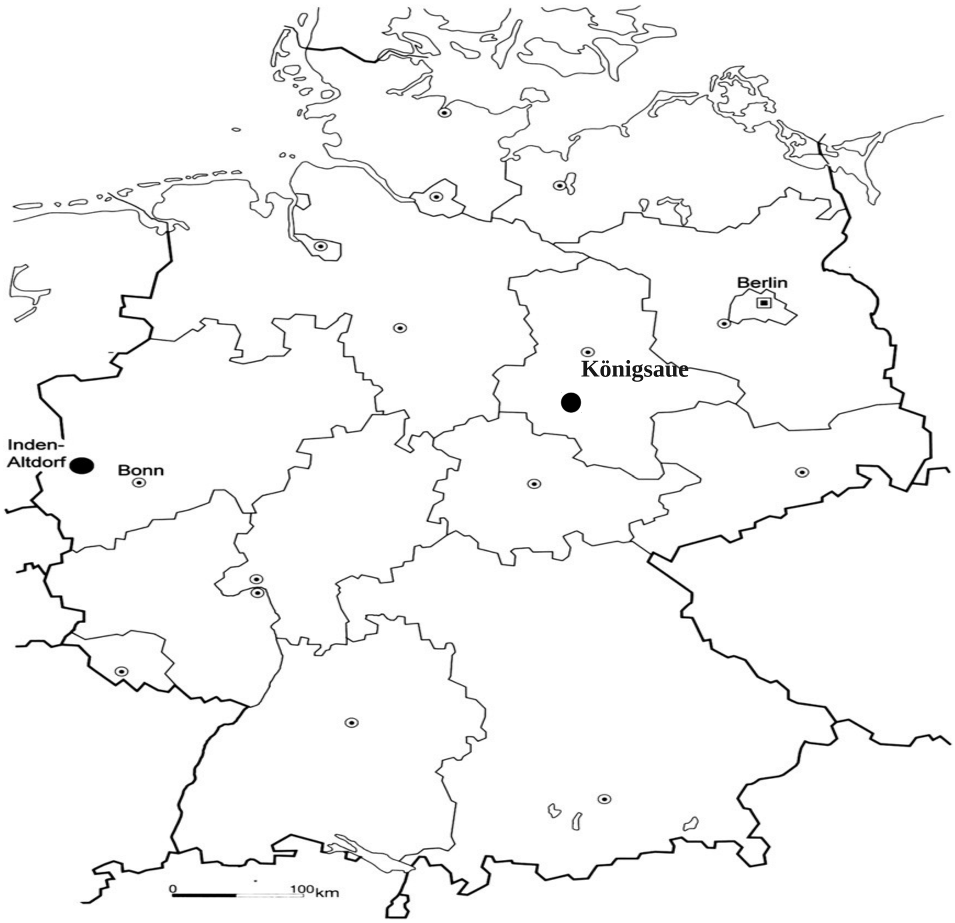


**Figure 8** Map showing the location of Königsaue and Inden-Altdorf.

**Figure 9** Pitch pieces from Königsaue A and B, respectively (Koller *et al.* 2001).

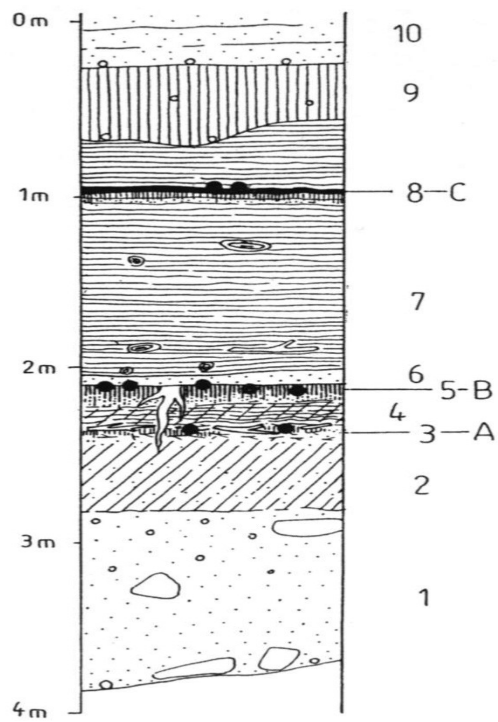


**Figure 10** Stratigraphy showing the Middle Palaeolithic horizons A, B and C of the northern bank of former lake Ascherleben (Koller *et al.* 2001).

This quite obviously does not correspond with the earlier mentioned geological dating. Due to the inaccuracy of radiocarbon measurements over 60 thousand years (Plastino *et al.* 2001), the authors argue that the dates for these pieces can be seen as a minimum value rather than a definite one (Koller *et al.* 2001). Due to their ages, these finds have been assigned to the Neandertal period. Accompanying finds such as the flint tools suggest that the horizons may belong to separate cultures however. The abundance of bifacial tools in layer A has led the authors to conclude that this layer belongs to the Micoquo-Prodnikian industry, possibly assigned to an early form of modern *Homo sapiens* (*ibid*.). This seems rather unlikely given the early date however, especially as this is considered a minimum value.

Layer B on the other hand shows mainly prepared cores, clearly linking it to the Neandertal Mousterian culture (Koller *et al.* 2001). The clear stratigraphy, along with a detailed analysis of the pitch pieces, which will follow, make this an excellent first site to use as a comparison for the finds at Sibudu Cave.

### *4.4 Inden-Altdorf, Germany*

The second site that will be used for comparison is that of Inden-Altdorf, also in Germany (fig 4.1). Over 3000 square meters in total, the site is situated in the Inde river valley in Western Germany, and borders the Pleistocene Maas river terrace. During lignite mining excavations in the valley in 2006, Middle Palaeolithic remains were found at the site. Finds include fireplaces, pits, large stones and many stone artefacts. Paleobotanical analysis of charcoal samples at the site have placed it in Marine Isotope stage 5e (Lang 1994), with dates between 128 and 115 ka BP, corresponding to the Eemian interglacial (Pawlik and Thissen 2011). The geology and stratigraphy for the eastern slope of the valley can be seen in figure 11, where layers 10 and 11 correspond with the Eemian interglacial (*ibid.*). The artefact assemblage found at the site consists of several different elements, such as unifacial knives typical of the Micoquian, Levallois flakes and cores, Kostenki and Pradnik knives, and Upper Palaeolithic tools such as burins, scrapers, blades and blade-cores. Many artefacts in the assemblage show blackish residues (fig 12), which were identified as dried pitch remains, and are discussed in more detail below. These residues were found on projectile points as well as other types of tools. Signs of wear and tool use could be seen on the distal parts of these tools, but not on the part where the pitch covered them, consistent with hafting (Pawlik and Thissen 2011). Use-wear analysis also indicated clear signs of hafting on many of the tools. Microscopic analysis showed the residues to be very similar to birch pitch residues found on tools from the sites of Burgaschisee-Sud, Switzerland (Pawlik 1995), Henauhof-Nord, Germany (Pawlik 1995,1997), and Ullafelsen, Austria (Pawlik 2004), confirming their nature. The similar industry, early age, and clear dating of this site, compared to the site of Königsaue, as well as of course the use of birch bark for the adhesive production, make this a good second site for analysis, which will be continued presently.

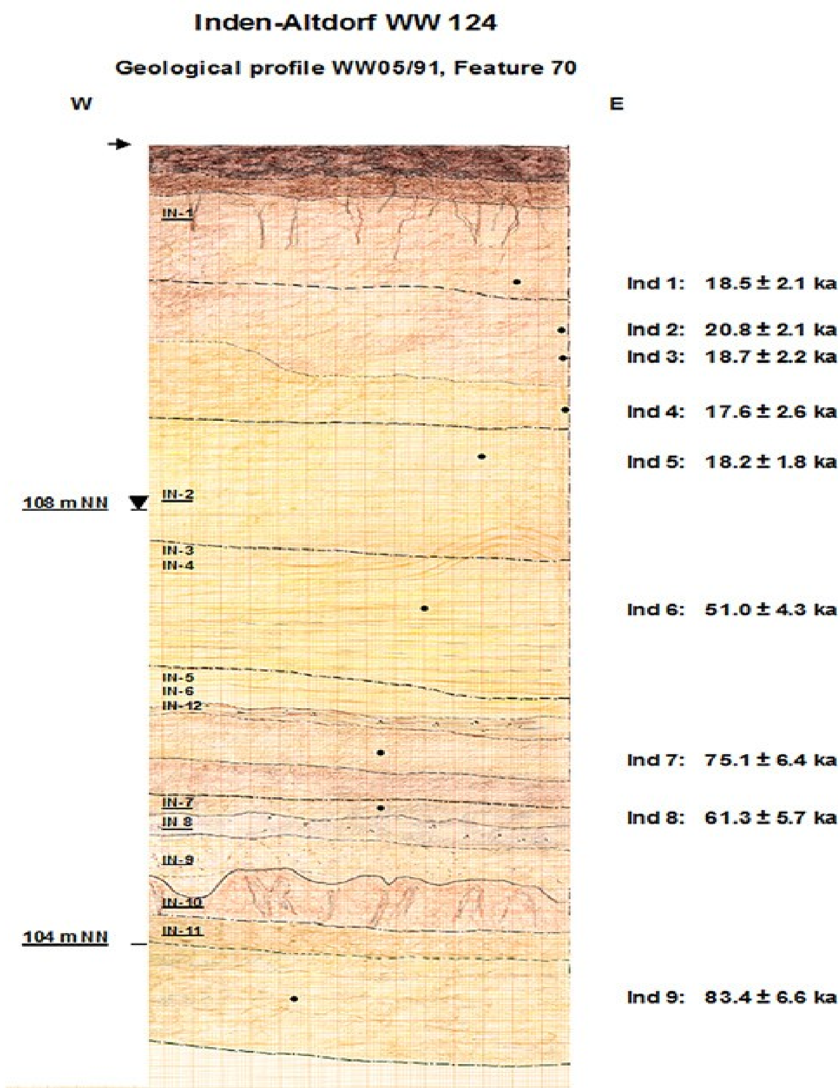


**Figure 11** Stratigraphy of the eastern slope of the Inde valley excavation, showing Eemian layers (Pawlik and Thissen 2011).

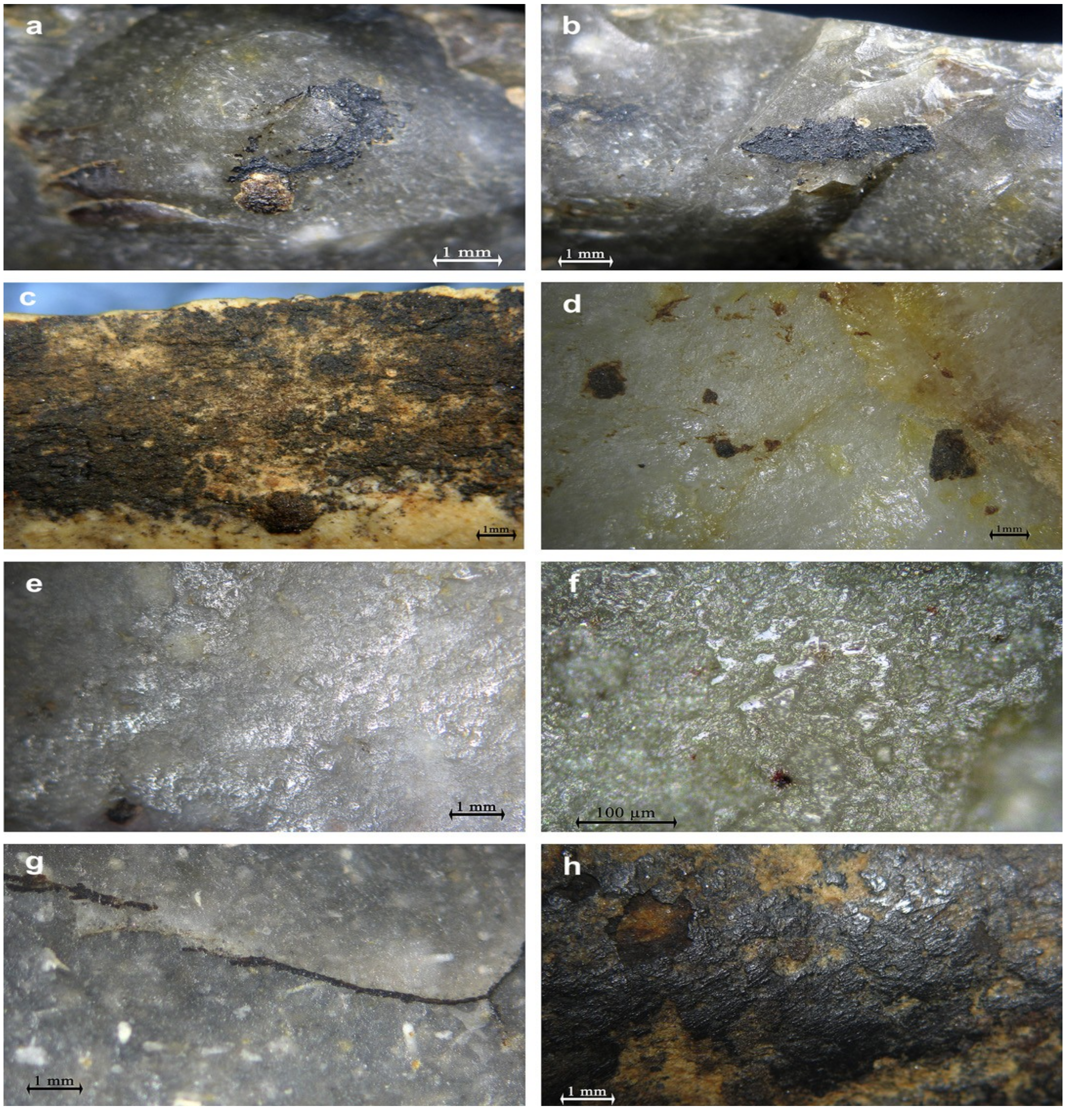


**Figure 12** Birch pitch residues found on artefacts from Inden-Altdorf (Pawlik *et al.* 2011)

## 4.5 Adhesive Production Process

### *4.5.1 Ingredients and Analyses*

In order to find out the composition of the adhesives from both sites, several analyses were performed by the authors in question. To identify the different elements in the samples, the pieces from Königsaue underwent a Gas chromatography-mass spectrometry analysis. The results were consistent with characteristics specific to birch tar, confirmed through results of earlier research (Sandermann 1965; Funke 1969; Sauter *et al.* 1980; Rottlander 1983). The sample from Königsaue B showed some plastisizers from contamination, but other than that both samples indicated no further ingredients than birch bark tar (Koller *et al.* 2001). The same is true for the adhesives found at Inden-Altdorf, where micro-wear and residue analysis was performed on a sample of 136 tools.

Micro-wear analysis indicated that 15 of these artefacts were used as projectile points, as indicated through the pattern of micro-wear. Most other tools showed indications of having been used in the processing of plants, skins, hides or harder tools such as bone, wood and antler. A total of 17 tools were identified as having been used for hafting and retooling purposes. Residue analysis showed residues on 83 artefacts. These residues then underwent closer inspection under a scanning electron microscope. The results of some of these can be seen in figure 12. The stereo microscopic analysis showed a dark black-brown viscous liquid with micro-hairline cracks in the surface (fig. 12a-d). Figure 12g supports the liquid state of the pitch at application, which had filled a hairline crack in the surface of the flint tool. The microscopic analysis indicated the presence of some plant tissue and fibers to be present in the some of the pitch samples, but these were shown to be derived from the birch bark itself, the sample not having been fully formed into pitch. Analysis showed a total of 39 tools to have been hafted and still carrying pitch residue. These included not only blades, but also flakes, pointed flakes, scrapers, retouched flakes, a unifacial point, and a combination tool point/burin. They were not only used as projectile points, but also for scraping, as knives, and several had multiple functions (Pawlik and Thissen 2011). A sandstone pebble was furthermore found to be completely covered with pitch residue. This item is thought to have acted as either a collection basin for the pitch during production, or as an item on which to keep the pitch during application, options which will be discussed further in the production process.

Further investigation through energy dispersal analysis of X-rays (EDX) was performed to investigate the elementary composition of the residues. Besides high amounts of carbon showing the organic nature of the pitch, peaks were also found for Potassium, Calcium, and Sulfur, as well as several other elements originating from the sediment itself. Comparisons with birch bark pitch from the Neolithic and Mesolithic sites mentioned above showed the same high peaks for these three elements, whereas these peaks were not found for analysis of pitch produced in air-tight metal containers often used in post-Neolithic pitch production (Pawlik 1995; Kurzweil and Todtenhaupt 1990). These results were found to be consistent with exposure to fire and ash during the production process, in line with results from other Mesolithic sites (Walker 2000, Dinnis *et al.* 2009).

Looking at Botha's diagram, this places us back at bridging argument B, connecting the artefact or feature of A; in this case stone tools and pitch residues; to the technical system C; hafting and adhesive making. An overview of this argument is given in figure 13 below. As extensive and archaeologically valid methods of analysis were used to conclude signs of hafting and adhesive production, this argument is grounded as well as warranted, the evidence definitely being relevant to the implication of hafting and adhesive making.

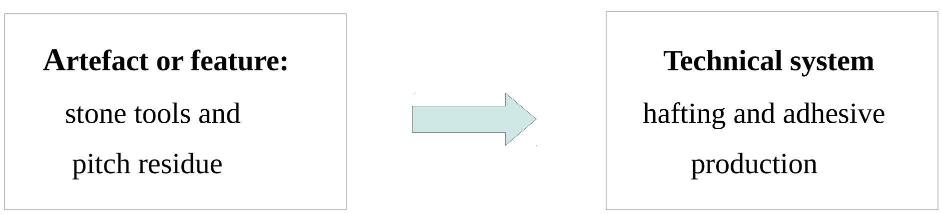


**Figure 13** Inferential step from artefact or feature to technical system, based on Wynn's (2009) adapted form of Botha's (2008) schematic argument.

*4.5.2 Production process*

Birch bark tar is created through a process known as dry distillation (Koller *et al.* 2001; Pomstra and Meijer 2010, Pawlik and Thissen 2011). This involves the heating of birch bark in an oxygen-free environment, creating a final product of birch bark tar which has been irreversibly transformed. The exact process by which this was done in the Palaeolithic times is not known for certain however. Besides the obvious tasks of gathering birch bark, wood, and making a fire, there are a few elements that are agreed upon by all to be critical to the successful production of birch bark tar. They are the absence of oxygen, or at least an oxygen low environment, and a controlled temperature of between 340 and 420 degrees Celcius (Koller et al. 2001; Pomstra and Meijer 2010; Pawlik and Thissen 2011). If these elements are not taken into account, one of three things may happen. Too low a temperature will leave the bark unchanged and produce no tar, too high a temperature will char the bark and turn it hard and brittle, and too much oxygen will burn the bark (Koller *et al.* 2001; Pomstra and Meijer 2010; Pawlik and Thissen 2011).

Though several attempts have been made to recreate this process, not all have been equally successful. Especially when  reproducing circumstances that would have been possible in Palaeolithic times, the production process is quite difficult. Methods are known from the 10th Century AD onwards where pitch is produced with the help of air-tight containers known as retorts (Czarnowski 1990; Kurzweil and Todtenhaupt 1990), where the containers are filled with birch bark rolls and placed in a charcoal fire. The lack of oxygen in the containers allows the birch bark to transform into tar (Pawlik and Thissen 2011). As ceramic or metal containers were not available in palaeolithic times however, a different method of production had to have been employed in these times. The presence of Potassium, Sulfur and Calcium in the analysis of the Inden-Altdorf pitch residues, indicating the exposure to fire and ash during the production, have led Pawlik and Thissen (2011) to propose that the pitch at the site may have been made through the the use of a narrow pit in the ground, functioning as the retort. They suggest that rolls of birch pitch may have been lighted at one end, and placed burning side down into the pit in the ground. The burning bark will cut off any oxygen from coming inside the pit, allowing the pitch to liquify. A stone placed at the bottom of the pit, such as the one found at the site, could have functioned to collect the pitch dripping down from the bark. This approach would be consistent with the findings at the sites of Inden-Altdorf and Königsaue. This approach is supported by evidence from the Mesolithic site of Henauhof-Nord, thought to be a hafting and re-tooling site for the repair of weapons and stone tools (Pawlik 1997), where an artefact made of birch bark wrapped around a core of pebbles and clay was found, presumably for the production of pitch (Kind 1997).

In an attempt to recreate the circumstances that produced the Königsaue pitch pieces, the Arbeitsgruppe Teerschweele of the Museumdorf Duppel performed several such experiments. These experiments consisted of heating rolls of birch bark covered in loam in a fire, heating them by placing them on pre-heated stone set in a hole in the ground, and distilling them underneath a fireplace (Todtenhaupt *et al.* 2007). Unfortunately, none of these attempts produced satisfying results.

Two methods that have been successful however were performed by Pomstra and Meijer in 2010. The description of these methods is adapted from their 2010 experimental report of the Steentijddag. The first method involved placing a flat piece of quartzite (15x18x4 cm) into a hole dug in the ground. On top of this flat stone a layer of birch bark approximately 3 cm thick was laid, and covered with a layer of sand, also approximately 3 cm thick. By flattening the surface from the outside, excess oxygen was prevented from reaching the layer of birchbark underneath. On top of these layers a fire was built and kept going for around an hour. A pyrometer was used to check the temperature of the fire, something that obviously was not available in prehistoric times, making the task that much more difficult in the past. After an hour a temperature of 380 degrees had been reached, and after another 15 minutes the decision was made to put the fire out and check the progress underneath. After a cooling off period of another 15 minutes the sand was removed, and a substantial amount of tar was found to have dripped onto the surface of the quartzite stone, enough to provide tar for the hafting of several tools. Because a large quantity of the bark had not been turned to pitch however, it was suspected that the fire could have been kept going for a while longer. The process may also have benefited from thinner strips of birch bark placed at cross angles to each other, to allow for better heat circulation over all the birch bark pieces, and thereby more room for adequate distillation of the tar. This method would be consistent with the findings of fire indications as well as the small flat stone covered in pitch found at Inden-Altdorf (Pawlik and Thissen 2011).

A second method was performed to see if tar could also be produced by means of a normal campfire, without having to go to the trouble of burying the birch tar, thereby hopefully reducing the time needed to produce the tar. Grooves were dug into the earth next to the campfire, into which rolls of birch bark 10-12 cm high and 5 to 7,5 cm thick were placed horizontally. The rolls were bound together with plant roots, covered with hot coals and woodash, and left to smoulder  for 10 to 25 minutes. This method produced small quantities of tar, which were stuck to the inside of the rolls and often mixed with sand and ash. Large parts of the birch bark also remained intact. In order to improve on this method the rolls of bark were rolled around sticks and placed in the ground vertically on top of a large piece of bark that was placed underneath to collect any tar dripping down. Though several attempts still showed the tar to collect within the rolls of birch bark instead of dripping onto the larger piece underneath, a significantly larger amount of tar formed through this method, with less contamination with sand and ash. This second method would also fit well with the findings at Inden-Altdorf (Pawlik and Thissen 2011).

Several attempts were made to improve upon these two methods, as some attempts using these methods still failed to produce a useful amount of tar. Failures were caused mainly by the temperature of the fire, the effect of wind, the length of time the birch bark was left to smoulder, and the depth and expertise with which it was buried. Especially without the help of a pyrometer as used in the first experiment, the temperature of the fire was very difficult to gauge, and required multiple attempts across many days to achieve correctly. During these attempts many of the pieces of bark either charred and were left unusable, or did not turn to tar at all. Wind was another highly influential factor in the process. A strong wind caused the temperature of the fire to drop out of range during several attempts, not allowing for any tar production. A windbreak was built in an attempt to keep the wind from influencing the temperature of the fire too much, which seemed to work well, yet on several occasions actually caused the temperature to rise so quickly as to exceed 400 degrees and char the birch bark underneath. The oxygen supply to the birch bark must be cut off to prevent the bark from burning and creating a useless end product. The depth at which the bark was buried (deep vs shallow), along with the way in which it was buried (vertically vs horizontally, thick strips vs thin strips), and the duration that it remained buried, all impacted the amount of tar that was produced and the quality of the final product.

In order to produce tar that is of a quality that can be worked with, and of a quantity that is worth the effort put into the production, complete attention is needed throughout the production process. The temperature of the fire must be minded constantly, the wind must be taken into account, the birch bark must be buried properly and taken out at the right time, and the oxygen supply must be properly cut off. If any of these elements is not done correctly, the tar will not form properly.

The authors suggest that it might have been possible that different methods were employed for different purposes. The second method achieved its goal faster, but also produced less tar, and therefore may have been used when only a little tar was needed, perhaps for the production or repair of only a few tools. The first method took longer, but also produced a significantly larger amount of tar, perhaps employed when large amounts of tar were needed, such as the production of several weapons and /or tools. Both methods fit well with the indications of fire and ash found at Inden-Altdorf, as well as the flat stone that was found covered in pitch residue. The experiments using these two methods have both shown that  it was definitely possible for people to create a birch bark tar even under Palaeolithic circumstances.

*4.6 Key Procedures and Knowledge*

In order to analyse the production sequence properly and be able to make any inferences on cognition, it is important to underline the key procedures and knowledge involved in the production sequence. This places us at bridging argument D in Botha's (2008) argument, linking the technical system to the knowledge and procedures, which can be seen in figure 14 below.

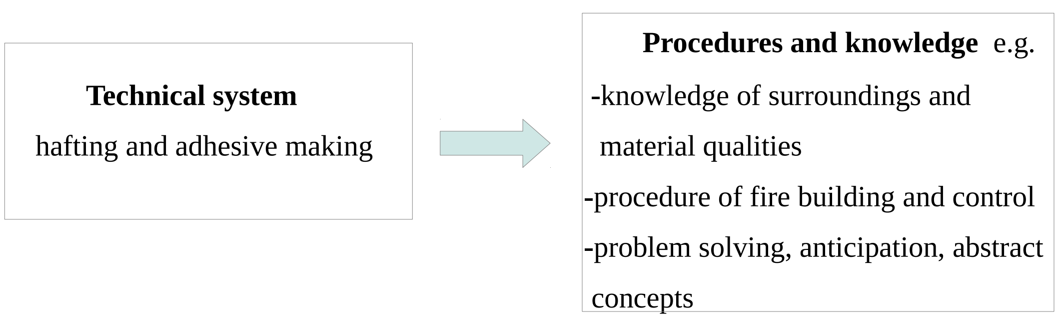


**Figure 14** Inferential step from technical system to procedure and knowledge, based on Wynn's (2009) adapted form of Botha's (2008) schematic argument.

The key elements of knowledge employed in the Neandertal adhesive production are as follows: 1. knowledge of the natural surrounding in order to find the birch bark, 2. knowledge of the qualities of birch bark in order to know how to use it in adhesive production, 3. knowledge of the technical procedures of fire making and temperature control, 4. knowledge of abstract concepts such as workability, dry, wet, liquid, solid, past, future. 5. Knowledge of the techniques of keeping and switching attention, anticipation, adapting to changing circumstances, and problem solving, 6. knowledge of the most beneficial duration of the distillation process. The key procedures involved in the adhesive production process include the following: 1. gathering the raw material, 2. burying the birch bark at the correct depth and angle,thereby cutting off the flow of oxygen to the birch bark, 3. building and controlling a fire at a temperature of between 380 and 420 degrees Celcius, 4. removing the birch bark and collecting the liquified tar for hafting. An overview of the steps taken in the production process can be seen in the flow chart below (fig 15).

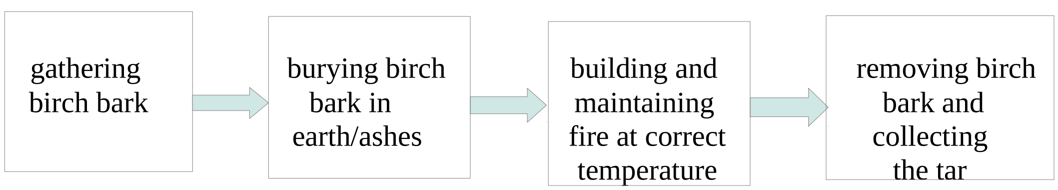


**Figure 15**. Flow chart of the Neandertal adhesive production squence.

### 4.7 Cognitive Prerequisites

Different methods are shown to have been capable of producing birch bark tar under palaeolithic conditions. A few elements have been shown to be crucial to the outcome of a useful end product. The temperature of the fire and the cutting off of oxygen are the main elements, but the duration of the fire, the depth at which the birch bark is buried, the manner in which it is buried, and the strength of the wind all play an important role in the outcome as well. Though the Neandertals adhesives described above are clearly an example of a simpler form of adhesive making that what we have seen from the Sibudu Cave context, this does not necessarily imply that simpler cognitive strategies were employed. As Haidle (2010) describes, only part of a people's cognitive capacities are visible in their material culture, and what is visible does not necessarily reflect their maximum cognitive capacity. Equally sophisticated cognitive abilities may have been employed, which is what will be analysed during the coming section.

The knowledge and procedures outlined above were crucial to the positive outcome of the adhesive production process, giving the inference cognitive validity. The archaeological validity of this inference, linking the technical system of hafting, to the procedures and knowledge listed above, is shown through the attempts at reproducing the adhesives discussed in the previous section. It seems that cognitive capabilities such as problem anticipation, ideas about future actions, and prepared responses and adjustments were equally necessary in the present context as in that of Sibudu Cave. Whether the capabilities listed above imply advanced cognitive sophistication or whether they were perhaps enabled through apprenticeship and learning, as suggested by Wynn and Coolidge (2007b) to be the main problem solving strategy of Neandertals, is discussed below. This places us at the final bridging argument of Botha's schematic argument, linking the procedures and knowledges involved in the production process to possible cognitive prerequisites, as shown in figure 16 below. The precise elements involved in the adhesive production process that correspond to each of the cognitive concepts under discussion is outlined in table 3 at the end of the cognitive prerequisite section.

**Procedures and Knowledge** e.g.:

-knowledge of surroundings and material qualities

-procedure of fire building and control

-problem solving, anticipation, abstract concepts

→

**Cognitive Prerequisites**

-Enhanced working memory

-Fourth-order abstraction

-Multi-level operations and non-routine thought

-Mental rotation

-Embedded recursion

-Cognitive fluidity

**Figure 16** Inferential step from technical system to procedure and knowledge, based on Wynn's (2009) adapted form of Botha's (2008) schematic argument.

### *4.7.1 Enhanced Working Memory*

For the theory of enhanced working memory to be a valid inference for Neandertal adhesive making, it needs to be shown that the makers of these adhesives used an enhanced form of working memory through construct such as attention, intelligence, language acquisition, learning or memory (Wynn and Coolidge 2009, 216). As mentioned in the previous chapter, this would require a temporal comparison, and therefore cannot be proven at this point. Enhanced memory being necessary for the adhesive making can also not be proven, and as has been discussed, the model itself lacks cognitive support, making the inference unwarranted. Haidle's (2010) approach of problem-solution distance can be analysed through the flow chart of Neandertal adhesive production as seen in figure 14 above. By itself this does not provide much information, yet a comparison between the AMH and Neandertal production sequences can be made, which will be done in the concluding section of this thesis.

### *4.7.2 Fourth-order abstraction*

Implementing the guidelines set up in the previous chapter, in order for the implication that the makers of the adhesives at Königsaue and Inden-Altdorf were capable of fourth-order abstraction to have archaeological validity, evidence needs to be given that abstract concepts were used during the production sequence. This has not been proven to be the case. A case can be made that the makers did have knowledge of abstract concepts such as past, future, workability and temperature, in order to be able to adequately evaluate the placement of the birch bark, adjust air flow and temperature and anticipate problems of wind and other influencing factors. In order for archaeological validity to be satisfied however, proof must be given that the production of the adhesives involved knowledge of these concepts. Cognitive validity, with Barnard's theory itself being supported by cognitive science, rests on the requirement that it be shown that the adhesive production process was not possible without active instructions using these abstract concepts. As this has not been done, the criteria for archaeological validity, as well as those for cognitive validity for fourth-order abstraction have therefore not been satisfied.

*4.7.3 Multi-level operations and non-routine thought*

The criteria for the archaeological validity of the argument that the makers of the adhesives at Königsaue and Inden-Altdorf were capable of multi-level operations and non-routine thought, are that evidence needs to be given that changing circumstances required the switching of attention, the capability to anticipate problems and the capacity to adapt adequately to these changes. The adhesive production sequence showed that the manner of cutting, stacking, burying and covering of the birch bark to require undivided attention, and to be of great consequence to the outcome of the final product. Successful tar production also required constant attention and evaluation of the temperature of the fire, and adaptation to the changing circumstances caused by wind. I would argue that archaeological validity for this inference is therefore intact, and groundedness to have been shown, were it not for the theory itself lacking archaeological support.

Though successful adhesive production does not seem to have been possible without the ability to switch attention, adapt to changing circumstances, and anticipate problems and their required solutions, because Amati and Shallice's (2007) model has not found any scientific neurological basis for their computational theory, the criteria for cognitive validity and warantedness have not been fully met.

*4.7.4 Mental rotation*

The criteria for archaeological validity of the argument that the makers of the adhesives at Königsaue and Inden-Altdorf were capable of mental rotation, are proof that mental rotation was used in the production sequence. The adhesive production sequenced showed that it took several attempts and many adjustments and counts of repositioning of elements within the production sequence to successfully create an adhesive (e.g. horizontal vs vertical placement of the birch bark). As this must have been true for the first attempts at adhesive making in Palaeolithic times as well, this would argue that the makers of the adhesives were capable of mental rotation. This would be in line with evidence for chimpanzee research indicating a spatial-praxis capability and sophisticated pattern recognition that would support mental rotation. This is however not a very strong line of evidence for mental rotation, as the placement may also have been accidental, or improved through simple trial and error, and therefore does not meet the requirements for archaeological validity. Though cognitive tasks involving this type of mental rotation have indeed been linked to higher order cognitive functions, they have not been proven to be necessary for the adhesive production process. Cognitive validity therefore does not hold up for this argument.

### *4.7.5 Embedded recursion*

Archaeological validity for the construct of embedded recursion in adhesive production rests on the criteria that the makers of the adhesives at Königsaue and Inden-Altdorf either used recursive language during the production process, which cannot be shown, or that they used technical recursive elements like the ones argued by Wadley for Sibudu Cave (i.e. attention, feedback, adjustment, concepts of past and future). The production process performed by Pomstra and Meijer shows attention, feedback and adjustments to have been highly necessary to keep the fire at the appropriate temperature, and knowledge of the concepts of past and future to be seen in the multiple stages of the production and the planning required to obtain raw materials, make preparations, carry out the production, and use the tar for hafting. Though the possibility should be considered that a positive outcome was reached through trial and error, making observations about the fire and adjusting their method for the next attempt, based on the production process described by Pomstra and Meijer (2011) I would still argue that the criteria for archaeological validity for a technical recursive element have been met. Though these elements also seem to be necessary for a successful adhesive production, as there is not yet any cognitive support for a technical elements of recursion to be an aspect of advanced cognition, the criteria for cognitive validity cannot be said to have been met in this context.

### *4.7.6 Cognitive fluidity*

For the argument that the makers of the adhesives at Königsaue and Inden-Altdorf possessed cognitive fluidity to be archaeologically valid, there needs to be evidence that different forms of intelligence were combined during the adhesive production process.

The process has been shown to require a combination of at least natural history knowledge; with the gathering and use of raw materials; and technical knowledge; seen through the techniques of fire maintenance and tar production and use in hafting. As has been discussed in the previous chapter however, evidence in the form of the Schöningen spears makes this theory ungrounded in archaeological evidence. Though the production sequence seemingly also requires these elements, the lack of any cognitive or neurological support for Mithen's (1996) theory causes the inferences on cognition during adhesive production to lack cognitive validity.

### *4.8 Apprenticeship and learning*

As none of the cognitive constructs discussed above have met the full criteria for both archaeological and cognitive validity, other options must be explored. Though it is still possible that the constructs are valid for Neandertal adhesive production, it cannot be proven with the evidence at hand. The theory of apprenticeship and learning seems therefore to be a very viable option as an alternative explanation to these cognitive constructs. As this model has been linked to both modern human problem solving (Wynn and Coolidge 2007), as well as that of chimpanzees and bonobos (Toth and Schick 2009; Boesch and Boesch-Achermann 2000), and has been proven to be capable of several very advanced techniques such as adze making (Stout 2002), and hafting (Wynn 2007b), it is very possible that this technique may have been employed in the adhesive making of Königsaue and Inden-Altdorf. Knowledge of procedures such as the correct depth and angle of burial of the bark pieces, the right duration of the fire before the bark is taken out, stopping the air flow to the bark, solving problems of wind and other influencing factors, even the keeping of the fire at the precise temperature required, may have been learned through a (prolonged) period of apprenticeship. If, as Wynn and Coolidge (2007b) argue, the expertise built up through years learning through trial and error, is stored in a range of procedural memories that can be recalled when needed, an entire sequence of procedures and activities regarding adhesive making may have been created during the apprenticeship period. If procedural memories were stored for all sorts of possible scenarios of problems and complications as well as basic procedural adhesive making knowledge, this might even account for the skills thought to have been markers of advanced cognition, such as switching attention, technical recursion and fourth order abstractions.

**Table 3.** Knowledge and procedures shown in Neandertal adhesive production process that correspond to cognitive inferences.

| **Cognitive construct** | **Steps of adhesive production process shown, corresponding to requirements of archaeological and cognitive validity** |
|---|---|
| **Enhanced Working Memory** | • No elements can be identified |
| **Fourth-order abstractions** | • Knowledge of required consistency of adhesive, knowledge of order of steps in the production procedure. |
| **Multi-level operations and non-routine thought** | • Keeping attention on fire to ensure beneficial outcome, adjusting to wind problems influencing temperature<br>• Adjusting position of birch bark for optimum outcome |
| **Embedded Recursion** | • Feedback and adjustment to keep fire at correct temperature |
| **Mental Rotation** | • Rotating the birch bark for a more productive outcome |
| **Cognitive Fluidity** | • Knowledge of e.g. raw materials and fire making/tool making |
| **Expertise through Apprenticeship and Learning** | • Knowledge of raw materials, fire making, adhesive application show stock of knowledge, procedures of fire building and control, birch bark burying and timing show umbrella plan, tools used show constellation. |

*4.9 Conclusions*

Though none of the constructs discussed above meet the criteria for both archaeological and cognitive validity, archaeological validity in itself has been met for the concept of embedded recursion. Though cognitive validity for this concept is lacking, it is not due to a lack of necessity of the constructs within the adhesive making process, but due to a lack of cognitive or neurological support for the model within cognitive science. Should evidence therefore be obtained of the validity of this model within cognitive science, that would indicate the inferences on Neandertal cognition made by this construct to be valid as well, showing Neandertals to have possessed certain elements regarded as markers of advanced cognitive sophistication. As of yet, this is not the case however. Wynn and Coolidge's theory of expertise makes a very viable alternative to these explanations.

Though enhanced working memory could also not be shown, Haidle's problem-solution paradigm could be useful for further research into human executive functions and working memory evolution.

## Chapter 5. Discussion and Conclusions

The main research question for this thesis was whether it was possible to comment on Neandertal cognition through the study of AMH and Neandertal adhesive production. This research question was divided into several subquestions. The first question was whether the inferences on AMH cognition, based on the evidence for adhesive production were convincing and well-founded. The second was whether the adhesive production processes of AMH and Neandertals under review are can be reliably compared. The third question was whether the cognitive concepts that have been linked to AMH can be linked to Neandertals as well. The fourth question was whether there were any possible alternative cognitive explanations that might explain the adhesive production process other than the constructs of modern cognitive sophistication implied.

In order to answer these questions, I will first outline the methods that I employed to come to my results. The results of the AMH context, concerning the validity of the cognitive inferences made by Wadley (2010) will then be discussed, after which the same will be done for the Neandertal context. The two contexts will then be compared, in order to come to the final conclusions concerning the levels of cognitive sophistication that can be derived from their adhesive production processes. Alternative approaches will be outlined, as well as possibilities for future research.

### *5.1 Methods*

The method employed to look into these questions involved several elements: 1. an elaborate review of the cognitive theories and models used within the field of cognitive archaeology and an analysis of their strong and weak points, 2. an inspection of the evidence for hafting at Sibudu Cave along with a closer look the adhesive production process and the implied cognitive constructs, 3. A summary of the key procedures and knowledge involved in AMH adhesive production, 4. An analysis of the cognitive and archaeological validity of the cognitive inferences made by Wadley (2010) for the makers of the Sibudu Cave adhesives, 5. The setting up of guidelines for the criteria of archaeological and cognitive validity for the cognitive constructs implied by Wadley

(2010), and the corresponding elements found within the production process, 6. an inspection of the evidence for hafting and adhesive production at the German sites of Königsaue and Inden-Altdorf, along with a closer look at the adhesive production processes that may have been employed at these sites, 7. A summary of the key procedures and knowledge involved in the Neandertal adhesive production, 8. An analysis of the possible cognitive constructs and alternative explanations that might be linked to Neandertal adhesive production and their cognitive and archaeological validity.

Two methods that were employed during the writing of this thesis were especially helpful. The first was working with the guide of Botha's (2008) structured line of argument for analysing the groundedness and warantedness of cognitive inferences, as well as the application of Wynn and Coolidge's (2009) strict standard of archaeological and cognitive validity. This allowed for a critical and structured line of analysis of the inferences made by Wadley (2010) for the Sibudu Cave adhesive makers, as well as a critical application of the same cognitive constructs to the Neandertal context. The second method was the creation of guidelines for the criteria necessary to obtain archaeological and cognitive validity for the cognitive constructs proposed by Wadley. These guidelines allowed me to analyse the knowledge and procedures shown in the Neandertal adhesive making process in a most effective and structured manner, whereas prior to the setting up of these guidelines, that involved a lot of repetition of previously discussed information.

## 5.2 Results

### *5.2.1 Literature review*

The review of the cognitive archaeological literature showed a strong reliance within the archaeological field on theories based on symbolism to help explain archaeological traces of modern behaviour and cognition. This was shown to be out of step with the current views of cognitive science which call for a redefinition of the concept of symbolism and a re-evaluation of archaeology's reliance on symbolic theory. They have argued that in order for archaeology to truly contribute to the discussion of the evolution of cognition, a different approach is required. Where archaeologists have often focused on traces from the archaeological record, and tried to connect those to elements of cognition, the argument is made that this process needs to be reversed to gain any true cognitive validity. They argue that archaeologists should take cognitive constructs as a starting point for their argument, and find a way to link these constructs to the archaeological record.

The Theory of Mind approach, though it could not be applied directly to the analysis of AMH and Neandertal adehesive production, showed that it could be promising in gaining a better understanding of the cognitive capabilities of different hominins.

Whereas the modularity and working memory approaches were shown to lack support from cognitive science, Haidle's (2010) problem-solution distance paradigm was shown to possibly provide an alternative to the investigation of the development of executive functions and working memory.

With Botha's (2008) and Wynn and Coolidge's (2009) strict standards and critiques having been shown to undermine many cognitive inferences made by archaeologists (d'Errico 2003; Henshilwood 2004), these strict standards were employed in the analysis of the cognitive inferences made by Wadley (2010) for the adhesive makers at Sibudu Cave.

### *5.2.2 The AMH context*

The inference of hafting at Sibudu Cave was shown through extensive use-wear and residue analysis to have been grounded and valid. The analysis of the production process showed the makers of the adhesive to possess a great deal of knowledge and skill. The steps in this production procedure were outlined in a flow chart, showing the broad problem-solution distance for AMH adhesive production. The archaeological and cognitive validity of the cognitive inferences based on the procedures and knowledge shown in the reproduction process of the adhesive making were shown not to be intact for all the cognitive constructs however. Barnard's (2010) construct of fourth-order abstraction, as well as Mithen's (1996) theory of cognitive fluidity, though both likely to have been present during adhesive production, were shown to lack both archaeological as well as cognitive validity. Embedded recursion (Reuland 2010) was shown to probably have been used during the production sequence, but through a technical element, not a linguistic one, which as of yet has no cognitive support. Amati and Shallice's (2007) model of multi-level operations and non-routine thought was shown not to rest on archaeologically sound arguments. Though the elements of non-routine thought and multi-level operations were also shown to be present during adhesive production, cognitive validity could also not be proven. Mental rotation was found to be suitably grounded in archaeological evidence, but as there is still debate about whether or not this is a trait specific to only anatomically modern humans, as this ability is also partially seen in species of great apes (Inoue and Matsuzawa 2007), this does not make a very strong case for cognitive sophistication.

As none of these constructs was able to provide both archaeological and cognitive validity, criteria were compiled for all five of the concepts, with the necessary requirements that had to be shown in order for a concept to be considered archaeologically and cognitively valid (chapter 3, table 1). The first subquestion set at the beginning of this thesis, of whether the inferences on AMH cognition based on adhesives production were found to be well grounded and valid, was therefore answered in the negative.

### *5.2.3 The Neandertal context*

The criteria set up in chapter three were then applied to the European context, where the adhesive production for the two German sites of Königsaue and Inden-Altdorf was discussed. Micro-wear, macrofracture, and residue analysis at these sites again provided strong proof that hafting had taken place at both of these sites. As the production processes of the African as well as the European contexts proved to involve many similar aspects of required procedures and knowledge, the second research sub-question, whether the two contexts could be reliably compared was answered in the positive. The steps in this production procedure were outlined in a flow chart, showing the broad problem-solution distance for Neandertal adhesive production.

Application of these requirements to the Neandertal context showed the construct of fourth-order abstraction to very likely have been present during adhesive production, though this could not be proven, making the claim ungrounded. The lack of support from cognitive science left the theory unwarranted in this case as well. Embedded recursion and multi-level operations and non-routine thought had the same problems as when applied to the AMH context, making them ungrounded, and unwarranted, though both likely to have been applied during adhesive production. Mental rotation were shown not to be able to convincingly meet the criteria for archaeological validity. As the necessity for mental rotation could not be shown in this case, cognitive validity also did not remain intact.

### 5.2.3 *Linking the contexts*

Though the Neandertal adhesive was definitely a simpler adhesive regarding production, elements of cognition involved proved to be very similar, despite none of them being able to meet the criteria for both archaeological and cognitive validity in either context. The third subquestion therefore, whether the cognitive concepts that have been linked to AMH could also be linked to Neandertals, is a difficult question to answer. With the exception of mental rotation, the same cognitive concepts linked to the production sequence of AMH adhesives, could also be linked to the production sequence of Neandertals, namely multi-level operations and non-routine thought, embedded recursion, and cognitive fluidity. Because these concepts did not meet the requirements of the strict standard for either context, no clear conclusions can be drawn from this information. What can be said is that if these models should find support from cognitive science, it would require a possible reconsideration of the cognitive capabilities of Neandertals, as the inferences for several of the constructs discussed above would be equally valid for the AMH context as for the Neandertal context.

Especially the models of embedded recursion, multi-level operations and non-routine thought, and fourth-order abstraction show considerable promise. Though abstract concepts are obviously very difficult to provide evidence for in past actions, it does seem highly probably that these concepts were in fact employed in the production sequence for both contexts. Multi-level operations and non-routine thought can be shown more easily, but would require a restructuring of the archaeological side of its model, as it does not currently hold up to the criteria of groundedness. Mithen's theory of cognitive fluidity seems least promising as it has been greatly critiqued from an archaeological as well as a cognitive perspective.

Haidle's (2010) problem-solution distance model could be compared for the two contexts however, through the flow charts set up in both chapters. These indicated AMH adhesive production to consist of more individual steps than that of Neandertals, possibly indicating a higher degree of flexibility in AMH cognitive capacities, and reflective of further developed executive functions of working memory (*ibid*.). This would of course require further investigation through more similar studies comparing the Nandertals and AMH through this line of investigation.

*5.3 Alternative explanations*

Looking at subquestion 4, whether there are any possible alternative explanations for the cognitive inferences made through the adhesive production process, other than that the procedures and knowledge that were used being were examples of modern cognitive sophistication, there is an explanation that might fit this description. I have argued that the model of expertise through apprenticeship and learning proposed by Wynn and Coolidge (2007b) could be responsible for the adhesive production of not just the two Neandertal sites, but also for that of Sibudu Cave. Apprenticeship and learning is not only one of the most employed problem solving strategies used today, but has also been shown to be used by chimpanzees and bonobos (Toth and Schick 2009; Boesch and Boesch-Achermann 2000) and to be capable of producing very well-worked adzes (Stout 2002), as well as hafted spears (Wynn and Coolidge 2007b). Levallois reduction has also been shown to employ elements of this strategy (Wynn and Coolidge 2009). It is thought to have been one of the main problem solving strategies used by Neandertals (Wynn and Coolidge 2009). As the two production sequences share so many similarities of required knowledge and skill however, I have made the case that expertise may also very well have been responsible for the adhesive production at Sibudu Cave. Whether or not the makers of the Sibudu adhesives in fact were more cognitively advanced, Occam's razor would argue that if expertise were capable of producing the adhesives at Sibudu, being the cognitively simpler explanation, this is likely the process that was responsible for its production.

*5.4 Concluding remarks and possibilities for future research*

Having reviewed the results of both AMH and Neandertal adhesive making and its cognitive implications, it has proven to be extremely difficult for any cognitive inferences that are made to live up to the standards of cognitive and archaological validity, groundedness, or warrantedness. None of the cognitive inferences discussed in this thesis have been able to meet these standards completely. This raises the question of whether the guidelines for proper cognitive archaeology employed in this study, namely Wynn and Coolidge's (2009) strict standard, and Botha's (2008) line of argument, are possibly too strict. I believe this is not the case. Though indeed strict, I believe this guidelines are necessary in order for archaeology to be able to contribute any valid information to the study of cognitive evolution that will be accepted by the field of cognitive science.

Though it seems likely that people producing these adhesives did possess certain elements of sophisticated cognition, the negative result of this study shows the difficulty of trying to comment on mental states of past people. Cognitive archaeology is certainly at a disadvantage not being able to study the subjects under discussion, yet even so, it cannot simply be content with likelihoods and probabilities. To be of any real value in the field of cognitive research, strong evidence must be found of the inferences on cognition that are made, however difficult that may be. I believe that these guidelines should therefore remain a standard for validity in cognitive archaeological research, and might inspire more careful multi-disciplinary work in the future that will produce more concrete results.

One possibility for further research would be the idea proposed by Barnard (2010). In order to validate the construct of fourth-order abstraction specifically for adhesive making, experiments would need to be set up where novices are instructed to create similar adhesives with and without the help of abstract concepts. Only when it can be proven that abstractions were absolutely necessary for the production of adhesives can the construct fulfill the criteria of archaeological and cognitive validity, though of course support would still need to be found for the theory itself.

Another possibility for further research would be studies looking into the problem-solution distance of AMH and Neandertals for different technical sequences, as proposed by Haidle (2010). These could provide information on the mental flexibility of hominins during different point of their evolution. This might be a way to comment on their cognitive development without implying very far-reaching changes in human cognition that have only weak archaeological links, or looking at very narrow and specific archaeological instances that are difficult to tie to any cognitive implications.

What this study has shown is the general under-appreciation of the cognitive skill of Neandertals. Where AMH are constantly linked with all sorts of concepts of cognitive sophistication, this is rarely done for Neandertals. This once again underlines the double standard at work in archaeolgy. This study has shown that, at least for the process of adhesive making, Neandertals possessed many similar forms of knowledge and skill as those of modern humans, and should as such, not simply be left out in the discussion of cognitive abilities as they often have been in the past.

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**Abstract**

This study focuses on the cognitive inferences that can be made through the production of Palaeolithic adhesives. Whereas this production sequence had been linked through its procedures and knowledge to several constructs of modern cognitive sophistication for anatomically modern humans, this has not been the case for Neandertals. This study compares adhesive production processes for AMH from Sibudu Cave, South-Africa (Wadley 2010), to those of Neandertals at the palaeolithic German sites of Konigsaue (Koller, Baumer and Mania 2002) and Inden-Altdorf (Pawlik and Thiseen 2011). Results show that the production sequences for the different contexts share many similarities, yet cognitive inferences made for the both contexts lack archaeological as well as cognitive validity. An alternative explanation is proposed in the form of Wynn and Coolidge's (2007b) theory of expertise through apprenticeship and learning.