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Anatomical Markers for Elevated Cognition in Dinosaurs

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ANATOMICAL MARKERS FOR ELEVATED COGNITION IN DINOSAURS

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INTRODUCTION

One of the goals of vertebrate paleontology is to reconstruct the behaviors of a long extinct animal. Questions about the behavioral complexity of extinct animals are difficult to answer because paleontologists only recover skeletal material that has been fossilized in the rock, and thus cannot directly observe the animals in life. Despite this limitation, there are many ways to study the behavior of fossil animals. Here I will introduce three examples: 1. fossil trackways, 2. death assemblages, and 3. paleoneurology. Fossil trackways occur when an animal leaves footprints in loose sediment like sand or mud (Lockley and Matsukawa, 1999). If the footprint remains undisturbed as more sand is deposited, then the footprint remains as an observable feature in the rock. In the past, several fossil trackways that all follow the same vector orientation have revealed insightful information about non-avian theropods moving as one social group or pack (Lockley and Matsukawa, 1999). Unfortunately the insights are not species-specific and can always be debated, because it is impossible to determine the species that created the footprints or whether they were made by a group of animals of the same species (conspecifics) moving together. It may be just as likely that individuals traversed the same path at different times and left multiple trackways (Lockley and Matsukawa, 1999).

A death assemblage refers to a fossil site containing many different animals from the biological community. In the Pleistocene tar pits near Los Angeles, fossil mammals have been compared to current biological communities in Africa, and this comparison supports the idea that the famous saber-toothed tiger was a social animal (Carbone et al., 2009). These tar seeps are sometimes known as predator traps because herbivores would become trapped in the tar and attract predator species that would also become trapped. Carbone and colleagues went to Africa and conducted an experiment in which recordings of dying herbivores were played and information about the predator species that were attracted to the sounds (size, gregarious vs...

solitary behavior) was recorded. They then tallied the fossil taxa in the tar seep in two ways: 1. *Smilodon* as a social predator and, 2. *Smilodon* as a solitary predator. They found that the fossil data matches the modern data more closely when the saber-toothed tiger is considered social. This study is innovative, but it relies on the rare fossil occurrence of many individuals fossilized together.

Another death assemblage containing ~40 members of a species of extinct flying reptile (pterosaur) and their eggs was discovered in Northwestern China yields and yields much information about their behavior as group nesters (Wang et al., 2014). These animals are not dinosaurs, but they are generally accepted as the sister group to Dinosauria. The fossil discovery reveals pterosaur nests that were simultaneously buried. These animals nested in groups and showed sexual dimorphism, a phenomenon in which there is a different morphology between the two sexes. Male birds, for example, are sometimes more brightly colored in order to attract female mates. Sexual dimorphism in pterosaurs may imply some form of sexual selection, but it cannot be said that they demonstrated complex courtship behaviors before mating based on exaggerated physical features. The animals could be programmed to seek these features, but still lack the neurological and cognitive adaptations to engage in intricate mating rituals. Although fossil assemblages like these are useful in deriving the behavior of extinct organism, it is not ideal to wait for the discovery of such a rare death assemblage site in order to study the behavior of a fossil group of interest. Rather, it would be helpful to develop techniques for extracting information about ancient behavior from single fossil specimens. Paleoneurology offers such an approach.

Paleoneurology is the study of the evolution of the brain in fossil vertebrates. The brains of ancient organisms can be difficult to study since the soft tissues of the head degrade long before the vertebrate can become fossilized. However, paleontologists can replicate the soft tissue structures in the cranial cavity (i.e.,, open space in the skull which houses the brain) in different ways. The least ideal method is to use the cranial cavity as a mold for a plaster cast, which is referred to as an endocast (Buchholtz, 2012). This technique requires the researcher to destroy the fossil skull in order to extract the hardened plaster, and the science of paleoneurology therefore evolved slowly since paleontologists are reluctant to destroy any fossil specimen. More recently, a new technology has been applied to study neural structures (Domínguez Alonso et al., 2004; Buchholtz, 2012). Computed tomography is being applied in vertebrate paleontologists as a means of creating a digital 3D model of fossil endocasts (Balanoff et al., 2015) These studies subject either fossilized or recently deceased skulls to a barrage of X-rays one slice at a time. This scanning process measures the weakening, or attenuation, of the rays as they pass through the material being scanned (Ketcham and Carlson, 2001). The attenuation data are then used to project the cranial cavity in a volume-rendering software program, many of which are free to download (Balanoff et al., 2015).

Intelligence

Intelligence in a non-human animal is difficult to measure, and it typically relies on experimental evidence from living animals (Zentall 2000). These carefully constructed experiments on modern animals are intended to measure aspects of cognitive ability in animal groups, but the results can be debated because the experiment may not capture the innovative and adaptive behavioral responses that research defines as intelligence. For example, training an animal to solve a problem does not demonstrate innovative thinking, but simply its ability to learn a response. Adaptive animal intelligence implies cognitive function rather than conditioned responses and involves rapidly changing behavior in order to adapt to changing conditions

(Zentall, 2000; Adophs 2001). Since “intelligence” is highly contestable in living animals, this study will instead discuss the potential “cognition” of extinct dinosaurs. Cognition, in this study, refers to an animal’s ability to integrate sensory information and devise unique and innovative behavioral responses. In less academic words, the animal is using its senses, consciously processing the information, and responding in a way that helps the animal adjust its behavior to new conditions (Zentall, 2000).

Some examples of adaptive intelligence in animals include the ability of primates and crows to make tools, theory of mind (i.e., awareness of the thoughts of conspecifics and the ability to adjust behavior using this information) demonstrated by blue jays, the ability to remember a past event to predict future outcomes, and learning by watching others (Adolphs 2001; Aplin et al., 2015; Emery and Clayton, 2005; Salwiczek et al., 2010; Zentall 2000). These examples will be discussed in greater detail later in this introduction. Daily experience tells us that not all animals are equal in terms of their ability to demonstrate cognitively demanding behaviors. We can expect cognitive ability to be associated with aspects of neuroanatomy. Therefore, I predict the presence of anatomical traits linked to the processes that make some animals more cognizant than others.

Mathematically, intelligence is a question of how much bigger the brain is in comparison with the expected brain weight as predicted by the unique allometric relationship of brain-body size for a particular group of vertebrates (Jerison, 2000). The excess is referred to as the Encephalization Quotient (EQ). The logic is that a minimum brain weight is required in order to carry out the basic functions of any vertebrate, and when that need is met the excess brain weight imparts a greater capacity for intelligent behavior. Jerison plotted the brain-body size allometric relationships for the different vertebrate groups including reptiles, mammals, fish, amphibians, and birds (Figure 1; from Jerison, 1985). This is a useful method of comparing relative brain sizes of different vertebrate groups. Most interesting is that the polygons representing the mammalian and bird sample sets overlap. This means that although birds have adapted for flight by becoming lighter, they have comparable EQs to mammals of equal size and therefore comparable cognitive potential. Dinosaurs represent the transition between low brain-body size ratios present in reptiles and the high ratios present in birds, which makes them very relevant in the discussion of the evolution of avian intelligence. Since some non-avian theropods show similar EQs to birds (Kundrát, 2007 and Hopson, 1977), it is possible that matching endocast morphologies can be used to predict which birds will serve as an example of the variety and form of cognitive behaviors demonstrated by dinosaurs. The distribution and range of EQs for archosaurs can be seen in Figures 2 and 3.

Encephalization as a means to measure intelligence is useful for living animals because their body mass can be measured easily. In order to determine the total mass of an animal from the remaining skeletal material, paleontologists might identify biomechanical principles like the potential supportive strength of a limb bone based on its cross-sectional area as a means for deriving how heavy the animal was in life, the relationship in felids between the size of nasal openings and body size based on oxygen demands for a given body size, and the relationship between the area of a modern bird's footprint to its weight (Torregrosa et al., 2010; Tanaka, 2015). These are innovative and useful for vertebrate paleontologists, but scientists of living animal cognition would criticize the use of calculated values for body mass rather than directly measured values to obtain a value for EQ. In addition, non-avian theropod dinosaurs may have a unique allometric relationship to the animal groups defined by Jerison (1985), but their close relationship to birds within the clade Archosauria suggests that they may follow the avian model (Rogers, 2005).

More certain than the EQ of extinct fossil species is the relative size and shape of the neural structures. It was shown that the endocranial volume (represented by the endocast) does serve as a means for calculating brain mass in birds, and since non-avian theropods are close to birds in the phylogenetic bracket, this can be assumed to be true for non-avian maniraptors as well (Iwaniuk and Nelson, 2002; Rogers, 2005). Therefore the endocasts obtained from these dinosaurs model externally visible brain structures very well because the brain fits tightly in the cranial cavity. According to the Principle of Proper Mass the relative size of brain structures shows the importance of the neural function associated with that structure in the animal's behavior. This principle predicts that if the structures that manage cognition, for example, are large in a fossilized endocast then the animal relied heavily on its cognitive ability in life. Thus, to search for intelligent behaviors among dinosaurs in the fossil record, we must first understand the locations of structures that are responsible for social cognition, adaptive intelligence, and sensory integration.

The regions of the brain that carry out specific tasks are located in the same location on different animals due to the conservative nature of the vertebrate nervous system (Jerison, 2000). This was the result of the sensory functions in the earliest chordate ancestors to all vertebrates. Their primitive nervous system received light and chemosensory stimuli from the front of their body while information about their bodies were received from the notochord. This is why sensory integration and cognition are conducted in the anterior portion of the brain, referred to as the forebrain, while motor-coordination is conducted in the hind-brain in vertebrates across all forms (Jerison, 2000; Buchholtz, 2012).

Birds have evolved a different nucleated architecture and structures that process sensory stimuli that are different from the mammalian neocortex and laminated neuroanatomy (Emery and Clayton, 2005). The slang term that refers to a slower individual, “bird brain,” is the outcome of poor assumptions of avian intelligence based on their lack of a mammalian-like cerebral cortex that since has been corrected (Morell, 2013). It is now understood that the pallial structures in the forebrain of birds carry out the same function as the mammalian neocortex. Figure 4 shows a comparison of the early misnomers about the avian neuroanatomical source for cognitive function. Since fossil endocasts preserve the cranial cavity rather than the brain, it may not be possible to identify pallial structures. Fortunately the forebrain houses the cognitive structures in vertebrates, so the Principle of Proper Mass can still be applied to the inflation of the brain anterior during the transition from dinosaurs to birds and the resulting increase in cognitive function.

Previous Work

The Principle of Uniformitarianism is often invoked in the geological sciences because it allows us to observe modern phenomenon and extrapolate them through time to understand earth systems in the past. The principle applies to paleontology when African animal populations, for example, are studied to understand the packing behavior of extinct predators (Carbone et al., 2009). In paleoneurology, scientists study the avian neuro-adaptations to interpret theropod phylogeny and behaviors (Balanoff et al., 2014; Domínguez Alonso et al., 2004; Kundrát, 2007; Rogers, 2005; Witmer and Ridgely, 2008; Zelenitsky et al., 2011). The information that can be extracted includes detailed anatomical descriptions of brain volume and the relative size of the different regions within the brain. Figure 5 shows examples of digital endocasts that are produced and studied by vertebrate paleontologists. The Principal of Proper Mass is then used to describe the animal's primary sensory modalities.

The vertebrate nervous system is also remarkably similar across different animal groups, which is to say that the trait is conserved (Jerison 2000). However, there are key differences to neuroanatomy that arose within the clade Archosauria, which includes birds, non-avian dinosaurs, and crocodilians. The debate over the behavioral complexity of dinosaurs has a long history with early assumptions of sluggish behavior as seen in modern reptiles that were heavily challenged by those arguing that dinosaurs and birds share a closer relationship (Hopson 1977). Today, endocast studies of one group of vertebrates that emerged within Dinosauria, known as Theropoda and including Aves, reveal that they share similar relationships between their body size, which is derived from fossil evidence for extinct species, and their brain volume. (Hopson, 1977; Jerison, 1985; Domínguez Alonso et al., 2004; Kundrát, 2007; Balanoff et al., 2013; Balanoff et al., 2014). The differences within the neuroanatomy of extinct theropods is important to this study because the results will only apply to the more avian-like theropod dinosaurs.

The large bodied theropods that branched off earlier than the small non-avian maniraptor dinosaurs that are the focus of this study had little in common with the modern avian neurological model (Franzosa, 2004; Rogers, 2005), and the dimensions of their inner ear suggest that their vocal communication was restricted to lower frequencies, which implies a lower level of social complexity in their behaviors (Walsh et al., 2009). Some fossil evidence that suggests that tyrannosaurids and similar dinosaurs did live in groups (Currie, 1998). Several fossil leg bones were discovered from different individuals of *Albertosaurus sarcophagus* in the same fossil quarry. Since these fossils were found without any fossils from herbivorous animals, it is not considered a predator trap as is the case with *Smilodon* in the tar seeps of Los Angeles

(Carbone et al., 2009).The most likely reason for this group of fossils found in one quarry is that the *Albertosaurus* lived in a group. However, the primitive brain structure of tyrannosaurids makes complex social dynamics unlikely as opposed to the inflated brains of the smaller-bodied theropods.

Philip Currie and Rodolfo Coria studied the braincase anatomy of the large South American dinosaur *Giganotosaurus carolinii* with the intention of establishing its evolutionary relationship within the clade Theropoda (Coria and Currie, 2002). According to the researchers, *Giganotosaurus* had much in common with other large bodied basal theropods including *Abelisaurus, Carcharodontosaurus,* and *Carnotaurus.* Another study on *Ceratosaurus* establishes the crocodilian nature of its brain. There is little expansion in any particular region of the endocast, and its auditory capabilities likely could not support complex vocalization. The large V2 branch of the trigeminal nerves in *Ceratosaurus* and other basal non-avian theropods is similar to crocodiles, but dissimilar to birds, and the olfactory bulbs were less expanded than *Tyrannosaurus* (Sanders and Smith, 2005). I expect that the avian endocasts in my study will not yield insights into the behaviors of these dinosaurs, but this primitive form may reveal the timing of derived theropod neuroanatomical adaptations.

A study of the endocast from the first known bird species from the Late Jurassic, *Archaeopteryx*, led to the discovery of several avian features in the endocranial anatomy including large optic lobes, divided cerebral hemispheres, and a relative brain size that is close to modern birds (Domínguez Alonso et al., 2004). They conclude that *Archaeopteryx* had the neurological capabilities of powered flight and that these neurological adaptations evolved much earlier in theropod evolution. This relates to my study by providing evidence that this particular animal likely demonstrated complex behaviors similar to those observed in modern birds. If

Archaeopteryx's brain organization was similar to modern birds, then it may have behaved like the group of modern birds that show the most similar brain morphology.

In 2007, Martin Kundrát described the neuroanatomy of a group of dinosaurs, oviraptors, that is a member of the maniraptorans. Potentially, this will be one species of dinosaur to which my study will be applied. It has a large number of avian characteristics that include expanded cerebral hemispheres and the position of the optic lobes towards the eyes themselves. According to this study, this feature would have resulted in vision-dominated sensory modality as opposed to larger theropods that relied heavily on olfaction (sense of smell). In addition, its level of encephalization is similar to modern birds. *Conchoraptor* followed the avian brain model more than *Archaeopteryx*, but my study will address which species of bird may serve as the best model for predicting oviraptorid cognitive ability and behavioral complexity. A follow up study on the braincase of *Conchoraptor gracilis* confirms Kundrát's original conclusions about the avian nature of the oviraptorid brain (Balanoff et al., 2014). They suggest that this group of dinosaurs is more closely related to birds than previously thought, and that the differences between non-avian and avian brain volumes and encephalization levels are increasingly blurred. This study adds evidence to the possibility of mapping the endocranial anatomies of extinct theropods onto extant groups to derive information about behaviors.

The same group of researchers conducted an extensive study of the evolutionary changes of the theropod brain and how they relate to the origin of avian flight (Balanoff et al., 2013). Cranial volumes of many living and extinct theropods were compared. This study revealed that the volume of the *Archaeopteryx* cranial cavity is equal to or smaller than non-avian maniraptoran volumes. Therefore, the avian brain increased its size many separate times in theropod evolution rather than once in a single common ancestor, which is very useful for my study because modern avian brains may be comparable across a wider range of non-avian maniraptoran endocasts than previously thought. However, this study is focused on avian flight rather than behavioral complexity and cognition, and the authors conclude that other non-avian theropods were capable of primitive flight. Being capable of flight does not address the question of which groups of modern birds serve as an analog for their level of cognitive ability because, for examples, insects are also capable of flying without complex brains.

The therizinosaurs were a special group of theropod dinosaurs known for a potential herbivorous diet rather than a carnivorous one like most other theropods (Lautenschlager et al., 2012). Most notable in this study was the expanded cerebral hemispheres that obscured the position of the optic lobes, but it is inferred that they are more bird-like based on other commonalities. The researchers discussed the enlarged forebrain and primary sensory functions of this dinosaur group and concluded that its auditory, visual, and cognitive capabilities were highly advanced. This demonstrates the current limitations on deducing behaviors by measuring the sizes of different brain regions. This group of theropods may have enough in common with the modern avian brain to make reasonable comparisons and hypothesize about its behavior.

Olfaction (sense of smell) was the focus of a very large research study on theropods (Zelenitsky et al., 2011). The authors calculated olfactory ratios of 157 extinct and living theropods by measuring the olfactory bulbs and the cerebral hemispheres. It was conducted to address the misconception that birds do not utilize their sense of smell. They found that olfaction was unchanged during the transition between the non-avian maniraptorans and the first birds. However, olfactory capabilities did show separate increases before and after this transition. This expansion likely resulted in behaviors following olfactory cues, but given the increase in auditory and visual capabilities, it may follow that overall sensory integration was expanding.

This would have a large impact on the cognitive abilities of derived archosaurs that lead to the mammalian-level of encephalization achieved by modern birds.

Cognitive Reputation of Sample Set

Certain groups of birds have different reputations for advanced cognitive function. My sample set can essentially be divided into three categories: 1. water birds/waterfowl, 2. songbirds/corvid, and 3. predatory birds. The first group is the least likely to demonstrate advanced cognitive function, and I include the American Coot, Canada Goose, Double-crested Cormorant, Sora, Great Blue Heron, and Ring Billed Gull in this group. They are social birds rather than solitary birds, and Canadian Geese are known to fly in formation, but those behaviors are not indicative of adaptive intelligence as a result of elevated cognitive function because gregarious behavior could be the result of innate behavior rather than a cognitively devised solution (Bajec and Heppner, 2009; Zentall, 2000). Also, if the famous "V" formation of geese in flight is somehow the most energy efficient pattern for group flight, then the flock could arrange themselves in this way without cognitively discovering it as a solution for energy conservation. The vocalizations in these birds are simple (Palmer, 1962), which implies little to no use of language for communication. However, Barnacle Geese (anseriform birds) do forage in family groups rather than with non-relatives, and relatives tend to stick together during their fission-fusion social dynamics (Silk et al., 2014). There is also a potential for communication by scents in this group of birds (Caro and Balthazart, 2010).

The second group of birds in the sample set is comprised of songbirds, or passeriform birds. I include the American Robin, House Sparrow, and the Blue Jay in the following discussion. These birds have a greater reputation for elevated cognitive function than the previous group. A study of sub-populations of Great Tits (also passeriforms) suggest the ability of socially-learned problem solving abilities (Aplin et al., 2015). The hummingbird may also have been included in this group, although it is not in the order Passeriformes, but it was excluded from the data set (Table 1). Songbirds can also distinguish related from non-related conspecifics during fission-fusion social dynamics (Silk et al., 2014). Cooperative hunting was also observed in shrikes, which is another passeriform bird (Frye and Gerhardt, 2001; Hannah, 2005) The Blue Jay deserves special comment because it is a member of the family Corvidae and is closely related to the highly cognizant crows. Corvids can fashion and use tools and gather in groups to chase away larger predators (Emery and Clayton, 2005; Morell, 2013). It is unfortunate that a crow was not included in the sample set, but the Blue Jay and the other passeriformes will stand in for the example of birds with high levels of cognitive function.

The third group is comprised of the Red-tailed Hawk and Common Nighthawk. Another species of raptor, Harris Hawks (*Parabuteo unicinctus*), do hunt as a social groups and show cooperative effort (Coulson and Coulson, 2013). My study will help to generate hypotheses about the potential for non-avian maniraptor dinosaurs to demonstrate the behaviors mentioned above.

I wish to study the cognitive potential of the smaller bodied bipedal carnivorous dinosaurs belonging to the clade Maniraptora. We require a model that characterizes endocast morphology in terms of social cognition and adaptive intelligence. The level of cognitive function in non-avian maniraptor dinosaurs is interesting because they are closely related to birds, and they share many physiological features (Domínguez Alonso, et al., 2004). I would like to create a model that allows paleontologists to generate hypotheses about the behavioral complexity and cognitive function of this group of dinosaurs. In this study I investigate the relationship between endocast morphology of modern birds and their demonstrations of sociality and cognition.

METHODS

Specimens

The specimens for this study were obtained from Nature's Nursery, which is a wildlife rehabilitation center based in Whitehouse, Ohio. During the bird migrations in the Fall of 2015 the facility received 13 different bird species across 10 orders and the heads of these birds were donated for this project. I collected these samples under Ohio Division of Wildlife Wild Animal Permit 16-174. See Table 1 for a complete list of the species that were used in the endocast analysis.

The specimens were kept frozen with dry ice and shipped to Dr. Larry Witmer's lab at Ohio University where they underwent computed tomography scans. The image spacing was 0.049211 mm for the American Robin, Blue Jay, Common Nighthawk, American Coot, The Ruby-throated Hummingbird, House Sparrow, and Sora. The Canada Goose, Great Blue Heron, Great Horned Owl, the Double-crested Cormorant, and the Red-tailed Hawk image spacing was 0.098423 mm. The DICOM files were shared via Dropbox© folder and the specimens were accessioned into the Ohio University Vertebrate Collection (OUVC) (Table 2). The axial planes of the CT scans were not properly aligned in the hummingbird and owl specimens, leading to distorted images in the 2D image. This distortion made it difficult to identify the same anatomical structures as found in the other 11 specimens, which is pertinent for the accuracy of the geometric morphometric analysis of the morphological changes in the forebrain across specimens.

Image Processing

The Division of Digital Arts agreed to download 3D Slicer 4.5 onto 2.7 GHz 12-core Intel Xeon E5 processor Macintosh computers with 32 GB 1866 MHz DDR3 ECC of memory and the Intel ® Xeon ® CPU E5-2630 v2 computers with a 2.60 GHz processor and graphics, and 32.0 GB of RAM. I used the volumes module to emphasize bone in three projections of the two-dimensional slices in the axial, coronal, and sagittal planes. I did not create a 3D model of the endocast, but rather used the 2D planes to track the inner surface of the cranial cavitiy. The terminology for orientations is unique because of the medical applications for CT technology. The axial plane for human anatomy is horizontal to the floor, but for animals the plane reported as "axial" by Slicer refers to the transverse plane. I then used the threshold effect found in the editor module to render the bone red. I followed the procedure described in the 3D Slicer 3.2 tutorial found on the online academic blog, The Open Source Paleontologist, and publications (i.e., Balanoff et al., 2015) to prepare the raw CT scan data for this study.

Landmark Placement

I placed landmarks on the axial slices of the CT data starting at the olfactory region using the landmark registration module. I used the eyes for reference and found the most anterior portion of the endocast, which also corresponds to either the olfactory bulb or tract. In the two-dimensional plane it appeared as a small round opening. In some cases the ventral (bottom) portion of the endocast was not distinguishable enough to ensure consistent landmark placement, so I began by placing landmark 1 in the top and center of the small opening. I followed the curvature of the inner wall of the frontal bone as I moved in the anterior-posterior direction. Once the small opening began to widen I place landmarks 2 and 3 to the left and of the center from the bird's perspective respectively. Then I placed landmark 4 in the top and center.

I then moved in the posterior direction through the axial slices until the inner wall of the skull reached its maximum radius. I then moved in the anterior direction and placed landmarks 5 and 9 to the left and right of the center respectively, where the tangential line to the endocast was parallel to the sagittal plane. Landmark 6 was placed in the top center, and landmarks 5 and 7 were placed at the approximate mid-points to the left and right respectively. Finally, landmarks 10-13 were placed when the radius of the endocast began to decrease in size. Figure 6 shows the dorsal view of the landmark configuration in a lollipop diagram that will be discussed later in greater detail.

Geometric Morphometric Analysis

3D Slicer uses RAS coordinates in place of traditional x, y, z coordinates. It is a system that is used in neuroscience and refers to the right, anterior, and superior axes as positive x, y, z, values in millimeter measurements. Each landmark yielded RAS coordinates, the unit of measurement was dropped, and the values were treated as x, y, z values. The values were then positive transformed by adding 300 to each value.

Geometric morphometrics is a method for studying the shape changes of anatomical structures in different species by measuring the variation of each x, y, z, coordinate point for all 13 landmarks. See Table 3 for the landmark coordinate data. These data were then uploaded into MorphoJ, a free shareware software program that is designed for both 2D and 3D morphometric studies, and I used it to generate a covariance matrix (Table 3). Each specimen had 39 variables from the x, y, z coordinates for a 13-landmark configuration, and the covariance matrix produces a data cloud of the specimens. This matrix was used in a principal components analysis (PCA), which identifies the axis of greatest and second greatest distance through the data cloud and designates it PC1 and PC2 respectively. Finally, these two components are reoriented to a horizontal and vertical axis so that the multi-dimensional data cloud can be observed in two dimensions. High vs... low PC scores correspond to different shapes and how the birds in this study plot on the PC1 vs.. PC2 graph allowed me to interpret the variation of the forebrain shape. I then compared the patterns of variation to the level of cognitive ability generally associated with the group of birds represented by each specimen.

RESULTS

Qualitative inspection of the endocasts reveals that non-avian maniraptor endocasts resemble the water bird endocasts more closely than the passeriform birds or the Common Nighthawk and Red-tailed Hawk (Figure 9). This observation implies that non-avian maniraptor dinosaurs did not share elevated cognitive function with passeriforms or modern raptors. Future studies should include endocasts from the fossil record in order to quantitatively show the similar morphologies between the extinct maniraptor dinosaurs and extant water bird species.

The results of the PCA analysis are shown in Figure 7. 71.481 percent of all shape variation between the specimens was captured in principal components 1 and 2. The Double-crested Cormorant plots alone and very far from all other birds in this study on the PC1 axis, making it an outlier. This is likely the result of an error in the placement of the second landmark. Most of the continuous variation is on the PC2 axis. The Sora has the highest PC2 score with a value of ~.16. The Great Blue Heron PC2 score is slightly less with a value of ~.15. The Canada Goose and the House Sparrow plot very closely on the PC2 axis with values of ~.05, and the American Coot plots just above a 0.00 PC2 score. The Ring Billed Gull, Blue Jay, and Common Nighthawk are found between a 0.00 and -0.1 PC2 score. Finally the American Robin and the Red-tailed Hawk have the lowest PC2 score that are ~-0.10.

The lollipop graphs in Figure 8, like the graph in Figure 6 that was used above to visualize the landmark configuration, represent shapes of Great Blue Heron and American Robin with a high and low PC2 score respectively. Landmarks 5-9 and 10-13 are more extended in an anterior-posterior direction in a specimen with a high PC2 score, and they are compressed in the same anterior-posterior direction in a specimen with a low PC2 score. Hence, a high PC2 score denotes a forebrain with an elongate shape and a low PC2 score denotes a more rounded forebrain shape.

CONCLUSIONS

Clusters do appear in the PC1 vs. PC2 plot that separate some of the water bird species from the song bird species, but the overall variation is not discrete. I cannot conclude that forebrain morphology in extant avian endocasts is related to their social cognition, or any form of adaptive intelligence based on these results. Ideally, I expected the three defined bird groups to plot together and completely separate on the PC1 vs. PC2 graph. The clusters can be circled on this graph around the less cognizant water birds and more cognizant songbirds, but the resulting circles would overlap, which should not occur if forebrain shape is related to adaptive intelligence from elevated cognitive ability. The close proximity of the Ring-billed Gull to the Blue Jay does not support the hypothesis. Interestingly, the specimens do not group by taxonomic family or order either, implying that the forebrain shape is not phylogenetically constrained.

The continuous variation may be the result of imprecise landmark placement. A more consistent method to place landmarks may result in more discrete variation between the birds. In other words, the water bird species may stay together, but plot further away from the passeriformes in future studies. Also, a greater sample set that includes birds with older evolutionary histories (i.e., Southern hemisphere birds or ratites) may be more useful in a comparative morphological study of extant birds and extinct maniraptors.

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APPENDIX

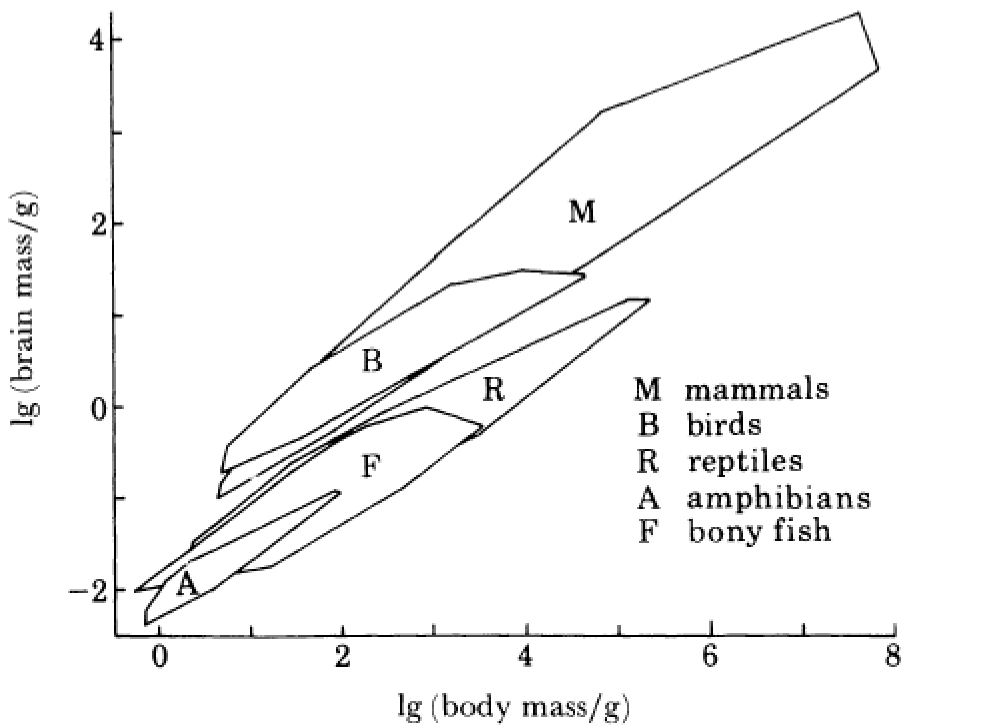

Figure 1: Allometric relationships of body mass to brain mass across different vertebrate groups. Birds plot within the range of mammals of equal body mass. Modified from Jerison 1985.

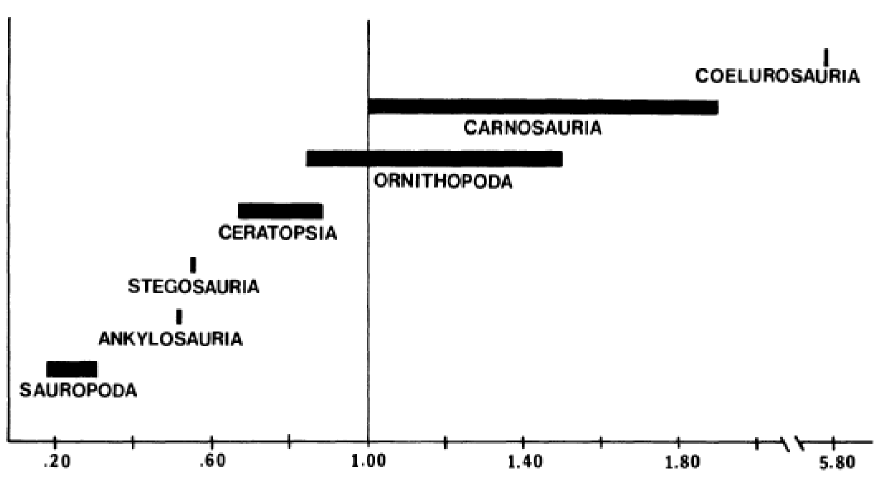

Figure 2: Encephalization Quotients for different Clades of Dinosaurs. Modified from Hopson 1977.

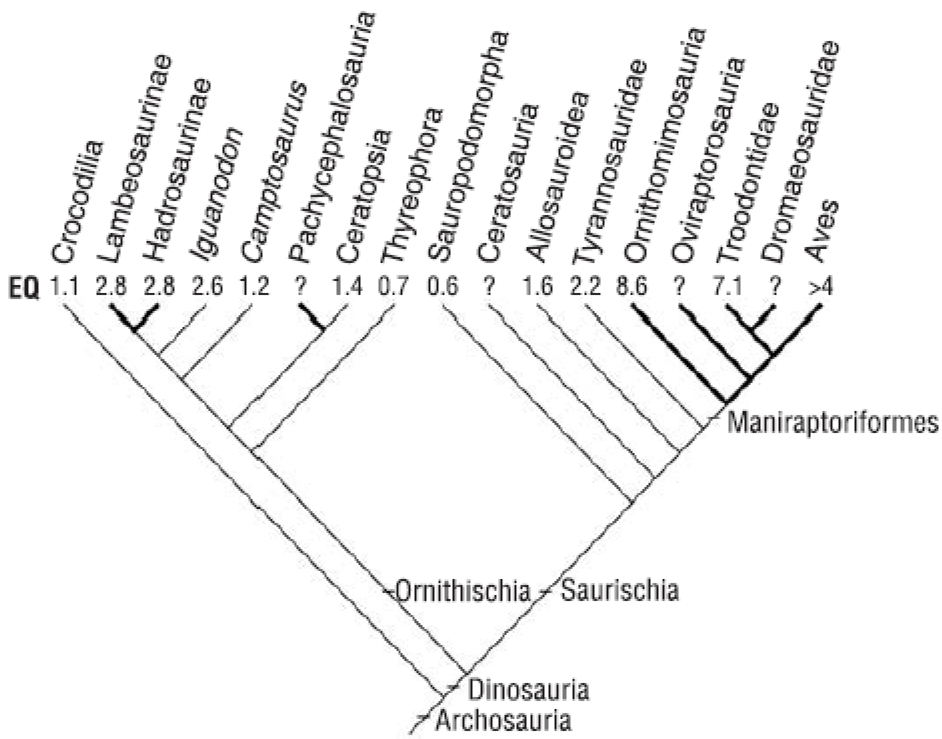

Figure 3. Phylogenetic distribution of Encephalization Quotients (EQs) for Archosaurs. The maniraptors show much higher values than basal forms of dinosaur. Modified from Evans 2005.

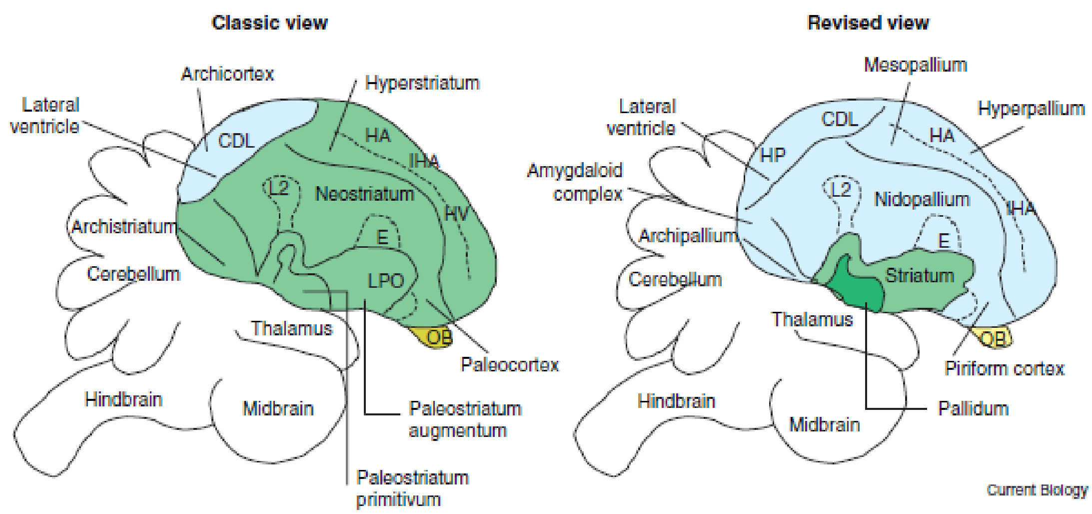

Figure 4. Comparison of early assumptions regarding avian brain organization with emphasis of the change from a striatum (green) dominated forebrain (left) and a pallial (light blue) dominated forebrain (right). In birds the pallial structure functions as the neocortex in mammals and is responsible for complex cognitive function. Modified from Emery and Clayton, 2005.

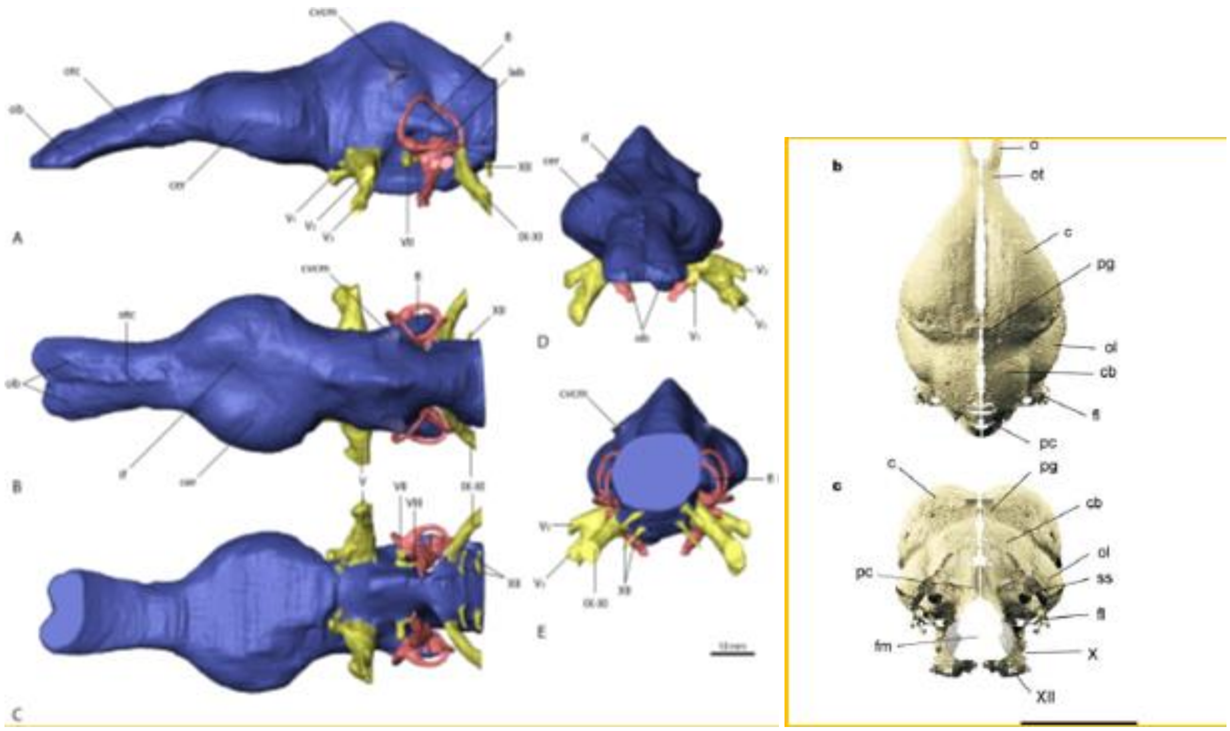

Figure 5. Left: *Erlikosaurus andrewsi* endocast. Modified from Lautenschlager et al., 2012. Right: *Archaeopteryx* braincase. Modified from Dominguez Alonso et al., 2004

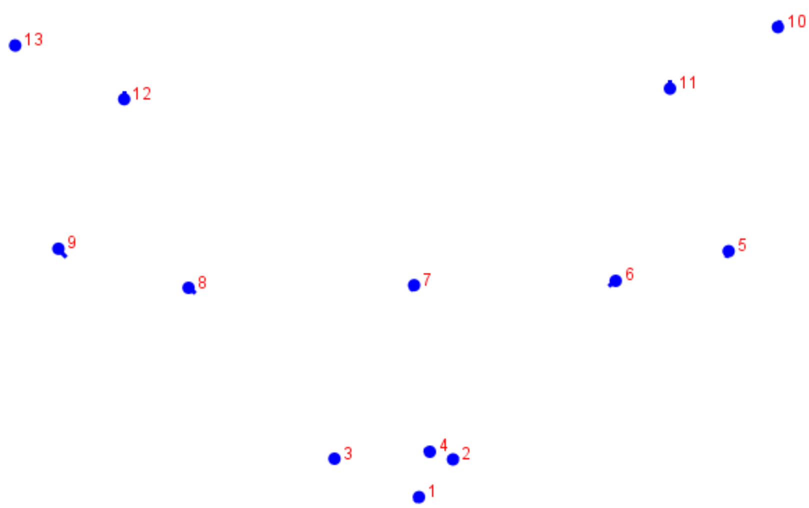

Figure 6. Dorsal view of the 3 dimensional landmark configuration around the forebrain region in the endocasts of the samples in 2 dimensions.

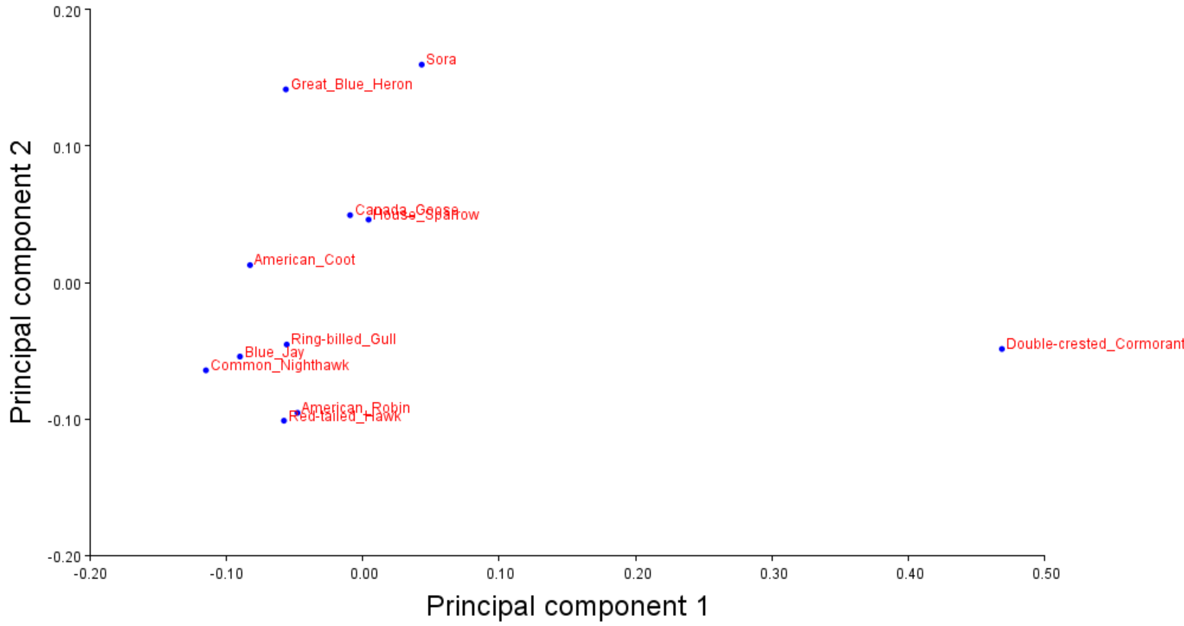

Figure 7. PCA analysis of endocast morphology of the forebrain region of 11 bird species. Note the Double-crested Cormorant as an outlier that defines PC1. Most of the continuous variation is in the PC2 scores.

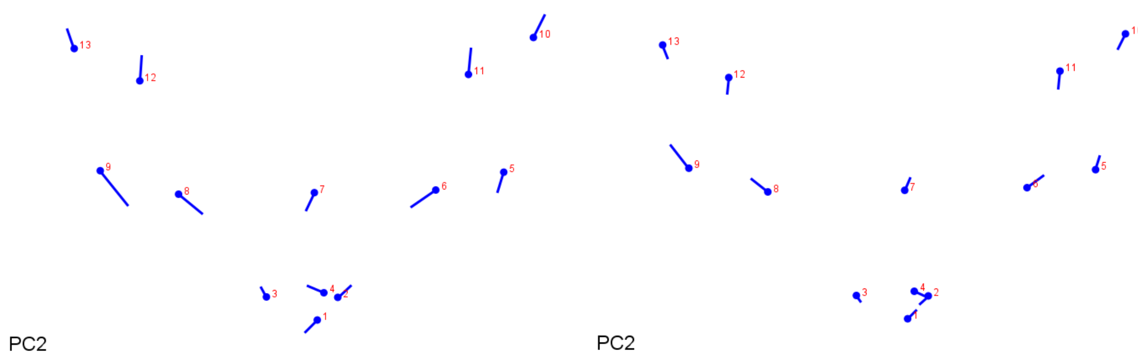

Figure 8. PC2 shape changes from a high PC2 score (left) to a low PC2 score (right). The points represent the average landmark position for all specimens and the ends of the lines represent the location of the landmark for the corresponding PC2 score.

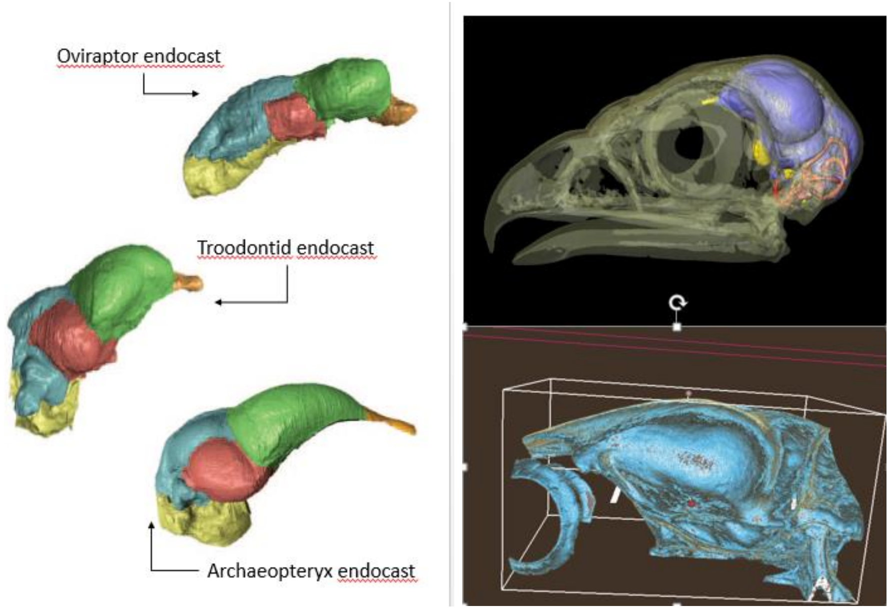

Figure 9. Qualitative comparison of extinct maniraptor endocasts (left) and extant avian endocasts from this study. Note the elongated shape of the extinct maniraptor endocasts and the cormorant braincase (bottom right) as opposed to the rounded shape of the Red-tailed Hawk endocast (top right). Left image modified from Balanoff et al., 2013.

Table 1. Complete list of birds by common name, scientific name, order, and family.

Common Name	Scientific Name	Order	Family	Reputation for Intelligence
Ring-billed Gull	Larus delawarensis	Charadriifromes	Laridae	Low
Great Horned Owl	Bubo virginianus	Strigiformes	Strigidae	Low
Ruby Throated Hummingbird	Archilochus colubris	Apodiformes	Trochilidae	High
American Robin	Turdus migratorius	Passeriformes	Turdidae	High
Canada Goose	Branta canadensis	Anseriformes	Anatidae	Low
House Sparrow	Passer domesticus	Passeriformes	Passeridae	High
Sora	Porzana carolina	Gruiformes	Rallidae	Low
Double-crested Cormorant	Phalacrocorax auritus	Suliformes	Phalacrocoracidae	Low
Great Blue Heron	Ardea herodias	Pelecaniformes	Ardeidae	Low
Red Tailed Hawk	Buteo jamaicensis	Accipitriformes	Accipitridae	Medium
Common Nighthawk	Chordeiles minor	Caprimulgiformes	Caprimulgidae	Medium
Blue Jay	Cyanocitta cristata	Passeriformes	Corvidae	High
American Coot	Fulica americana	Gruiformes	Rallidae	Low

Table 2. Accession Numbers for Specimens Used in this study.

OUVC	10842	BGSU	American Robin
OUVC	10843	BGSU	Blue Jay
OUVC	10844	BGSU	Canada Goose
OUVC	10845	BGSU	Common Nighthawk
OUVC	10846	BGSU	Coot
OUVC	10847	BGSU	Cormorant
OUVC	10848	BGSU	Great Blue Heron
OUVC	10849	BGSU	Great Horned Owl
OUVC	10850	BGSU	House Sparrow
OUVC	10851	BGSU	Hummingbird
OUVC	10852	BGSU	Red Tailed Hawk
OUVC	10853	BGSU	Ring Billed Gull
OUVC	10854	BGSU	Sora

Table 3. Raw data used in the PCA analysis. Note that the landmark numbers were transformed +1 before being entered into MorphoJ.

	LM3=13					
0	287.967	27.895	289.604	1	0	1
1	288.566	3.732	292.368	1	1	2
2	286.499	26.106	292.368	1	2	3
3	286.499	28.764	292.368	1	3	4
4	291.912	38.212	296.698	1	4	5
5	285.909	35.85	296.698	1	5	6
6	283.842	28.862	296.698	1	6	7
7	283.054	22.169	296.698	1	7	8
8	285.613	18.134	296.698	1	8	9
9	294.668	40.968	304.572	1	9	10

10	284.531	37.72	304.572	1	10	11
11	281.48	20.102	304.572	1	11	12
12	288.566	14.689	304.572	1	12	13
	ID=Double-crested_Cormorant					
	LM3=13					
0	278.025	20.145	332.821	1	0	14
1	269.411	24.764	328.589	1	1	15
2	270.458	16.616	328.589	1	2	16
3	272.425	20.929	328.589	1	3	17
4	271.184	34.676	324.061	1	4	18
5	267.967	28.085	324.061	1	5	19
6	269.731	20.975	324.061	1	6	20
7	269.407	13.502	324.061	1	7	21
8	272.833	8.623	324.061	1	8	22
9	275.116	35.974	314.061	1	9	23
10	267.643	29.279	314.061	1	10	24
11	268.266	14.073	314.061	1	11	25
12	276.258	7.378	314.061	1	12	26
	ID=Great_Blue_Heron					
	LM3=13					
0	310.692	21.497	455.486	1	0	27
1	314.232	19.077	455.486	1	1	28
2	315.604	23.772	455.486	1	2	29
3	314.81	21.136	455.486	1	3	30
4	313.943	12.901	447.486	1	4	31
5	317.121	16.549	447.486	1	5	32
6	317.41	21.786	447.486	1	6	33
7	317.916	26.77	447.486	1	7	34
8	313.676	33.051	447.486	1	8	35
9	310.331	11.637	443.486	1	9	36
10	316.977	14.779	443.486	1	10	37
11	317.771	29.045	443.486	1	11	38
12	310.476	33.74	443.486	1	12	39
	ID=Ring-billed_Gull					
	LM3=13					
0	320.211	26.345	357.913	1	0	40
1	323.48	23.579	361.913	1	1	41
2	322.657	28.777	361.913	1	2	42
3	322.558	25.884	361.913	1	3	43
4	320.127	11.925	370.913	1	4	44
5	325.66	17.961	370.913	1	5	45
6	323.816	26.681	370.913	1	6	46
7	324.822	33.514	370.913	1	7	47

8	318.406	39.596	370.913	1	8	48
9	310.472	9.549	377.913	1	9	49
10	323.304	15.458	377.913	1	10	50
11	321.279	37.498	377.913	1	11	51
12	308.785	41.385	377.913	1	12	52
	ID=Canada_Goose					
	LM3=13					
0	314.336	24.472	300.894	1	0	53
1	314.9	22.616	298.975	1	1	54
2	316.206	28.917	298.975	1	2	55
3	315.477	24.761	298.975	1	3	56
4	313.391	18.74	295.087	1	4	57
5	316.11	21.48	295.087	1	5	58
6	316.912	25.718	295.087	1	6	59
7	316.24	32.358	295.087	1	7	60
8	310.926	35.411	295.087	1	8	61
9	308.557	17.858	289.132	1	9	62
10	314.725	20.033	289.132	1	10	63
11	315.069	33.683	289.132	1	11	64
12	309.761	35.858	289.132	1	12	65
	ID=American_Coot					
	LM3=13					
0	293.036	27.312	439.57	1	0	66
1	292.302	28.396	440.8	1	1	67
2	292.035	26.845	440.8	1	2	68
3	292.174	27.503	440.8	1	3	69
4	293.401	32.549	443.31	1	4	70
5	291.205	30.678	443.31	1	5	71
6	290.584	27.991	443.31	1	6	72
7	290.294	25.274	443.31	1	7	73
8	291.139	23.403	443.31	1	8	74
9	297.941	33.947	447.69	1	9	75
10	292.518	33.474	447.69	1	10	76
11	290.398	22.655	447.69	1	11	77
12	294.516	20.162	447.69	1	12	78
	ID=Sora					
	LM3=13					
0	304.757	15.866	463.699	1	0	79
1	305.102	13.773	462.912	1	1	80
2	306.37	17.48	462.912	1	2	81
3	305.487	15.117	462.912	1	3	82
4	302.155	7.968	457.203	1	4	83
5	306.307	10.043	457.203	1	5	84

6	307.588	15.194	457.203	1	6	85
7	307.895	21.754	457.203	1	7	86
8	301.694	25.188	457.203	1	8	87
9	298.517	7.916	453.66	1	9	88
10	304.564	8.993	453.66	1	10	89
11	306.717	23.163	453.66	1	11	90
12	301.95	26.084	453.66	1	12	91
	ID=American_Robin					
	LM3=13					
0	290.402	20.792	303.511	1	0	92
1	288.305	24.345	301.641	1	1	93
2	286.053	19.122	301.641	1	2	94
3	287.839	21.704	301.641	1	3	95
4	292.281	28.998	296.769	1	4	96
5	286.818	27.077	296.769	1	5	97
6	285.077	22.004	296.769	1	6	98
7	284.657	14.8	296.769	1	7	99
8	289.28	10.508	296.769	1	8	100
9	296.244	28.968	292.98	1	9	101
10	288.859	28.038	292.98	1	10	102
11	284.837	14.17	292.98	1	11	103
12	290.997	8.917	292.98	1	12	104
	ID=Blue_Jay					
	LM3=13					
0	300.725	39.832	321.337	1	0	105
1	300.767	42.67	322.617	1	1	106
2	303.585	40.883	322.617	1	2	107
3	301.524	41.367	322.617	1	3	108
4	299.674	44.458	326.111	1	4	109
5	299.68	44.466	326.111	1	5	110
6	302.239	41.661	326.111	1	6	111
7	306.326	39.558	326.111	1	7	112
8	305.94	36.025	326.111	1	8	113
9	295.51	41.829	328.03	1	9	114
10	298.622	44.079	328.03	1	10	115
11	306.109	38.759	328.03	1	11	116
12	304.847	35.352	328.03	1	12	117
	ID=Common_Nighthawk					
	LM3=13					
0	303.718	28.047	383.954	1	0	118
1	304.352	29.071	383.511	1	1	119
2	302.223	28.729	383.511	1	2	120
3	303.458	28.729	383.511	1	3	121

4	308.724	29.704	380.411	1	4	122
5	306.351	31.232	380.411	1	5	123
6	302.808	30.468	380.411	1	6	124
7	299.167	29.087	380.411	1	7	125
8	298.127	25.869	380.411	1	8	126
9	311.081	27.738	376.622	1	9	127
10	308.139	30.94	376.622	1	10	128
11	297.347	27.023	376.622	1	11	129
12	298.127	22.228	376.622	1	12	130
	ID=House_Sparrow					
	LM3=13					
0	318.555	22.462	316.124	1	0	131
1	317.034	25.988	317.6	1	1	132
2	322.426	20.941	317.6	1	2	133
3	319.522	23.914	317.6	1	3	134
4	309.291	35.458	326.655	1	4	135
5	317.31	33.177	326.655	1	5	136
6	322.564	24.536	326.655	1	6	137
7	328.509	13.959	326.655	1	7	138
8	324.776	5.526	326.655	1	8	139
9	304.176	31.587	332.068	1	9	140
10	316.066	31.799	332.068	1	10	141
11	327.126	12.853	332.068	1	11	142
12	321.043	5.111	332.068	1	12	143
	ID=Red-tailed_Hawk					

Table 4. Covariance matrix produced by MorphoJ.

	ProcCoord1	ProcCoord2	ProcCoord3	ProcCoord4	ProcCoord5	ProcCoord6	ProcCoord7	ProcCoord8	ProcCoord9	ProcCoord10	ProcCoord11	ProcCoord12
	ProcCoord13	ProcCoord14	ProcCoord15	ProcCoord16	ProcCoord17	ProcCoord18	ProcCoord19	ProcCoord20	ProcCoord21	ProcCoord22	ProcCoord23	ProcCoord24
	ProcCoord25	ProcCoord26	ProcCoord27	ProcCoord28	ProcCoord29	ProcCoord30	ProcCoord31	ProcCoord32	ProcCoord33	ProcCoord34	ProcCoord35	ProcCoord36
	ProcCoord37	ProcCoord38	ProcCoord39									

ProcCoord1	6.179070466529721E-4	1.0908579343345956E-4	-5.484455898677002E-4	-0.00184085719907244	-3.274774486387162E-4	8.439230192932969E-4
	1.7828843070275932E-4	2.8639090499031903E-6	-1.3904320112149792E-4	4.800691068298444E-4	2.9471521647315854E-5	-2.7481244887969783E-4
	-2.2703401725165587E-5	5.2803082687418066E-5	1.7842196524246325E-4	2.581662653634479E-4	8.873358700201936E-5	8.037792401020722E-5
	2.637976874016085E-4	-8.273967716994715E-6	-1.9529571343641499E-4	-5.973103536137186E-5	-4.05973863799888E-6	1.3422582489711018E-5
	1.3467986206604367E-5	6.220970505382178E-5	3.651680517230106E-4	1.3355662178670608E-5	6.421110649885349E-5	-6.092956286964908E-5
	7.89153101423802E-5	9.542308816482587E-5	-7.87054145106012E-5	-1.370679745155207E-4	-3.729989704400344E-5	-6.468462274308876E-5
	1.56392115196221E-4	-1.2769074150007645E-4	-1.1939698933004166E-4			
ProcCoord2	1.0908579343345956E-4	4.8699648006517447E-4	-3.3997684719476E-4	1.6805835581953392E-4	-1.6298371316360674E-5	3.024182613332233E-4
	2.0840032663981366E-4	-8.0300551366742E-5	6.152962394822894E-5	6.724108612193283E-5	-6.605376254549743E-5	9.538411600538997E-6
	-1.0317039993037631E-4	1.8271550575545663E-4	2.0637163847222616E-4	1.4771696367567894E-4	9.842141941173773E-5	-3.0106418358708068E-5
	9.128061759012591E-5	7.948810218801178E-5	-3.776405511513389E-4	-2.5093749790846924E-4	1.8642711843912206E-4	-1.5264491452367116E-4
	-1.604194225086789E-4	3.633955831612312E-4	2.3281588545745368E-4	-5.221483422001539E-5	-3.609089417649934E-4	-3.214116473918171E-5

	2.4286317213127506E-4	-3.9320540156416006E-4	9.902018025979888E-5	-4.3392694967600706E-4	-3.2261820399916114E-4	-2.4271425292919305E-5
	-3.397721116826975E-5	-1.580589764639631E-4	4.5087320189066874E-5			
ProcCoord3	-5.484455898677002E-4	-3.3997684719476E-4	0.0018438514369879804	0.0027919834315436637	2.0064391859180315E-4	-0.0012735041328525473
	-5.937547166464005E-4	-1.6642473161821052E-4	-2.4297181070953743E-4	-3.508840569519306E-4	-1.485074084689175E-4	3.3245910985708985E-4
	-2.7774879931723856E-4	-1.3522634106635407E-4	-8.805023955362678E-4	-2.0113240301985425E-4	2.2040416181425427E-4	-2.7205766179709973E-5
	-2.446592360117261E-4	4.203957071914617E-4	6.181969257657877E-4	-1.7853122099006415E-5	3.591104145334737E-4	-1.5176556080450265E-5
	-6.91721466140902E-4	5.993150010353287E-5	-4.099654020104027E-4	-1.5054805574021146E-4	-4.395723239037857E-4	-4.371346477826458E-5
	-3.067500168056795E-4	-4.211021239198508E-5	2.1769015905012825E-4	7.917939709349319E-4	1.3404850225350018E-4	-1.1225574602321689E-4
	-2.0027993987797952E-4	-1.2271633984352437E-4	-6.902357490507936E-6			
ProcCoord4	-0.00184085719907244	1.6805835581953392E-4	0.0027919834315436637	0.019586105275487542	0.0022952113658755756	-0.005607077197101845
	-0.0026813527763518844	-8.340210950170566E-4	-2.6941500659445177E-4	-0.001484362972290283	-9.549581369694603E-4	0.0013806107248101524
	-0.0018828317824756905	-5.632494322882766E-4	-0.001164934871727652	-0.00141358256358214	-8.008504909684845E-4	3.51512238642938E-4
	-9.593593903670202E-4	1.3039678539174677E-4	4.1655778721537054E-4	-0.0023920863114501784	0.0011013634843178885	-4.561130821095877E-4
	-0.0033448486674803705	0.002896450444959572	0.0014402576785179418	-0.002610544843858171	-0.0018765607774897616	5.404027870518685E-4
	-6.239902113770897E-4	-0.002741358025920262	0.0018381755413209733	1.2356506193088572E-6	-3.986359202744574E-4	-1.2152701088769908E-4
	-3.535242078017512E-4	0.0015781534425639513	-0.0011404330206821812			
ProcCoord5	-3.274774486387162E-4	-1.6298371316360674E-5	2.0064391859180315E-4	0.0022952113658755756	5.940565973046405E-4	-8.471343581063124E-4
	-3.971955241511853E-4	1.9725179303065743E-4	-6.019864816930959E-5	-3.021433297430742E-4	1.888632003953184E-4	1.7199592089914626E-4
	-1.0041700733680863E-4	-3.266555977489967E-4	-2.5408126754592192E-5	-2.1847493712907478E-4	-3.973425466531449E-4	6.270891563520922E-5
	-1.2765882694248782E-4	-3.321540757563011E-4	8.072452628694334E-5	-3.9340595728480036E-4	-1.9618501695497286E-4	1.2142279469023951E-4
	-1.2356880458746787E-4	-5.908646959478513E-5	3.5279070592244424E-5	-1.5226905650190568E-4	1.3120068325204369E-5	1.1901734085713977E-4
	-3.142050374320816E-5	-1.0223066165304355E-4	2.2055145847012662E-4	-5.931195674965142E-5	1.1592089466277396E-4	4.739892585624432E-5
	-6.186801306721343E-5	3.2074018595934056E-4	-1.2700173884901502E-4			
ProcCoord6	8.439230192932969E-4	3.024182613332233E-4	-0.0012735041328525473	-0.005607077197101845	-8.471343581063124E-4	0.0021120138943649027
	9.410301912008452E-4	4.028463015824172E-5	1.1715329858599026E-4	6.86093588497256E-4	7.922928773167728E-5	-4.661198194479613E-4
	4.392067925816392E-4	4.1278342668103285E-4	4.503756476768626E-4	6.068344665575722E-4	4.201004956320163E-4	-8.075407237008862E-5
	4.020395201419638E-4	1.6164756288050263E-4	-4.289054734399601E-4	3.811316698971552E-4	-2.2019160435490814E-5	-3.706232789733305E-5
	6.057010863822427E-4	-2.517628659199411E-4	2.0211779105046737E-5	5.456509457084957E-4	2.0528409629079423E-4	-1.4904781495924665E-4
	2.8446104342852603E-4	3.3230562438455016E-4	-4.508209476763764E-4	-3.375228219875576E-4	-2.29957979102372E-4	-4.667954937278778E-6
	2.0852769540043807E-4	-6.031790215283536E-4	1.911279238480727E-4			
ProcCoord7	1.7828843070275932E-4	2.0840032663981366E-4	-5.937547166464005E-4	-0.0026813527763518844	-3.971955241511853E-4	9.410301912008452E-4
	6.533270239204988E-4	5.017614540323934E-6	2.7430842176543173E-4	1.1462347824341066E-4	1.031012232195235E-5	-1.1964180092058833E-4
	1.0011496796992012E-4	2.604638562475966E-4	1.429527708811889E-4	1.809478363239291E-4	2.0465489162635169E-4	-1.3391529924003067E-4
	8.012797950602714E-5	1.0926876393038271E-4	-2.2720222981458378E-4	4.4309683243517957E-4	-3.247390449635529E-5	-1.1702156384816578E-4
	5.72003068213763E-4	-2.0489811631050709E-4	-3.6123450458774213E-4	3.868256367272582E-4	1.6115368262150607E-4	3.965427454708537E-5
	3.273688963533283E-4	9.679129972712958E-5	-2.7222263035638934E-4	-3.66639960129345E-4	-1.9365283759277934E-4	4.32425483472191E-5
	1.126858608517275E-5	-2.2784017510430588E-4	3.8380453867217E-4			
ProcCoord8	2.8639090499031903E-6	-8.0300551366742E-5	-1.6642473161821052E-4	-8.340210950170566E-4	1.9725179303065743E-4	4.028463015824172E-5
	5.017614540323934E-6	3.1623524993828827E-4	-4.8068091732852245E-5	-3.300375742889217E-5	3.312877560985938E-4	-5.967683737818177E-5
	1.5506428019769735E-4	-2.3749539032840044E-4	1.0404642325158634E-4	1.192372473704814E-5	-2.502002592135298E-4	7.119466377315601E-6
	3.2143519703960965E-5	-3.2310532515396833E-4	4.521924342798515E-5	1.9284060362986126E-7	-3.5124274463881283E-4	1.8874914191082117E-4
	3.740192618990322E-4	-5.016431113865283E-4	-1.861357443609656E-4	2.4332280358209008E-4	3.1459875795956536E-4	4.646644921759339E-5
	5.43998641999689E-5	3.3420715186509585E-4	-7.330150501948342E-5	-1.356957042811625E-5	1.7912439790587339E-4	4.750358385012531E-5
	1.646604360418423E-6	7.128227529017923E-5	5.421797191598166E-5			
ProcCoord9	-1.3904320112149792E-4	6.152962394822894E-5	-2.4297181070953743E-4	-2.6941500659445177E-4	-6.019864816930959E-5	1.1715329858599026E-4
	2.7430842176543173E-4	-4.8068091732852245E-5	2.8745337193809514E-4	-1.6471054780076177E-4	-8.046473207432341E-5	5.9854033950433075E-5
	-8.498489679590202E-5	7.336708635590973E-5	-1.437200316618722E-5	-1.4429004922205464E-4	-3.5901752579674813E-6	-6.05340743491164E-5

	-1.0708255733187718E-4	1.4741284624048744E-5	-5.119175204718588E-5	3.1397067362482986E-4	-3.596858177808697E-5	-9.488481223428757E-5
	3.3979904092809615E-4	-7.303551066734025E-5	-3.5986576638229574E-4	1.1850624469476416E-4	1.377365367105871E-4	1.255795544826094E-4
	1.8808260335603623E-4	-4.000544341802785E-5	-1.0247845617003208E-4	-2.886678024946486E-4	-5.520872664428419E-5	7.161326630956127E-5
	-3.6472923007966776E-5	1.0916537810346473E-4	2.6464514979193676E-4			
ProcCoord10	4.800691068298444E-4	6.724108612193283E-5	-3.508840569519306E-4	-0.001484362972290283	-3.021433297430742E-4	6.86093588497256E-4
	1.1462347824341066E-4	-3.300375742889217E-5	-1.6471054780076177E-4	4.508055240824135E-4	1.0871449489260003E-5	-1.989968128354759E-4
	8.018836048959302E-5	1.5283927574907835E-4	6.513590003910101E-5	4.047329402715148E-4	1.938965761200096E-4	3.4132449709580424E-5
	2.4705573290856786E-4	1.2628901112924084E-4	-1.204095484591691E-4	-2.3360255367129963E-4	1.0575280882154277E-4	-3.040084176809708E-5
	-1.900883452557 91E-4	2.201802332578281E-4	4.582940051129945E-4	-4.5425376921434256E-5	-8.025973934769683E-5	-8.156696030164639E-5
	-8.472418814393918E-6	-3.563691731636254E-5	-1.1901422867705407E-5	3.2280111400311687E-6	-1.582338503850357E-4	-6.0501005957565735E-5
	1.8124851298782E-4	-2.677928464680369E-4	-2.242847464166025E-4			
ProcCoord11	2.9471521647315854E-5	-6.605376254549743E-5	-1.485074084689175E-4	-9.549581369694603E-4	1.888632003953184E-4	7.922928773167728E-5
	1.031012232195235E-5	3.312877560985938E-4	-8.046473207432341E-5	1.0871449489260003E-5	3.6173237246564256E-4	-6.063326529352975E-5
	1.5169801634477717E-4	-2.1777580865889613E-4	6.028466369766638E-5	1.0779895488278082E-4	-2.1926011694204268E-4	-3.0429659683294345E-6
	6.534869054442248E-5	-2.948074072430181E-4	4.6681758376027134E-5	-8.134350544047922E-5	-3.3421411217019446E-4	1.7442713664001284E-4
	3.3035841498400733E-4	-4.666188020760943E-4	-1.3163855452821258E-4	2.440153176091132E-4	2.796167094232626E-4	4.918977431310775E-5
	7.549868448285093E-5	3.0446160020819967E-4	-4.934807416904244E-5	-1.2342542263248262E-5	1.2507372018245448E-4	3.991615541276252E-5
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ProcCoord12	-2.7481244887969783E-4	9.538411600538997E-6	3.3245910985708985E-4	0.0013806107248101524	1.7199592089914626E-4	-4.661198194479613E-4
	-1.1964180092058833E-4	-5.967683737818177E-5	5.9854033950433075E-5	-1.989968128354759E-4	-6.063326529352975E-5	1.9551120969266218E-4
	-1.8211542362628152E-4	-3.554818735655192E-5	-2.9489532255407735E-4	-3.916636673847071E-5	1.981868521916134E-6	4.328102849844266E-6
	-1.094483653148629E-4	8.931772140991504E-5	1.376820967914242E-4	-1.3200292238105447E-4	8.846968520144366E-5	-9.2002090604495E-5
	-1.876036231549415E-4	1.378734800803168E-4	-1.1921939309685208E-4	-1.0416815504332003E-4	-1.501531838347157E-4	6.010110090166143E-5
	3.9410177748608764E-5	-1.8591155868868402E-4	1.5583101150921423E-4	-4.829459648128061E-5	-5.890214093482079E-5	3.296701697873238E-5
	-2.377038718281683E-5	5.164808577341619E-5	-6.497056827758391E-6			
ProcCoord13	-2.2703401725165587E-5	-1.0317039993037631E-4	-2.7774879931723856E-4	-0.0018828317824756905	-1.0041700733680863E-4	4.392067925816392E-4
	1.0011496796992012E-4	1.5506428019769735E-4	-8.498489679590202E-5	8.018836048959302E-5	1.5169801634477717E-4	-1.8211542362628152E-4
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	3.2782827571599044E-5	6.217130343010892E-7	-4.3441049132918105E-5	-8.433868094314974E-6	-5.2606554702801864E-5	2.1287881590106254E-4
	-4.546487303998198E-5	-2.9066327730492526E-4	1.1094013703666713E-5	2.600766929086435E-4	-7.312609043719004E-6	-3.452420971561215E-4
	-6.335025507948217E-4	2.2295707095893098E-4	-2.9030373994466734E-4	5.869382262415918E-4	1.4652936805426118E-5	3.9636577865652374E-5
	6.612146627100131E-5	-3.791583300085581E-4	-6.111776221648657E-5			
ProcCoord14	5.2803082687418066E-5	1.8271550575545663E-4	-1.3522634106635407E-4	-5.632494322882766E-4	-3.266555977489967E-4	4.1278342668103285E-4
	2.604638562475966E-4	-2.3749539032840044E-4	7.336708635590973E-5	1.5283927574907835E-4	-2.1777580865889613E-4	-3.554818735655192E-5
	2.5595276644066933E-4	5.487253419848415E-4	1.796968470330136E-4	3.229490902519679E-4	3.971614027224151E-4	-1.926306542598697E-4
	4.6954748669886704E-5	4.155393453169302E-4	-2.471849327423829E-4	-9.51815621427856E-5	3.957678906213735E-4	-2.2662455236346256E-4
	-3.107634380353939E-4	5.939239478138908E-4	3.041408828138144E-4	-1.0709230285376908E-4	-3.6577410881066244E-4	-4.003769460174543E-5
	-9.374640184734352E-5	-5.090879093356942E-4	-6.080799680236307E-5	3.706141349688572E-5	-5.166838668873757E-4	-5.7337840735749557E-5
	4.100890362407337E-5	-3.60360752445431E-4	2.5409957044823003E-5			
ProcCoord15	1.7842196524246325E-4	2.0637163847222616E-4	-8.805023955362678E-4	-0.001164934871727652	-2.5408126754592192E-5	4.503756476768626E-4
	1.429527708811889E-4	1.0404642325158634E-4	-1.437200316618722E-5	6.513590003910101E-5	6.028466369766638E-5	-2.9489532255407735E-4
	6.934017838376094E-4	1.796968470330136E-4	0.0012679294697456023	-1.6612108095013665E-4	-2.0363482458935666E-4	-6.932762859642653E-5
	7.346918154327844E-5	-3.8007708104870647E-4	-5.872856437438457E-4	1.759330262726481E-4	-1.9819137144933121E-4	1.7738537981612247E-4
	3.1893437223935603E-4	-9.288424963166351E-5	4.16475672281056E-4	5.6376449633722436E-5	1.2863993298808084E-4	-2.5302751705783027E-4
	-2.627962756359482E-4	7.560138488127503E-5	-2.631382167591531E-4	3.6746227784453875E-6	5.186002111344543E-5	-2.3434551067077278E-5
	-1.1444784415396202E-4	9.369474203540011E-5	7.38171089615315E-5			

ProcCoord16	2.581662653634479E-4	1.4771696367567894E-4	-2.0113240301985425E-4	-0.00141358256358214	-2.1847493712907478E-4	6.068344665575722E-4
	1.809478363239291E-4	1.192372473704814E-5	-1.4429004922205464E-4	4.047329402715148E-4	1.0779895488278082E-4	-3.916636673847071E-5
	2.7660057710630356E-4	3.229490902519679E-4	-1.6612108095013665E-4	8.515053591072899E-4	3.6518408208660315E-4	-5.660338556133567E-5
	2.5410416983516666E-4	3.334427344077375E-4	-1.4738881096353884E-5	-6.164547723457506E-4	2.1916673602144447E-4	-1.6681430786520646E-4
	-4.459362712458337E-4	3.8039497838859973E-4	4.305292905960009E-4	-1.2477924133559039E-5	-3.25166506911993E-4	-9.16407201224741E-5
	-2.0748425482702458E-5	-3.0234238963370143E-4	1.1801292039430109E-4	7.987493780607755E-7	-4.7675706024976965E-4	-1.1221882334764963E-6
	2.8234405940422906E-4	-5.658363705274346E-4	-2.737472947386209E-4			
ProcCoord17	8.873358700201936E-5	9.842141941173773E-5	2.2040416181425427E-4	-8.008504909684845E-4	-3.973425466531449E-4	4.201004956320163E-4
	2.0465489162635169E-4	-2.502002592135298E-4	-3.5901752579674813E-6	1.938965761200096E-4	-2.1926011694204268E-4	1.981868521916134E-6
	1.3238139454463285E-4	3.971614027224151E-4	-2.0363482458935666E-4	3.6518408208660315E-4	5.035580734889784E-4	-9.584462435377505E-5
	7.361979499694722E-5	5.2161336926151E-4	4.328823488403245E-6	-3.931901673938238E-5	4.2409664410397415E-4	-1.909058210323141E-4
	-3.80795180543393E-4	3.8175874051464987E-4	7.83254389117721E-5	-2.2163333636509286E-6	-4.0128398540762095E-4	-1.2446436487605045E-4
	-7.26488983622103E-5	-2.4337338044917527E-4	-2.2521407190771115E-5	1.7528266750187573E-4	-3.262061157779126E-4	-5.652504287813302E-5
	6.207692609866277E-5	-4.88943245060093E-4	-2.7654528189926387E-5			
ProcCoord18	8.037792401020722E-5	-3.0106418358708068E-5	-2.7205766179709973E-5	3.51512238642938E-4	6.270891563520922E-5	-8.075407237008862E-5
	-1.3391529924003067E-4	7.119466377315601E-6	-6.05340743491164E-5	3.4132449709580424E-5	-3.0429659683294345E-6	4.328102849844266E-6
	-1.1126421569971866E-4	-1.926306542598697E-4	-6.932762859642653E-5	-5.660338556133567E-5	-9.584462435377505E-5	1.4960123319053358E-4
	2.515072519102982E-5	-1.0150410434539892E-4	9.70644687977147E-5	-6.092870032932842E-5	-7.722119536784755E-5	4.7512017953998336E-5
	-6.386289486254553E-5	-9.176586286295768E-5	3.173080072334043E-5	-6.04265328812342E-5	4.4359835462678985E-5	-7.124263924521967E-5
	-2.05361161412737E-5	1.5188440593430545E-4	8.36750568930715E-5	-3.556826839638423E-5	2.0732868037070883E-4	2.4885266944668308E-5
	5.1932075558086565E-5	1.18714521736756E-4	-1.2973276661266291E-4			
ProcCoord19	2.637976874016085E-4	9.128061759012591E-5	-2.446592360117261E-4	-9.593593903670202E-4	-1.2765882694248782E-4	4.020395201419638E-4
	8.012797950602714E-5	3.2143519703960965E-5	-1.0708255733187718E-4	2.4705573290856786E-4	6.534869054442248E-5	-1.094483653148629E-4
	3.2782827571599044E-5	4.6954748669886704E-5	7.346918154327844E-5	2.5410416983516666E-4	7.361979499694722E-5	2.515072519102982E-5
	1.6918586607986993E-4	8.017194365206206E-6	-1.0966824095574914E-4	-1.671361134531059E-4	6.097951439515512E-6	1.334373576484932E-6
	-3.359815930999206E-5	5.947110726455577E-5	2.849839996056674E-4	1.999505779754406E-5	-4.003421257698247E-5	-6.848089206690057E-5
	7.261202848014893E-5	3.144989601709817E-5	1.5629947562160354E-5	-6.027578010876132E-5	-7.106088821576479E-5	-2.7336412955812873E-5
	8.070809365834711E-5	-1.7562959285654585E-4	-1.359320429836962E-4			
ProcCoord20	-8.273967716994715E-6	7.948810218801178E-5	4.203957071914617E-4	1.3039678539174677E-4	-3.321540757563011E-4	1.6164756288050263E-4
	1.0926876393038271E-4	-3.2310532515396833E-4	1.4741284624048744E-5	1.2628901112924084E-4	-2.948074072430181E-4	8.931772140991504E-5
	6.217130343010892E-7	4.155393453169302E-4	-3.8007708104870647E-4	3.334427344077375E-4	5.2161336926151E-4	-1.0150410434539892E-4
	8.017194365206206E-6	6.139320505453487E-4	7.681009830688136E-5	-1.339348517749626E-4	5.276214243349878E-4	-2.6204778410465507E-4
	-5.792740134984874E-4	5.726573822003908E-4	7.106863153371453E-5	-1.353395406467598E-4	-5.022568011052557E-4	-4.7993282131654776E-5
	-9.943833222031226E-5	-4.41259371120157E-4	5.920636087097378E-5	1.7702043733825741E-4	-4.1025476333471074E-4	-6.224339781531288E-5
	7.120406626060722E-5	-4.27013930133953E-4	-3.932171737173206E-5			
ProcCoord21	-1.9529571343641499E-4	-3.776405511513389E-4	6.181969257657877E-4	4.1655778721537054E-4	8.072452628694334E-5	-4.289054734399601E-4
	-2.2720222981458378E-4	4.521924342798515E-5	-5.119175204718588E-5	-1.204095484591691E-4	4.6681758376027134E-5	1.376820967914242E-4
	-4.3441049132918105E-5	-2.471849327423829E-4	-5.872856437438457E-4	-1.4738881096353884E-5	4.328823488403245E-6	9.70644687977147E-5
	-1.0966824095574914E-4	7.681009830688136E-5	5.516655805712213E-4	7.9129823911407E-5	-7.442120432922666E-5	6.077355409735382E-5
	-9.376022448589431E-5	-3.4219608745108003E-4	-4.62706422175719E-4	6.457899491421227E-5	1.3910997196128397E-4	3.6342348355755895E-7
	-1.810498977678166E-4	3.1222300805273755E-4	4.7036711682410915E-5	3.4459291282046837E-4	2.8568944143909073E-4	5.941020187796538E-5
	8.070626628739922E-5	5.0655904335102106E-5	-4.210367166077201E-5			
ProcCoord22	-5.973103536137186E-5	-2.5093749790846924E-4	-1.7853122099006415E-5	-0.0023920863114501784	-3.9340595728480036E-4	3.811316698971552E-4
	4.4309683243517957E-4	1.9284060362986126E-7	3.1397067362482986E-4	-2.3360255367129963E-4	-8.134350544047922E-5	-1.3200292238105447E-4
	-8.433868094314974E-6	-9.51815621427856E-5	1.759330262726481E-4	-6.164547723457506E-4	-3.931901673938238E-5	-6.092870032932842E-5
	-1.671361134531059E-4	-1.339348517749626E-4	7.9129823911407E-5	0.001409465390975104	-3.1728805496686216E-4	1.0685408342276589E-4
	0.0011264384050680793	-9.437137529261623E-4	-0.0010572160378500175	5.542266268548584E-4	6.589216549627975E-4	-3.294497663972492E-5

	1.3623652713438007E-4	8.14980192571373E-4	-5.175007696190319E-4	5.918664227654554E-5	5.292188697414697E-4	3.446196925177965E-5
	-2.5120577036804134E-4	2.5181064130463807E-4	7.269652825378775E-4			
ProcCoord23	-4.05973863799888E-6	1.8642711843912206E-4	3.591104145334737E-4	0.0011013634843178885	-1.9618501695497286E-4	-2.2019160435490814E-5
	-3.247390449635529E-5	-3.5124274463881283E-4	-3.596858177808697E-5	1.0575280882154277E-4	-3.3421411217019446E-4	8.846968520144366E-5
	-5.2606554702801864E-5	3.957678906213735E-4	-1.9819137144933121E-4	2.1916673602144447E-4	4.2409664410397415E-4	-7.722119536784755E-5
	6.097951439515512E-6	5.276214243349878E-4	-7.442120432922666E-5	-3.1728805496686216E-4	5.700034560781733E-4	-2.4130563957405947E-4
	-7.426627217259763E-4	7.81527756244541E-4	3.5089613409944824E-4	-3.03841370752864E-4	-6.228217712604438E-4	-4.9330993068278296E-5
	-1.2292937301337247E-4	-6.114226448980427E-4	1.4372590766656567E-4	1.1934258584357543E-4	-4.3806156412579513E-4	-9.451763928120453E-5
	2.4138151852234995E-5	-3.3149643577421427E-4	-1.4922635621737634E-4			
ProcCoord24	1.3422582489711018E-5	-1.5264491452367116E-4	-1.5176556080450265E-5	-4.561130821095877E-4	1.2142279469023951E-4	-3.706232789733305E-5
	-1.1702156384816578E-4	1.8874914191082117E-4	-9.488481223428757E-5	-3.040084176809708E-5	1.7442713664001284E-4	-9.2002090604495E-5
	2.1287881590106254E-4	-2.2662455236346256E-4	1.7738537981612247E-4	-1.6681430786520646E-4	-1.909058210323141E-4	4.7512017953998336E-5
	1.334373576484932E-6	-2.6204778410465507E-4	6.077355409735382E-5	1.0685408342276589E-4	-2.4130563957405947E-4	2.461832889056771E-4
	2.339031499587924E-4	-4.34695586037003E-4	-9.218271634872451E-5	1.5910941663734276E-4	2.376250480688553E-4	-5.909259904356207E-5
	-1.1684817799761478E-4	4.0257515335599003E-4	-1.0391215393354971E-4	2.1061357600771503E-4	3.13809889859871E-4	8.25490144168549E-6
	-5.091802440518503E-5	6.961513310943792E-5	-4.579588607239493E-5			
ProcCoord25	1.3467986206604367E-5	-1.604194225086789E-4	-6.91721466140902E-4	-0.0033448486674803705	-1.2356880458746787E-4	6.057010863822427E-4
	5.72003068213763E-4	3.740192618990322E-4	3.3979904092809615E-4	-1.90088345255791E-4	3.3035841498400733E-4	-1.876036231549415E-4
	-4.546487303998198E-5	-3.107634380353939E-4	3.1893437223935603E-4	-4.459362712458337E-4	-3.80795180543393E-4	-6.386289486254553E-5
	-3.359815930999206E-5	-5.792740134984874E-4	-9.376022448589431E-5	0.0011264384050680793	-7.426627217259763E-4	2.339031499587924E-4
	0.0016511307007507033	-0.0012417054434954652	-8.88264905494205E-4	7.406978236911205E-4	0.0010157160100493989	1.5442462023932595E-4
	5.272947958192116E-4	9.760828704278749E-4	-4.8121503541478103E-4	-3.805570983640029E-4	5.158423517266128E-4	1.1858038260231788E-4
	-1.905393650534411E-4	3.271701153083319E-4	6.350854972031791E-4			
ProcCoord26	6.220970505382178E-5	3.633955831612312E-4	5.993150010353287E-5	0.002896450444959572	-5.908646959478513E-5	-2.517628659199411E-4
	-2.0489811631050709E-4	-5.016431113865283E-4	-7.303551066734025E-5	2.201802332578281E-4	-4.666188020760943E-4	1.378734800803168E-4
	-2.9066327730492526E-4	5.939239478138908E-4	-9.288424963166351E-5	3.8039497838859973E-4	3.8175874051464987E-4	-9.176586286295768E-5
	5.947110726455577E-5	5.726573822003908E-4	-3.4219608745108003E-4	-9.437137529261623E-4	7.81527756244541E-4	-4.34695586037003E-4
	-0.0012417054434954652	0.0016403717500642595	0.0011702027421894607	-8.24480585449708E-4	-8.993770195750679E-4	1.050284010142284E-4
	-8.002204355481618E-5	-0.0013303335022694636	4.164421603513117E-4	-1.6658994698890727E-4	-8.690601609336031E-4	-1.337866190429476E-4
	1.3336669710606173E-4	-2.0751609416397115E-4	-4.69351502126033E-4			
ProcCoord27	3.651680517230106E-4	2.3281588545745368E-4	-4.099654020104027E-4	0.0014402576785179418	3.5279070592244424E-5	2.0211779105046737E-5
	-3.6123450458774213E-4	-1.861357443609656E-4	-3.5986576638229574E-4	4.582940051129945E-4	-1.3163855452821258E-4	-1.1921939309685208E-4
	1.1094013703666713E-5	3.041408828138144E-4	4.16475672281056E-4	4.305292905960009E-4	7.83254389117721E-5	3.173080072334043E-5
	2.849839996056674E-4	7.106863153371453E-5	-4.62706422175719E-4	-0.0010572160378500175	3.5089613409944824E-4	-9.218271634872451E-5
	-8.88264905494205E-4	0.0011702027421894607	0.0016495207697826814	-6.948269910790524E-4	-5.345039270577746E-4	-9.154025717583786E-5
	-1.401952280444622E-4	-7.313713327675212E-4	3.588602709454082E-4	-6.6486825324243E-6	-4.7369993188332995E-4	-1.4062683078186185E-4
	1.580593103286116E-4	-1.853792950007633E-4	-8.006925048659652E-4			
ProcCoord28	1.3355662178670608E-5	-5.221483422001539E-5	-1.5054805574021146E-4	-0.002610544843858171	-1.5226905650190568E-4	5.456509457084957E-4
	3.868256367272582E-4	2.4332280358209008E-4	1.1850624469476416E-4	-4.5425376921434256E-5	2.440153176091132E-4	-1.0416815504332003E-4
	2.600766929086435E-4	-1.0709230285376908E-4	5.6376449633722436E-5	-1.2477924133559039E-5	-2.2163333636509286E-6	-6.04265328812342E-5
	1.999505779754406E-5	-1.353395406467598E-4	6.457899491421227E-5	5.542266268548584E-4	-3.03841370752864E-4	1.5910941663734276E-4
	7.406978236911205E-4	-8.24480585449708E-4	-6.948269910790524E-4	5.953246682777118E-4	3.7697710389576387E-4	-4.9281852286296725E-5
	1.6290128831187038E-4	6.26561098755411E-4	-3.106203580935524E-4	1.1069098625124535E-5	2.4657208047704747E-4	6.207731943131847E-5
	-7.602441045961275E-5	-1.5999438053050847E-4	3.635725741038845E-4			
ProcCoord29	6.421110649885349E-5	-3.609089417649934E-4	-4.395723239037857E-4	-0.0018765607774897616	1.3120068325204369E-5	2.0528409629079423E-4
	1.6115368262150607E-4	3.1459875795956536E-4	1.377365367105871E-4	-8.025973934769683E-5	2.796167094232626E-4	-1.501531838347157E-4
	-7.312609043719004E-6	-3.6577410881066244E-4	1.2863993298808084E-4	-3.25166506911993E-4	-4.0128398540762095E-4	4.4359835462678985E-5

	-4.003421257698247E-5	-5.022568011052557E-4	1.3910997196128397E-4	6.589216549627975E-4	-6.228217712604438E-4	2.376250480688553E-4
	0.0010157160100493989	-8.993770195750679E-4	-5.345039270577746E-4	3.7697710389576387E-4	8.740579664760972E-4	1.5118751591304292E-4
	1.5652285206634408E-4	7.509776996328653E-4	-2.9465069264002767E-4	-9.490266774299124E-5	4.997428362085214E-4	9.97468429570685E-5
	-9.26589698148646E-6	4.2030858989884796E-4	2.7519034708391274E-4			
ProcCoord30	-6.092956286964908E-5	-3.214116473918171E-5	-4.371346477826458E-5	5.404027870518685E-4	1.1901734085713977E-4	-1.4904781495924665E-4
	3.965427454708537E-5	4.646644921759339E-5	1.255795544826094E-4	-8.156696030164639E-5	4.918977431310775E-5	6.010110090166143E-5
	-3.452420971561215E-4	-4.003769460174543E-5	-2.5302751705783027E-4	-9.16407201224741E-5	-1.2446436487605045E-4	-7.124263924521967E-5
	-6.848089206690057E-5	-4.7993282131654776E-5	3.6342348355755895E-7	-3.294497663972492E-5	-4.9330993068278296E-5	-5.909259904356207E-5
	1.5442462023932595E-4	1.050284010142284E-4	-9.154025717583786E-5	-4.9281852286296725E-5	1.5118751591304292E-4	3.455983025227601E-4
	2.4912151374682133E-4	-2.0980623403316816E-4	2.538674438134004E-5	-2.576006702916058E-4	-1.6008941771050375E-4	7.004231228946049E-6
	4.084536149286016E-6	1.9297366984584154E-4	1.0363093525893565E-4			
ProcCoord31	7.89153101423802E-5	2.4286317213127506E-4	-3.067500168056795E-4	-6.239902113770897E-4	-3.142050374320816E-5	2.8446104342852603E-4
	3.273688963533283E-4	5.43998641999689E-5	1.8808260335603623E-4	-8.472418814393918E-6	7.549868448285093E-5	3.9410177748608764E-5
	-6.335025507948217E-4	-9.374640184734352E-5	-2.627962756359482E-4	-2.0748425482702458E-5	-7.26488983622103E-5	-2.05361161412737E-5
	7.261202848014893E-5	-9.943833222031226E-5	-1.810498977678166E-4	1.3623652713438007E-4	-1.2292937301337247E-4	-1.1684817799761478E-4
	5.272947958192116E-4	-8.002204355481618E-5	-1.401952280444622E-4	1.6290128831187038E-4	1.5652285206634408E-4	2.4912151374682133E-4
	7.092666328393551E-4	1.4880776901795732E-5	4.605928231725129E-5	-6.614097522508528E-4	-1.001612258184602E-4	2.0837668361050248E-5
	-6.647212036083486E-5	5.620142877804695E-5	2.0020342343426067E-4			
ProcCoord32	9.542308816482587E-5	-3.9320540156416006E-4	-4.211021239198508E-5	-0.002741358025920262	-1.0223066165304355E-4	3.3230562438455016E-4
	9.679129972712958E-5	3.3420715186509585E-4	-4.000544341802785E-5	-3.563691731636254E-5	3.0446160020819967E-4	-1.8591155868868402E-4
	2.2295707095893098E-4	-5.090879093356942E-4	7.560138488127503E-5	-3.0234238963370143E-4	-2.4337338044917527E-4	1.5188440593430545E-4
	3.144989601709817E-5	-4.41259371120157E-4	3.1222300805273755E-4	8.14980192571373E-4	-6.114226448980427E-4	4.0257515335599003E-4
	9.760828704278749E-4	-0.0013303335022694636	-7.313713327675212E-4	6.26561098755411E-4	7.509776996328653E-4	-2.0980623403316816E-4
	1.4880776901795732E-5	0.001276682682859801	-3.378082323636265E-4	2.850955422711016E-4	8.594750597948565E-4	8.12851785508704E-5
	-8.488450292516772E-5	1.0510867692925348E-4	1.9113825850338535E-4			
ProcCoord33	-7.87054145106012E-5	9.902018025979888E-5	2.1769015905012825E-4	0.0018381755413209733	2.2055145847012662E-4	-4.508209476763764E-4
	-2.7222263035638934E-4	-7.330150501948342E-5	-1.0247845617003208E-4	-1.1901422867705407E-5	-4.934807416904244E-5	1.5583101150921423E-4
	-2.9030373994466734E-4	-6.080799680236307E-5	-2.631382167591531E-4	1.1801292039430109E-4	-2.2521407190771115E-5	8.36750568930715E-5
	1.5629947562160354E-5	5.920636087097378E-5	4.7036711682410915E-5	-5.175007696190319E-4	1.4372590766656567E-4	-1.0391215393354971E-4
	-4.8121503541478103E-4	4.164421603513117E-4	3.588602709454082E-4	-3.106203580935524E-4	-2.9465069264002767E-4	2.538674438134004E-5
	4.605928231725129E-5	-3.378082323636265E-4	3.161680232559185E-4	-1.1298847881106948E-4	-1.3115832552644248E-4	-7.0150014874933465E-6
	5.758015802307208E-5	3.065016609313924E-5	-2.772832016910534E-4			
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	-3.66639960129345E-4	-1.356957042811625E-5	-2.886678024946486E-4	3.2280111400311687E-6	-1.2342542263248262E-5	-4.829459648128061E-5
	5.869382262415918E-4	3.706141349688572E-5	3.6746227784453875E-6	7.987493780607755E-7	1.7528266750187573E-4	-3.556826839638423E-5
	-6.027578010876132E-5	1.7702043733825741E-4	3.4459291282046837E-4	5.918664227654554E-5	1.1934258584357543E-4	2.1061357600771503E-4
	-3.805570983640029E-4	-1.6658994698890727E-4	-6.6486825324243E-6	1.1069098625124535E-5	-9.490266774299124E-5	-2.576006702916058E-4
	-6.614097522508528E-4	2.850955422711016E-4	-1.1298847881106948E-4	9.764925845268415E-4	2.2794482956916146E-4	-7.573139182511444E-5
	-3.299839743900212E-5	-2.411038421722402E-4	-1.8765236972122164E-4			
ProcCoord35	-3.729989704400344E-5	-3.2261820399916114E-4	1.3404850225350018E-4	-3.986359202744574E-4	1.1592089466277396E-4	-2.29957979102372E-4
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	1.4652936805426118E-5	-5.166838668873757E-4	5.186002111344543E-5	-4.7675706024976965E-4	-3.262061157779126E-4	2.0732868037070883E-4
	-7.106088821576479E-5	-4.1025476333471074E-4	2.8568944143909073E-4	5.292188697414697E-4	-4.3806156412579513E-4	3.13809889859871E-4
	5.158423517266128E-4	-8.690601609336031E-4	-4.7369993188332995E-4	2.4657208047704747E-4	4.997428362085214E-4	-1.6008941771050375E-4
	-1.001612258184602E-4	8.594750597948565E-4	-1.3115832552644248E-4	2.2794482956916146E-4	7.698048950873259E-4	6.0139629205108746E-5
	-9.842938873941348E-5	3.337428712169862E-4	5.614035756010121E-5			

ProcCoord36	-6.468462274308876E-5	-2.4271425292919305E-5	-1.1225574602321689E-4	-1.2152701088769908E-4	4.739892585624432E-5	-4.667954937278778E-6
	4.32425483472191E-5	4.750358385012531E-5	7.161326630956127E-5	-6.0501005957565735E-5	3.991615541276252E-5	3.296701697873238E-5
	3.9636577865652374E-5	-5.7337840735749557E-5	-2.3434551067077278E-5	-1.1221882334764963E-6	-5.652504287813302E-5	2.4885266944668308E-5
	-2.7336412955812873E-5	-6.224339781531288E-5	5.941020187796538E-5	3.446196925177965E-5	-9.451763928120453E-5	8.25490144168549E-6
	1.1858038260231788E-4	-1.337866190429476E-4	-1.4062683078186185E-4	6.207731943131847E-5	9.97468429570685E-5	7.004231228946049E-6
	2.0837668361050248E-5	8.12851785508704E-5	-7.0150014874933465E-6	-7.573139182511444E-5	6.0139629205108746E-5	5.888701343632182E-5
	3.206616674341211E-5	5.2691649214154374E-5	2.4978186079012113E-5			
ProcCoord37	1.56392115196221E-4	-3.397721116826975E-5	-2.0027993987797952E-4	-3.535242078017512E-4	-6.186801306721343E-5	2.0852769540043807E-4
	1.126858608517275E-5	1.646604360418423E-6	-3.6472923007966776E-5	1.8124851298782E-4	2.3273012366710455E-5	-2.377038718281683E-5
	6.612146627100131E-5	4.100890362407337E-5	-1.1444784415396202E-4	2.8234405940422906E-4	6.207692609866277E-5	5.1932075558086565E-5
	8.070809365834711E-5	7.120406626060722E-5	8.070626628739922E-5	-2.5120577036804134E-4	2.4138151852234995E-5	-5.091802440518503E-5
	-1.905393650534411E-4	1.3336669710606173E-4	1.580593103286116E-4	-7.602441045961275E-5	-9.26589698148646E-6	4.084536149286016E-6
	-6.647212036083486E-5	-8.488450292516772E-5	5.758015802307208E-5	-3.299839743900212E-5	-9.842938873941348E-5	3.206616674341211E-5
	1.9268143787986246E-4	-6.828934878723996E-5	-1.6706708986247425E-4			
ProcCoord38	-1.2769074150007645E-4	-1.580589764639631E-4	-1.2271633984352437E-4	0.0015781534425639513	3.2074018595934056E-4	-6.031790215283536E-4
	-2.2784017510430588E-4	7.128227529017923E-5	1.0916537810346473E-4	-2.677928464680369E-4	7.694650862576814E-6	5.164808577341619E-5
	-3.791583300085581E-4	-3.60360752445431E-4	9.369474203540011E-5	-5.658363705274346E-4	-4.88943245060093E-4	1.18714521736756E-4
	-1.7562959285654585E-4	-4.27013930133953E-4	5.0655904335102106E-5	2.5181064130463807E-4	-3.3149643577421427E-4	6.961513310943792E-5
	3.271701153083319E-4	-2.0751609416397115E-4	-1.853792950007633E-4	-1.5999438053050847E-4	4.2030858989884796E-4	1.9297366984584154E-4
	5.620142877804695E-5	1.0510867692925348E-4	3.065016609313924E-5	-2.411038421722402E-4	3.337428712169862E-4	5.2691649214154374E-5
	-6.828934878723996E-5	7.145121838846311E-4	1.4146540612590386E-4			
ProcCoord39	-1.1939698933004166E-4	4.5087320189066874E-5	-6.902357490507936E-6	-0.0011404330206821812	-1.2700173884901502E-4	1.911279238480727E-4
	3.8380453867217E-4	5.421797191598166E-5	2.6464514979193676E-4	-2.242847464166025E-4	2.3906224331036113E-5	-6.497056827758391E-6
	-6.111776221648657E-5	2.5409957044823003E-5	7.38171089615315E-5	-2.737472947386209E-4	-2.7654528189926387E-5	-1.2973276661266291E-4
	-1.359320429836962E-4	-3.932171737173206E-5	-4.2103671077201E-5	7.2696		

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