Experiments in the function and performance of the weighted atlatl

Anan Raymond

Introduction

‘The blood clot of giants slain in Creation
time with lightning of the gods of war.’

With those words, Frank Hamilton Cushing (1895: 341) described a black limonite rock fastened to the shaft of a Basketmaker II atlatl, found in the Grand Gulch, San Juan County, Utah. Since then, the question of the purpose of atlatl weights, as well as the function of the atlatl, has stimulated both scholars and laymen to speculation and experimentation.

The nearly global use and tremendous time range of the atlatl (or spearthrower) and dart (or spear) (Figure 1) attests to the effectiveness of this simple weapon. The atlatl has been used by hunter gatherers on all continents except Africa and Antarctica (Cressman and Krieger 1940: 28). Some Magdalenian spearthrowers in France are 13,000 years old (Garrod 1955), while the Eskimos, Australian Aborigines, and the Tarascan Indians of Mexico have continued to hunt with atlatls in the 20th century (O. Mason 1884, Davidson 1936, Gould 1970, Stirling 1960).

While basic curiosity has motivated this researcher and many others to experiment with the atlatl and dart, such experimentation may offer the only means to investigate the use of a weapon whose current users are rapidly embracing 20th century technology. Indeed, experimentation remains the only method to assess the function and performance of weighted atlatls, which are only known from prehistory. Furthermore, atlatl experiments provide important clues to explain why this weapon maintained its effectiveness for some people for millennia, yet was replaced in other regions by more sophisticated tools, namely the bow and arrow.

Many of the anthropologists listed in the references have dabbled with the atlatl and dart, though fewer have conducted controlled experiments in order to describe the function and performance of this weapon. The goal of some experiments has been to determine the utility of weights occasionally found attached to archaeologically recovered atlatls. Although many of these experiments provide valuable insight on how the atlatl served prehistoric and contemporary hunters, two basic issues remain
unresolved: (1) There is confusion in the literature on how one should operate an atlatl, and (2) there is disagreement over whether atlatl weights increase the performance of the weapon.

The present article reports on results of my own research and on experiments that were aimed at resolving these two issues. Although conducted as a whole, I will present my research, experiments, and results in two parts. The first section is concerned with atlatl function and use, while in the second section I examine the utility of atlatl weights. This article contains a brief review of previous models and experiments on atlatl function and performance. I suggest why these experiments contribute to the confusion and disagreement mentioned above. I then offer my experience and research with replicas of Basketmaker II atlatls as a better description of how to use an atlatl, and a better assessment of the utility of atlatl weights. I conclude the article with a brief discussion that contrasts the performance of the atlatl and dart with the bow and arrow. This provides insight into the evolution of hunting technology.

Atlatl function

Many Euro-American explorers and ethnographers have commented on the use of atlatls
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by indigenous people (Krause 1904: 621, Potter 1976: 510, Swanton 1938: 357, Nelson 1899, Bockstoce 1977: 44–45). However, none of these observations provides enough detail to ascertain how the atlatl works when used correctly.

The simplest and most common descriptions explain that the atlatl effectively increases the length of the human arm, and thereby increases the amount of time during which force is imparted to the dart (O. Mason 1884: 280, Kellar 1955, Webb 1957: 21, J. A. Mason 1928: 292, Krause 1904: 619). By allowing the hunter to apply the force of his arm for a longer period of time, the atlatl imparts a much higher velocity to the dart than that provided by the arm alone.

Some researchers have proposed models based on mechanical and physical principles to describe atlatl function. These models recognize that the atlatl rotates on an axis at the handle of the weapon. Webb (1957), in a stimulating discussion on the evolution of the speartrower, compares the motion of an atlatl propelling a dart with the motion of a pendulum or baseball bat striking an object. Ingenious as the analogy is, it does not apply, because the atlatl is not a percussive instrument. It does not strike a stationary dart.

Butler (1975) employs principles of mechanical physics to show that, when propelling a dart, the arm and atlatl sweep an arc, which has a radius larger than the radius described by the arm alone. The velocity of a point on this radius is higher the further it is from the axis of revolution. Thus, velocity of the atlatl and arm is highest at the distal end, where the atlatl spur engages with the nock of the dart. Butler (1975: 106) calculates that despite the increase in inertia presented by the atlatl over the arm alone, velocity of the dart propelled by an atlatl increases 1.7 times the velocity of the same dart thrown by the arm alone.

Although Butler recognizes that his model presents an idealized description of atlatl function, it suffers from a simplistic and incorrect notion of how to actually use the weapon. Butler invokes Jim Browne’s (1940) description of ‘catapulting’ a dart with the atlatl. ‘The arm and atlatl are extended to the height above the head equal to the length of the arm and atlatl.’ (Browne 1940: 211–12). The viability of this particular technique is questionable, however. Even Browne concedes that with this ‘uncontrolled throw. . .I wouldn’t be sure of hitting a buffalo at thirty yards once out of ten shots.’ (1940: 212.)

Howard (1974) describes a more effective method of hurling a dart with the atlatl. Like a hand-thrown spear, a straight and predictable flight path of the dart requires a straight trajectory in its launch path. Although the atlatl does rotate, its axis of rotation (at the handle) revolves downwards near completion of the throw. This ensures that the spur of the atlatl, which pushes the dart, will reach a height no greater than the original elevation of the handle. Thus, the dart will be propelled in a straight trajectory before it leaves the atlatl. Howard’s (1976: 314) experiments demonstrate that a dart launched by an atlatl will fly 60 per cent further than the same dart propelled by the unaided hand.

Howard (1974, 1976), Butler (1975, 1977), and Patterson (1975, 1977) debated the proper technique of throwing a dart with the atlatl, but left the subject unresolved.

I have been experimenting with atlatls and darts since 1978. Although I am quite comfortable and fairly proficient with the weapon, I doubt that I possess the same ability that one might expect from an individual who hunts with the atlatl and dart for a living. However, my extensive experience along with that of an atlatl-wielding colleague,
Gilbert Gilennie, led us to believe that Howard’s (1974) description was correct. The movements involved when throwing a dart with the atlatl preclude documentation with traditional still photography. Consequently, we enlisted the aid of high speed motion pictures.

The atlatls and darts used by us in the motion pictures were replicas of those recovered from archaeological contexts in the American Southwest (for a more detailed discussion of these weapons see below). The darts were propelled toward a target approximately 20

![Figure 2](image1.png) **Figure 2** At time 0, the marksman takes aim with the atlatl by stretching his throwing arm behind his head. He arranges his shoulders parallel to the projected line of fire with his body weight on the rear leg. The fingers of the hand hold the atlatl grip and secure the dart to the atlatl spur.

![Figure 3](image2.png) **Figure 3** At 0.48 seconds the marksman has rocked forward from the rear leg. He has stepped forward with his front leg towards the target and plants his heel. The upper body, shoulders, arms, and atlatl have moved forward but have not changed their basic position from that in Figure 2.

![Figure 4](image3.png) **Figure 4** At 0.65 seconds, the marksman firmly plants his forward leading foot and leg. His upper body and shoulders begin to rotate around the spinal axis from a line parallel with the projected dart path to a line perpendicular to that path. The throwing arm is still bent at a 90 degree angle at the elbow.

![Figure 5](image4.png) **Figure 5** At 0.72 seconds, his body weight has moved completely forward to the leading leg. His shoulders are perpendicular to the line of fire and his throwing arm is parallel with shoulders but still bent to 90 degrees at elbow. At this point the fingers, which have held the dart flush with atlatl, release their grip.
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metres distant. The camera was set up perpendicular to the throwing plane, while the film ran at 150 frames per second. The throw requires approximately two-thirds of a second. The line drawings (Figures 2–9) traced directly from the projected film image have been selected to illustrate key points in launching a dart with the atlatl.

In Figure 2, time 0, the marksman takes aim with the atlatl by stretching his throwing arm behind his head. He arranges his shoulders parallel to the projected line of fire, with his body weight on the rear leg. The fingers of the hand hold the atlatl grip and secure the

Figure 6 At 0.75 seconds, the elbow has reached its maximum forward extension in the line of fire. The forearm breaks the 90 degree angle at the elbow and begins to rotate downward.

Figure 7 At 0.77 seconds, the forearm continues its downward extension, while the wrist begins to rotate forward. The atlatl flexes under the stress.

Figure 8 At 0.78 seconds, the forearm completes its extension as the wrist continues to rotate, pivoting the atlatl.

Figure 9 At 0.79 seconds the atlatl completes its revolution to form a 90 degree angle with the arm. The dart is released.
dart to the atlatl spur. Figure 3, at 0.48 seconds, shows that the marksman has rocked forward from the rear leg. He has stepped forward with his front leg towards the target, and he plants his heel. The upper body, shoulders, arms, and atlatl have moved forward but have not changed their basic position from that in Figure 2. In Figure 4, at 0.65 seconds, the marksman firmly plants his forward leading foot and leg. His upper body and shoulders begin to rotate around the spinal axis from a line parallel with the projected dart path to a line perpendicular to that path. The throwing arm is still bent at a 90 degree angle at the elbow. In Figure 5, 0.72 seconds, his body weight has moved completely forward to the leading leg. His shoulders are perpendicular to the line of fire and his throwing arm is parallel with shoulders but still bent to 90 degrees at the elbow. At this point the fingers, which have held the dart flush with the atlatl, release their grip. Figure 6, at 0.75 seconds, shows that the elbow has reached its maximum forward extension in the line of fire. The forearm breaks the 90 degree angle at the elbow and begins to rotate downward. In Figure 7, 0.77 seconds, the forearm continues its downward extension while the wrist begins to rotate forward. The atlatl flexes under the stress. In Figure 8, 0.78 seconds, the forearm completes its extension as the wrist continues to rotate, pivoting the atlatl. In Figure 9, 0.79 seconds, the atlatl completes its revolution, forming a 90 degree angle with the arm. The dart is released.

A composite of the line drawing (Figure 10) illustrates that the point defining the juncture of the atlatl spur and dart nock essentially travels a straight line through space. Howard (1974: 102) is correct when he states that the atlatl spur ‘follows through in the original portion of the spear’s flight path.’ The dart nock does not reach an elevation greater than that reached by the atlatl handle. An accurate throw requires that, upon release from the atlatl, the force must be applied through the dart’s centre of gravity in a line toward the target. By accelerating the dart and atlatl in a straight line through space before release, the marksman is best prepared to apply force through the dart’s center of gravity upon release. Browne (1940: 212), Butler (1976: 211–212), and Patterson

Fig. 10 Superposition of Figures 2 through 9 shows that the point defined by the junction of the atlatl spur with the dart nock travels essentially in a straight line through space.
(1977: 159) do not describe a viable throw when they suggest that the atlatl and arm are extended and rotated to a height above the head equal to the length of the arm and atlatl. Patterson and Howard are correct when they state that the atlatl does rotate. However, the axis of rotation, the atlatl handle, describes a downward curving arc, because the forearm rotates about the elbow. Consequently, the spur, on the distal end of the atlatl, maintains a straight line through space, pivoting with the nock of the dart.

Atlatl weights

A second debated and unresolved issue concerns the function of atlatl weights. Although hundreds of ground stone artifacts, described as atlatl weights, have been found in North America (e.g. Neuman 1967, Butler and Osborne 1959), only ten atlatls, all archaeological specimens, have been recovered with weights actually attached to them (Figure 11). This number does not include the numerous alignments of socketed antler hooks, handles and drilled atlatl weights, essentially complete atlatls, except for the wood stave that connects the parts, which have been excavated in Kentucky (Webb and Haag 1939). Many carved spearthrowers from the Palaeolithic of western Europe are in

\[\text{Figure 11} \text{ Distribution of weighted atlatls in the western United States.}\]
Table 1 Data for prehistoric atlatls with attached weights

<table>
<thead>
<tr>
<th>Name</th>
<th>L</th>
<th>W</th>
<th>T</th>
<th>Weight in grams</th>
<th>Material</th>
<th>Weight in grams</th>
<th>Materials</th>
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<td>0.6</td>
<td>—</td>
<td>Cercocarpus</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Nicholasen</td>
<td>58.1</td>
<td>1.8–0.6</td>
<td>1.4–0.4</td>
<td>122</td>
<td>Cercocarpus</td>
<td>60.0</td>
<td>slate</td>
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<td>53.9</td>
<td>21–1.5</td>
<td>0.9–1.2</td>
<td>58</td>
<td>“hardwood”</td>
<td>30.3</td>
<td>sandstone</td>
</tr>
<tr>
<td>Hogup Cave</td>
<td>56.5</td>
<td>3.5</td>
<td>0.4</td>
<td>—</td>
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<td>slate</td>
</tr>
<tr>
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<td>—</td>
<td>—</td>
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<td>“hardwood”</td>
<td>—</td>
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<tr>
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<td>3.4</td>
<td>0.6</td>
<td>—</td>
<td>Quercus</td>
<td>—</td>
<td>fossil tooth</td>
</tr>
<tr>
<td>Broken Roof Cave</td>
<td>53.3</td>
<td>2.5</td>
<td>0.6</td>
<td>—</td>
<td>Quercus</td>
<td>56.0</td>
<td>—</td>
</tr>
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<td>—</td>
<td>Quercus</td>
<td>28.0</td>
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<td>0.7</td>
<td>—</td>
<td>Mesquite</td>
<td>—</td>
<td>Gypsum</td>
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<tr>
<td>Grand Gulch No. 2</td>
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<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>quartz</td>
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</tbody>
</table>

Categories without values indicate that such values were not supplied in the original reference.
Figure 11 supplies the references to the atlatls numbered above.
effect weighted atlatls. Garrod (1955) discusses and illustrates several spearthrowers that integrate an animal effigy with the spur (or hook) on the distal end of the spearthrower, and therefore may have functioned similarly to weights found attached to North American specimens.

In western North America, all archaeologically recovered weighted atlatls share many features (Table 1). They all range from 40 cm. to 70 cm. in length and 2 cm. to 3.5 cm in width. Most western North American atlatls are very thin (less than 1 cm.) and are constructed of relatively hard wood such as mountain mahogany (Cercocarpus sp.) and scrub oak (Quercus gambelii). These attributes, manifest in my replicated atlatls, result in an extremely flexible weapon.

Several researchers and experimenters have postulated that atlatl weights serve to increase the performance of the weapon, and several similar, yet independent, experiments have been conducted to test this. In all cases, performance has been measured by comparing the distances achieved by darts launched by weighted and unweighted atlatls. Dart distance is an indirect measure of dart velocity and force of impact. However, the experiments of dart distances conducted with weighted and unweighted atlatls are not conclusive.

Another line of research concerns the placement of weights along the shaft of atlatls. Webb (1957) concludes that a marksman will obtain greatest dart velocity and distance when he attaches the weight close to the distal end of the weapon. Other scholars (Peets 1960, Mau 1957) have speculated and experimented with different locations of the weight along the shaft of an atlatl. Although this is an interesting area of study, for practical reasons I confined my research to atlatls from western North America whose weights (9 out of 10) occur along the middle of the shaft.

Howard’s (1974) experiments demonstrated an 18 per cent decrease in the range of darts thrown from a weighted atlatl versus an unweighted atlatl. In a different experiment, Palter (1976) showed that dart distance is indirectly proportional to an increase in the weight of the stone attached to the atlatl, that is, the heavier the atlatl weight, the less distance will be obtained by the dart thrown from that atlatl. Although Van Buren (1974: 27) conducted a thorough set of experiments with atlatl darts of different sizes, he offers only an ‘observation’ that atlatl weights do not improve the range of darts.

Butler (1975) employed a model based on physics and mechanics to demonstrate that atlatl weights cannot increase the performance of the weapon. Conversely, Mau’s (1963) experiments indicated that a weighted atlatl will increase by 15 per cent to 25 per cent the distance of darts thrown, as compared with an unweighted atlatl. After experimenting with a wide variety of atlatl styles and dart sizes, Hill (1948) concluded that a weighted atlatl and lightweight dart provides the best combination for maximum distances. On the other hand, Peets’ (1960) experiments showed that there is no difference in distance achieved by darts thrown from a weighted or unweighted atlatl.

The scholars who have worked with atlatls and darts have generated a wealth of useful information and have contributed significantly to a comprehension of the weapon’s function. However, their experiments offer only conflicting testimony on the role of weights in atlatl and dart performance.

Some experiments indicate that an atlatl weight increases atlatl performance, while
other experiments suggest that a weight detracts from performance, and still another experiment indicates that an atlatl weight does not make a difference. Why do these differences occur? A close look at the experimental weapons reveals why.

To construct their atlatls, experimenters have used alder and pine instead of oak or mountain mahogany (Hill 1984, Mau 1963). Atlatl weights were too heavy and in one instance constructed from a lead pipe (e.g. Mau 1963). Van Buren (1974: 27) notes that his method of attaching the weight to the atlatl may not have been the same as that used by prehistoric native Americans. In fact, many of the weapons were 'generic' atlatls, meaning that they incorporated the basic features of an atlatl (i.e., spur, handle, etc.), but they were scarcely replications of an aboriginal specimen. Only Peets (1960) used a replica of a prehistoric atlatl (cf. Baylor Rock Shelter atlatl, Fenega and Wheat 1940) for his experiments. However, the validity of his experiments may be marred by the fact that he 'used a rather heavy dart to reduce the distance to be measured' (1960: 109) between each throw. In fact, many of the darts used by previous experimenters were inadequate replicas of those used aboriginally. Store-bought bamboo, and machine-cut dowels tipped with copper and steel, can hardly compare with the materials used prehistorically. Finally, and most importantly, the general lack of descriptive data concerning the size, shape, and weight of experimental atlatls, weights, and darts frustrates any attempt to assess the comparability of these modern experiments with the prehistoric reality. It became apparent that new experiments with adequate replicas of prehistoric atlatls, weights, and darts are required to assess the performance of the weighted atlatl.

The experiments

My experiments were designed similarly to previous experiments, i.e., the performance of a dart and unweighted atlatl was compared with the performance of the same dart and atlatl with an added weight. Performance was measured in three ways: (1) dart distance, (2) dart speed, and (3) atlatl and dart speed immediately before the dart was released from the atlatl.

Experimental materials

For the purposes of these experiments, I constructed replicas of Basketmaker II atlatls and weights (Figure 12) based on illustrations and descriptions provided by Guernsey (1931: 72), Guernsey and Kidder (1921: 80–83) and Cosgrove (1974: 48–58 and Figures 68–71).

The experimental atlatls were carved from straight sections of scrub oak (*Quercus Gambellii*) obtained in southwestern Colorado. A 40 gram catlinite weight was used in each experiment. For a secure grip, leather thongs were attached to the handle of the atlatl with a sinew. Pepper (1905), Fenega and Wheat (1940), Grange (1952: 336–84), Lindsay et al. (1968: 64) and Spencer (1974, 1984) also provide excellent information to guide the replication of atlatls.

Although complete atlatl darts are rarely found in archaeological context, (see Heizer 1938 for an exception) their size and shape can be reconstructed on the basis of
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fragmentary remains. Hattori (1982: 112–120), Aikens (1973), Grange (1952), and Cosgrove (1974), provide detailed metrical data on archaeologically-recovered fragments of atlatl darts. The diameter of fragments of dart mainshafts and foreshafts suggests a certain size range. Furthermore, the size of the atlatl also limits the maximum length, diameter, and weight of the dart thrown by it. It is simply too awkward to launch a two-meter dart, weighing 300 grams, with a typical 50 cm. long Basketmaker atlatl.

I reconstructed darts from single saplings of willow (Salix sp.), fletching them with feathers and sinew. The darts were not fitted with foreshafts or stone points. Other experiments with stone-tipped darts quickly indicated that I would have spent more time repairing broken foreshafts and projectile points than in throwing darts (Flenniken and Raymond 1984). To compensate for the absence of stone points, and to ensure a stable flight, I constructed my darts with their center of gravity slightly forward of the middle of the dart. Table 2 lists materials and metrical attributes for replicated atlatls and darts used in the experiments.

Dart distance

This experiment was designed to compare the maximum distance obtained by the same darts thrown by a weighted atlatl and by the same atlatl without its weight. Three separate tests were conducted in different locations and weather conditions. Sixty throws, thirty with a weighted atlatl and thirty with an unweighted atlatl, comprised each...
<table>
<thead>
<tr>
<th>Table 2 Replicated atlatls and darts</th>
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</thead>
<tbody>
<tr>
<td><strong>Materials</strong></td>
</tr>
<tr>
<td>Basketmaker No. 1</td>
</tr>
<tr>
<td>Basketmaker No. 2</td>
</tr>
<tr>
<td>Basketmaker No. 3</td>
</tr>
<tr>
<td>Atlatl Weight</td>
</tr>
<tr>
<td><strong>Darts</strong></td>
</tr>
<tr>
<td>1</td>
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<td>2</td>
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<td>3</td>
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</table>
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In each case, I launched the darts at approximately a 40 degree angle with as much force as possible.

The results of these tests (Figure 13) indicate that darts thrown by the weighted atlatl achieve average distances that are two to seven meters farther than achieved with the unweighted atlatl. Put another way, weighted atlatls can propel darts 5 per cent to 11 per cent farther than nonweighted atlatls. However, in two of the three tests, the mean distance of darts thrown with a weighted atlatl falls within 1 standard deviation of the mean dart distance obtained with an unweighted atlatl.

![Figure 13 Distances of darts thrown with the weighted atlatl (plain columns) and unweighted atlatl (stippled columns). The cross hatched area indicates one standard deviation around the mean distances (heavy line). Atlatl No. 1 and darts 1–6 used in all tests.]

Although this experiment suggests higher performance with the weighted atlatl, these results may not be entirely applicable to the prehistoric situation. Darts can be hurled over 70 meters, but accuracy at that range is extremely variable. Having been launched at 40 degrees, the dart obtains a great height and may be blown off course by the wind. Furthermore, the dart descends to earth at a similarly steep (45 degree) angle. Would a prehistoric hunter attack an animal 50, 60, or 70 meters away, when considerable distance and velocity are required merely to get his dart within range of the animal? A more advantageous strategy would permit a hunter to draw very near his prey before striking. Then, success would require accuracy only. The Australian Aborigines employ such a strategy when hunting kangaroos with spearthrowers (K. Ackerman, personal communication). Although distance is a valid measure of performance, it does not apply to the reality of hunting with the atlatl and dart.
Dart speed

A second experiment directly measured the speed of darts thrown toward a target 20 meters distant. I employed a radar gun, similar to the tools used by traffic police to clock moving automobiles. Four inches of aluminum foil, attached to the proximal (nock) end of each dart, transmitted the speed of the darts back to the radar gun. This experiment

*Figure 14* Bird’s-eye view illustrating how speed experiments were conducted.

*Figure 15* Mean speed of darts thrown with the weighted atlatl (plain column) and unweighted atlatl (stippled column). The cross-hatched area indicates one standard deviation around the mean speeds (heavy line).
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was carried out twice, once by the author and again by Ricky Ray Lightfoot, also an accomplished atlatl and dart marksman. Figure 14 illustrates how the experiment was conducted.

The results (Figure 15) indicate that mean speed of darts launched by a weighted atlatl is 8.2 per cent faster than the mean speed of darts by the same atlatl without its weight. In both tests, a one standard deviation from the mean dart speed obtained by the weighted atlatl overlaps 1 standard deviation of the mean dart speed thrown by unweighted atlatls. However, a random error in measurement may compromise the results of this experiment. The speed gun projects a narrow beam with which to detect the movement of an object. And the dart contains a small surface area that can bounce the beam back to the radar gun. Therefore, I found it very difficult to read the speed of each dart at the same point in its flight path. Gravity and air resistance slow a dart through its trajectory. Consequently, some readings represented relatively high speeds recorded immediately after the dart was released, while other values indicated the speed of the dart 15 to 20 meters after it left the atlatl, and presumably slowed down.

Atlatl and dart launching velocity

A third, and perhaps more objective measure of atlatl performance, involved a mathematical translation of the movement recorded in the previously mentioned high speed motion picture films. With the aid of a digitizer, I calculated the change in the position of the point where the atlatl spur and dart make contact during the last 0.06 second of the throw. This represents the portion of the throwing motion where the atlatl leaves a horizontal plane and rotates to a vertical position before releasing the dart (Figures 5–9). This movement was recorded for eight throws with a weighted atlatl and eight throws with an unweighted atlatl. These measurements allowed me to calculate the velocity (a product of distance and time) for the atlatl and dart together, immediately before the dart was released. Table 3 and Figure 16 reveal that the speed obtained by the weighted and unweighted atlatl is essentially the same. The addition of a weight to the atlatl has a negligible effect towards diminishing the ability of the marksman to bring the weighted atlatl to a velocity as high as that obtained by the same atlatl without the weight.

Discussion

Despite the shortcomings of the distance and speed experiments, they both point toward the same conclusion: i.e., a weighted atlatl imparts greater velocity to a dart than does an unweighted atlatl. However, the third experiment shows that the weighted atlatl cannot bring the dart to a higher velocity than an unweighted atlatl.

Perhaps this discrepancy can be explained by the fact that slightly different Basketmaker atlatls were used in each experiment. But if weights really were attached in order to increase dart speed and distance, then all weighted Basketmaker-style atlatls should carry an advantage. On the other hand, the motion pictures may not have recorded enough detail with which to accurately calculate velocity and acceleration of the weighted and unweighted atlatl and dart.
Table 3  Velocities of the weighted atlatl and dart compared with the unweighted atlatl and dart.

<table>
<thead>
<tr>
<th>Round</th>
<th>Weighted Velocity</th>
<th>Round</th>
<th>Unweighted Velocity</th>
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<th>Unweighted Velocity</th>
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<tr>
<td>1</td>
<td>21.88 m/sec</td>
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<td>20.07</td>
<td>4</td>
<td>22.16</td>
<td>4</td>
<td>20.00</td>
<td>4</td>
<td>19.37</td>
</tr>
<tr>
<td>( \bar{X} )</td>
<td>21.42</td>
<td>( \bar{X} )</td>
<td>21.60</td>
<td>( \bar{X} )</td>
<td>20.33</td>
<td>( \bar{X} )</td>
<td>20.71</td>
</tr>
<tr>
<td>( \sigma )</td>
<td>0.89</td>
<td>( \sigma )</td>
<td>0.40</td>
<td>( \sigma )</td>
<td>0.42</td>
<td>( \sigma )</td>
<td>0.99</td>
</tr>
<tr>
<td>95% C.I.</td>
<td>+/-0.87</td>
<td>95% C.I.</td>
<td>+/-0.39</td>
<td>95% C.I.</td>
<td>+/-0.41</td>
<td>95% C.I.</td>
<td>+/-0.97</td>
</tr>
</tbody>
</table>

Atlatl No. 2 and Dart 7 used in all experiments.
Experiments in the function and performance of the weighted atlatl

The high-speed motion pictures did illustrate that the Basketmaker atlatl flexes and recovers as it sweeps the arc immediately before the dart is released (Figure 7). Perhaps the addition of a weight on a flexing atlatl serves to increase the speed and force of the recoil, resulting in higher velocities and distance for the darts. Unfortunately, the motion pictures did not resolve the flexing of the atlatl into more than a few frames. Film speeds of over 400 frames per second would be required to measure accurately the acceleration of the atlatl as it recoils in the last few milli-seconds before releasing the dart.

Regardless of what one wishes to conclude from these and other experiments, we must not forget the survival role of the atlatls and darts. How important is a 10 per cent increase in dart speed provided by a weighted atlatl? Does it really matter whether one dart travels at 80 kilometers per hour while another flies at 70 kilometers per hour if they both miss the quarry? A hunter becomes successful as a result of marksmanship, not from the speed at which he can fire his projectile. A more appropriate question for weighted atlatls would address the role they play in hurling a dart accurately.

Jeffrey L. Brown (1967) has applied principles of mechanical physics (MacKinnon 1978, Weidner and Sells 1965) to argue that atlatl weights serve to stabilize the throw and to obtain dart accuracy. As demonstrated earlier, when launching a dart, the atlatl pivots about a fulcrum located at the handle of the weapon. The inertia of this rotation is expressed in the following equation

\[ I = \frac{1}{3} ML^2 \]

where \( I \) = moment of inertia
\( M \) = mass of atlatl
\( L \) = length of the atlatl from distal end to axis of rotation at handle (cf. Weidner and Sells 1965: 310).
A small weight added to the atlatl will increase the moment of inertia by $M_w R^2$, where $M_w$ equals the mass of the weight and $R$ equals the distance of the weight from the axis of rotation. Thus a weighted atlatl will obtain a greater moment of inertia.

Greater inertia works against obtaining maximum potential velocity (it is simply more difficult to accelerate a heavy object as fast as a light one). However, it contributes positively to the throwing system by adding angular momentum. Angular momentum refers to the inherent stability of a rotating object, such as a gyroscope. Angular momentum is a product of the moment of inertia and the angular velocity of the atlatl before release of the dart.

$$\text{Angular Momentum} = I \times W$$

The high speed motion pictures illustrated that, prior to release of the dart, both the weighted and unweighted atlatl sweep a 90 degree arc in 0.06 to 0.07 seconds. This is equivalent to an angular velocity of 4.2 revolutions per second.

Table 4 Inertia and angular momentum for unweighted and weighted atlatls

<table>
<thead>
<tr>
<th>Inertia of unweighted atlatl, $I = \frac{1}{3}ML^2$</th>
<th>Inertia of atlatl and weight, $I_w = \frac{1}{3}ML^2 + M_wR^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Where</td>
<td>Where</td>
</tr>
<tr>
<td>$M = \text{mass of atlatl} \neq 3 = 0.077$ kg</td>
<td>$M_w = \text{mass of atlatl weight} = 0.04$ kg</td>
</tr>
<tr>
<td>$L = \text{length of atlatl from handle axis to distal end} = 0.46$ m</td>
<td>$R = \text{distance of weight from axis of rotation} = 0.22$ m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Inertia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unweighted atlatl</td>
</tr>
<tr>
<td>$5.29 \times 10^{-3}$ KgM²</td>
</tr>
</tbody>
</table>

$\text{Angular Momentum} = \text{Inertia} (I) \times \text{Angular Velocity} (W)$

$I_{\text{unweighted atlatl}} = 5.29 \times 10^{-3}$ Kg M²

$I_{\text{weighted atlatl}} = 7.23 \times 10^{-3}$ Kg M²

$W = 4.2$ revolutions per second.

<table>
<thead>
<tr>
<th>Angular Momentum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unweighted atlatl</td>
</tr>
<tr>
<td>$0.022$ Kg M²/sec</td>
</tr>
</tbody>
</table>

Table 4 shows that an unweighted atlatl obtains only two thirds the angular momentum of a weighted atlatl. The reader can demonstrate this principle for himself with a simple experiment. Hold an ordinary ruler at one end and sweep an arc through the air with the other end. Next, tape a couple of large coins near the distal end of this ruler and again sweep an arc. Notice that it is easier to maintain a smooth and stable arc with the weighted ruler than with the unweighted ruler.
Greater angular momentum of the weighted atlatl contributes stability to the throwing arc and therefore helps achieve accuracy (Brown 1967). Lateral deviations in the dart launch path can result from difficulty in maintaining a stable downward rotation of the atlatl handle. These lateral deviations not only diminish an efficient transfer of force from the arm to the dart, but also detract from maintaining a straight and stable launch path of the dart. Howard (1974) describes this as ‘hooking’, and it results in an inaccurate throw. By increasing angular momentum, atlatl weights help to smooth and stabilize the launch path of a dart. If prehistoric people attached small rocks to the atlatls (as good luck charmstones?) then accuracy and hunting success would have followed (Brown 1967).

Comparing weapon performance

It is useful to compare the performance of darts thrown with an atlatl with that of arrows launched by bows (Table 5). Based on the velocity data provided by the radar gun and high-speed motion pictures, one can calculate the kinetic energy and momentum (force) values of a dart upon release from the atlatl. These values can be compared with those for modern and ethnographic arrows used in bow hunting.

Table 5 shows that dart velocity is about two-thirds of the velocity obtained by Ishi (Pope 1962) with his own bow and one ounce arrow. However, a modern compound hunting bow will propel an arrow three times as fast as an atlatl dart (Mullaney 1984: 40), while a 50-pound English long bow (Pope 1962) will propel an arrow twice as fast as the atlatl dart. The momentum (force) gained by a dart thrown with an atlatl is approximately twice as great as the momentum imparted to a one-ounce arrow from Ishi’s bow, and still greater than the momentum obtained by arrow shot from an English long bow. However, despite its light weight, an arrow shot from a modern compound hunting bow delivers considerably more force upon impact than an atlatl dart.

Today, modern ballistics testing employs the value of kinetic energy to measure the amount of potential force carried by bullets and hunting arrows. The atlatl dart carries more kinetic energy than an arrow fired from a primitive bow. However, a modern compound bow provides far greater kinetic energy upon projectile impact than the more primitive weapons.

It is generally considered that, in much of the world, the bow and arrow replaced the atlatl because the bow is a superior weapon. The experiments reported here provide data and observations to define the relative advantages of both weapons. People did not embrace bow and arrow technology because it packs a bigger punch than the atlatl, since it does not. Although the bow serves to increase the speed of the projectile, this speed does not offset the loss in momentum and kinetic energy conferred to relatively lightweight arrows in comparison to the more massive atlatl darts.

The chief advantage of the bow and arrow lies in the ease and swiftness of the movements involved when shooting the projectile. Once nocked and drawn, the arrow launch time is a fraction of the two-thirds of a second required to launch an atlatl dart. Furthermore, launching a dart with an atlatl presents a more violent set of body movements (which could frighten the intended prey), than releasing an arrow from a
<table>
<thead>
<tr>
<th>Table 5 Comparison of weapon performance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Projectile Velocity</strong></td>
</tr>
<tr>
<td>Baskettaker atlatl</td>
</tr>
<tr>
<td>and 70 g. dart</td>
</tr>
<tr>
<td>Ishi’s bow and</td>
</tr>
<tr>
<td>28 g. arrow</td>
</tr>
<tr>
<td>50 lb. English</td>
</tr>
<tr>
<td>longbow, 28 g. arrow</td>
</tr>
<tr>
<td>60 lb. compound</td>
</tr>
<tr>
<td>hunting bow and</td>
</tr>
<tr>
<td>38 g. arrow</td>
</tr>
<tr>
<td>21 m/sec.</td>
</tr>
<tr>
<td>1.47 kg/m</td>
</tr>
<tr>
<td>15.43 joules</td>
</tr>
</tbody>
</table>

(Momentum = Mass × Velocity)

(Kinetic Energy = \(\frac{1}{2}\) Mass × Velocity²)
bow. Finally, accuracy with the bow and arrow depends primarily on good aim from a stationary and relaxed posture, while success with the atlatl depends on a complex and coordinated set of body movements that must confer an accurate flight path to the projectile. If the bow and arrow is swifter, easier, and more accurate than the atlatl and dart, what can explain the persistence of atlatl technology into the 20th century?

Despite the existence of bow and arrow technology, the ancient Aztec chose atlatls to fish and hunt water fowl from boats (Nuttall 1891: 175). The Tarascan Indians of Mexico have carried this tradition into this century, using atlatls to hunt waterfowl from canoes (Stirling 1960). The Eskimos also wield spearthrowers to hunt waterfowl (and seals) from small boats (kayaks) (O. Mason 1884: 279). The retention of the spearthrower, in spite of the bow and arrow, among the Tarascan and Eskimo can be explained by the functional context in which the weapon is used. It requires two hands to shoot an arrow from a bow. However, once the dart is set in the spur, using an atlatl requires only one hand. Thus, the other hand becomes free to steer and stabilize the boat (Kellar 1955: 336). The retention of the atlatl by ancient Aztec and Inca warriors can be explained by the advantage gained in projectile force and kinetic energy over the bow and arrow. The conquering Spaniards feared the atlatl more than any other native weapon, because the darts could easily penetrate their protective armour (Garcilaso de la Vega in Swanton 1938: 358, Nuttall 1891). Among Australian Aborigines, the spearthrower persisted to the total exclusion of the bow and arrow because the latter is not necessary. The Aborigines of the Kimberly region frequently employ a hunting strategy that brings them as close as one meter to their intended prey before firing the spear. Therefore, they rarely missed (K. Ackerman: personal communication). For Aborigines of the Western Desert, the atlatl serves many utilitarian and ceremonial activities in addition to hunting, including fire-making, woodworking, mixing pigments and tobacco, music-making, clearing ground, and as a mnemonic device to recall the location of waterholes and other geographic features (Gould 1970: 22).

**Summary and conclusions**

I have argued that a valid assessment of the weighted atlatl’s function and performance requires that experiments be conducted by skilled users of replicas of archaeological specimens. Using replicas of prehistoric atlatls and darts, three experiments were undertaken to determine if atlatl weights increase the distance and speed of atlatl darts. The results suggest that weights impart only slightly higher speed and distance to darts. However, statistically as well as functionally, a slightly higher dart speed and distance is not significant. Instead I have argued that by adding angular momentum, atlatl weights confer greater accuracy to the weapon.

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References


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The experiments
Raymond, Anan

Abstract

Raymond, Anan

Experiments in the function and performance of the weighted atlatl

The atlatl (or spearthrower) has been used on one continent or another for at least 13,000 years, making it one of the most pervasive weapons in human history. Yet, anthropologists disagree on
how to wield an atlatl, and about the purpose of stone weights often attached to prehistoric examples of this weapon in North America. This paper briefly reviews the contributions and oversights of previous experiments and models on the function of atlatls and atlatl weights. I conducted three new experiments with replicas of prehistoric weapons to describe how an atlatl operates and to assess the performance of a weighted atlatl versus an unweighted atlatl. The results indicate that a weighted atlatl cannot launch a dart (or spear) significantly further than an unweighted atlatl. However, physical models do suggest that a weighted atlatl will hurl a dart more accurately than an unweighted atlatl. Additionally, a comparison of the performance of the atlatl and dart with the bow and arrow provides insight to the evolution of hunting technology.