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The Atlatl as a Cyborg Kinematic Device

B.Tondu

Abstract— The atlatl, or spear-thrower, is a primitive weapon, which is generally understood as a simple wrist lever. We propose to renew this interpretation by a simple kinematic analysis of the serial chain constituted by the arm, the forearm, the hand holding the atlatl and the dart, moving in a vertical plane. While the release velocity of a hand-delivered spear towards the target is made difficult due to the limited joint range in wrist radial/ulnar deviation, the atlatl's passive hook makes possible to overcome this difficulty. The atlatl can therefore be seen as a clever cyborg device, understood as a substitute of the hand with a special ability to orient the dart to be thrown. In a kinematic point of view, it realizes a shifting of the optimal throwing configuration from the upper-limb fully extended in a vertical position, badly adapted to human shoulder and wrist, to a much more efficient horizontal position. As a consequence, a summation of shoulder, elbow and wrist speeds results, leading to dart release velocities much greater than these got with a hand-delivered spear, while throw accuracy is kept. Because the atlatl's learning is based on our natural ability to throw by comparison, for example, with the bow technology, and because its use is based more on gesture quality than on purely muscular power, the atlatl is according to us a remarkable historical example both of easy-to-learn and nongendered cyborg device.

I. INTRODUCTION

It sounds strange to propose a technical analysis of a primitive weapon in a humanoid robotics congress. It sounds even more bizarre to propose an interpretation of this primitive weapon as a cyborg device. The originality of our approach is justified by the current difficulties to interpret the universal dissemination of a prehistoric weapon, which played a fundamental role for the humanity development and could help us to understand some points of the current debate about the development of the so-called cyborg technologies.

The atlatl, or spear thrower, is a primitive weapon whose origin dates back to the prehistoric eras [1], defined by Whittaker and Maginniss [2] as “a stick with a handle at one end, and a hook or socket at the other” (Fig. 1). Despite its simplicity, despite the fact that remote populations still used this weapon until a recent past and despite the fact that amateurs today practice and compete by using actual replicas of the antique atlatls, the functioning principle of the atlatl is still discussed. For some people, the atlatl would work like a rigid stick, flexing the dart before releasing it, with suggesting that flexing atlatls led directly to the invention of the bow [3]. For most of actual specialists in primitive weapons, however, “the atlatl is a lever, and not a spring” and “the atlatl simple makes a longer level at the wrist” [4]. However, it is not so clear how exactly the atlatl, as a lever, does for increasing the dart release speed through the upper-limb kinematic chain. In this framework, we suggest to consider the atlatl as a kind of kinematic cyborg intended for overcoming the upper-limb

joint limitations especially in the case of throwing hand-held spears. According to Warwick's classification of cyborg technologies, the atlatl would be a case of “technology positioned close to the human body, but not integrated into the body” [5]. The term “cyborg” is understood as a device devoted to enhance the physiological natural human body performance but differently than other weapons like the bow with which it will finally compete. This is for justifying the cyborg nature of the atlatl that we are attempting to show how it can be added to the human upper-limb for extending its kinematic performances. Before that, we discuss the traditional interpretation of the atlatl as a wrist lever.



Figure 1. An artist's reconstruction of prehistoric big game hunting with atlatl (with the courtesy of the French INRAP).

II. THE ATLATL AS A WRIST LEVER?

Initially, the thrower using an atlatl takes in his/her hand both the atlatl and the dart. This grip can be made according to the scheme of Fig. 2.a, leading to a final pitching movement by wrist ulnar deviation (adduction), or the atlatl and its dart can be laterally grasped by two fingers, as shown in Fig. 2.b, leading to a final flexion wrist movement. During prehistory, it seems that only the first way was used for holding the atlatl and its dart while the second way would be more recent. It is important to notice that, according to Kapandji, joint range in radial/ulnar deviation – corresponding to a wrist abduction/adduction movement – is limited to about 60° while wrist flexion/extension range is about equal to 170° [6]. In the case of a hand-held spear, only radial/ulnar deviation can be used for throwing and it is clear that its limited range is a critical point for both accurately and powerfully throwing a spear (let us think to the Olympic discipline of throwing the javelin, which is well far from hunting techniques). In some way, the atlatl technology can be understood as a very clever attempt to overcome such wrist movement limitation by, as

we will see us later, to substitute to the hand a more adapted distal link including a special ability to orient the dart to be thrown.

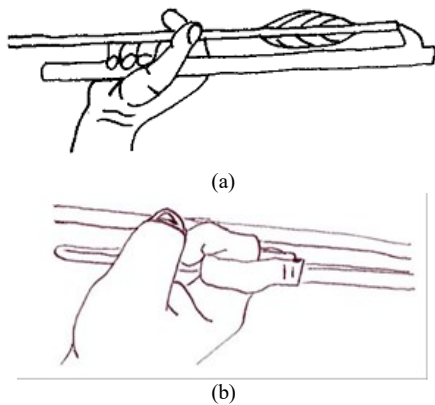


Figure 2. Two ways for holding the atlatl and its dart: (a) Wrist ulnar deviation movement-based grip, (b) Wrist flexion-based grip also said “knuckle grip”: the dart is hold between the index and middle fingers – redrawn from Daryl Hrdlicka [7].

We show in Figs. 3.a and 3.b a typical sequence of body positions during a dart throwing with an atlatl [8]. Throwing movement with an atlatl can be divided into two different phases: during a first phase, the thrower holds both the atlatl and the dart, before, in a second phase, he/her released the dart, which however remains jointed to the atlatl by the

intermediary of the hook. The interpretation of the atlatl’s functioning by means of the theory of levers only concerns this second phase for explaining the speed increase at the release time of the dart leaving the atlatl, by comparison with a simple throwing by hand. The atlatl pushing its dart under the action of the wrist muscles corresponds to a first-class lever in which the fulcrum would be the wrist joint “center”, the effort would be the force F_W generated by the wrist muscles and the resistance would be the pushing force F_A applied by the atlatl to the dart as illustrated in Fig. 4. This is a typical speed lever, operating at a mechanical disadvantage equal to (d_A/d_W) , where distances d_A and d_W are defined as shown in Fig. 4. Such a kinematic model with constant d_A and d_W parameters is obviously a radical simplification of insertion points of wrist musculature but, according to us, it captures the way the wrist moves during atlatl use. A similar diagram was considered by Whittaker [4] who, curiously, reproduced it from a figure proposed by Cotterel and Kamminga, in their classical text book, for illustrating “the deflection of a spear during throwing” ([9], Fig. 7.7, page 169).

Let us note P the tip point of the atlatl at which is applied the dart pushing force and let us note δ_P the associated elementary displacement of this point while δ_H denotes the elementary displacement of the ideal hand point H at which is applied the wrist contraction force; we get:

$$\delta_P = (d_A/d_W)\delta_H \tag{1}$$

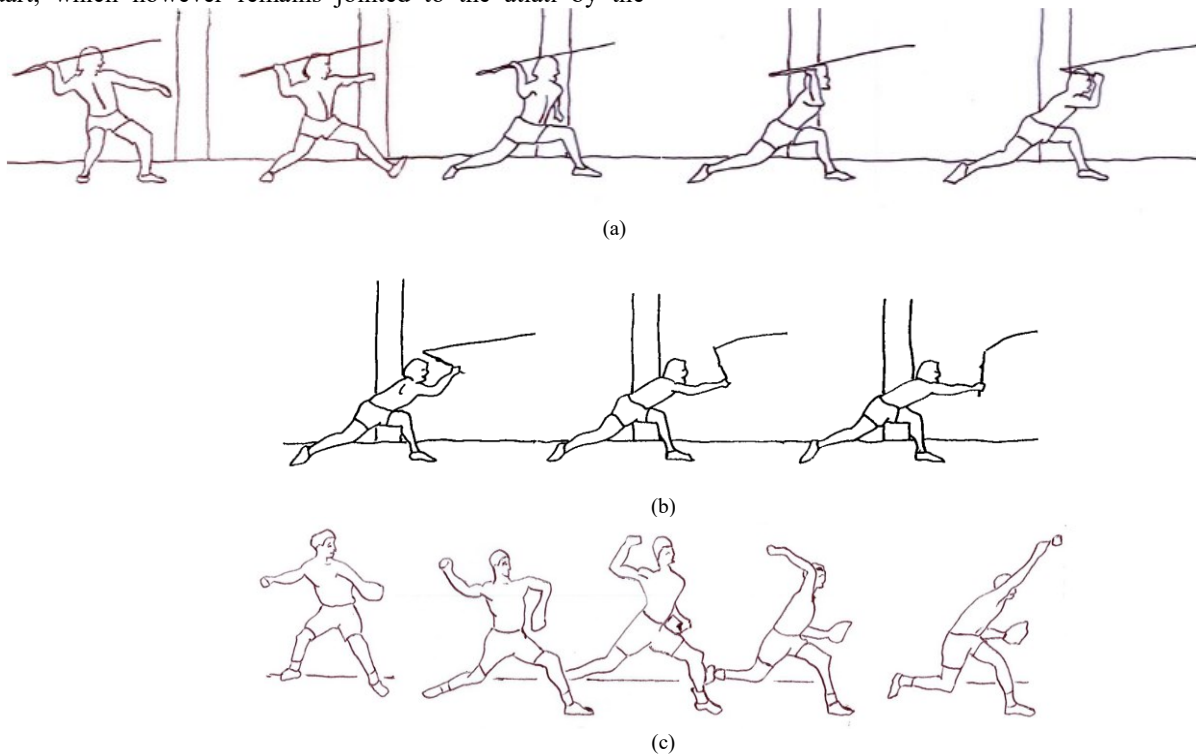


Figure 3. Position sequence during dart throwing with an atlatl: (a) Step forward and trunk rotation while the dart is hold with fingers, (b) Phase during which the dart is freely jointed to the atlatl – redrawn and reorganized from Raymond [8], and Typical baseball pitch (c) – redrawn from Werner *et al.* [10].

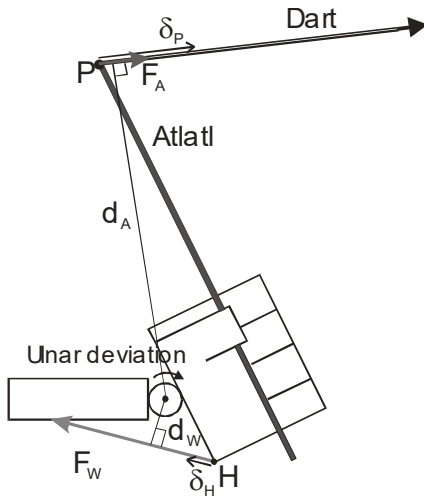


Figure 4. Interpretation of the atlatl functioning according to the theory of levers – please note that if the atlatl is used according to Fig. 2.b grip, flexion has to be considered instead of ulnar deviation .

It is clear that the higher will be the ratio (d_A/d_w) , the higher will be the speed of point P for a same contraction velocity of wrist muscles. Baugh [11] proposed a dynamic model of the atlatl directly inspired by this lever-type interpretation of the atlatl's functioning, which combines the datum of a wrist torque with an experimentally determined horizontal force applied to the hand of the thrower. A more advanced model would consist to model the full kinetic chain engaged into the spear throwing process as it is done for simulating the baseball pitching [12]. If these models are able to predict the speed given to the dart by the atlatl, they do not explain how the 'atlatl+dart' derives advantage of the body kinematic chain inside which they are included. Very simple robotic methods can help us to reply this question.

III. A SIMPLE PLANAR ROBOTIC MODEL OF THE UPPER-LIMB THROWING A DART WITH AN ATLATL

As any human throwing technique, the movement of throwing a dart with an atlatl is a complex movement involving trunk rotation and movements of the shoulder complex. Because, in the framework of this article, we want to emphasize the originality of the atlatl as a cyborg device of the human hand, we voluntarily limit our kinematic analysis to the human arm moving in a vertical plane.

We propose to model the atlatl and its dart by a kinematic couple with two links, the atlatl and its dart, jointed by the hook, considered as a passive joint. As shown in Fig. 3.b, the movement phase during which the dart moves with respect to the atlatl is mainly performed in a vertical plane. As a consequence, we propose to model the gestural sequence leading to the dart release by a simple planar robotic model, shown in Fig. 5. The model is composed of four links: the arm, the forearm, the hand holding the atlatl and the dart. Corresponding joints are the following ones: shoulder extension moving the arm with respect to a fixed reference frame (O, X, Y) , elbow extension moving the forearm with respect to the arm, wrist ulnar deviation or wrist flexion, according to the way the atlatl is hold by the hand, moving the atlatl with respect to the forearm and, finally, the atlatl passive joint allowing the rotation of the dart with respect to the atlatl. The distal link of our model is clearly the dart, assuming it

remains in contact with the atlatl until it is released. The location of the distal link, with respect to the reference frame, will be defined by the point P at the proximal tip of the dart, whose coordinates

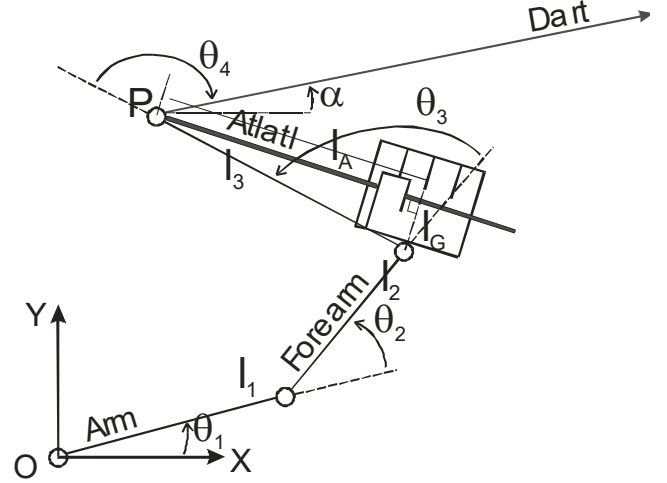


Figure 5. Proposed planar robotic model of the upper limb throwing a dart with an atlatl during the phase where the dart is jointed freely to the atlatl.

in frame (O, X, Y) will be noted x, y , and its orientation will be defined by the angle α with respect to X -axis. Link lengths are respectively noted l_1, l_2, l_3 from the base to the end, and joint angles are respectively noted $\theta_1, \theta_2, \theta_3, \theta_4$. The way the dart moves with respect to the atlatl, i.e. the trajectory of θ_4 -variable, belongs to the art of using the atlatl we will not discuss here: as said by Hrdlicka [7], "Don't worry about releasing the dart. As long as you're holding right it will come free on its own at the proper moment".

The direct kinematic model of our system is very simple:

$$\begin{cases} x = l_1 C_1 + l_2 C_{12} + l_3 C_{123} \\ y = l_1 S_1 + l_2 S_{12} + l_3 S_{123} \\ \alpha = \theta_1 + \theta_2 + \theta_3 + \theta_4 \end{cases} \quad (2)$$

where C_{ijk}, S_{ijk} are respectively for $\cos(\theta_i + \theta_j + \theta_k)$ and $\sin(\theta_i + \theta_j + \theta_k)$. Moreover, if the lengths l_1, l_2 respectively correspond to the physiological distances between glenohumeral joint and elbow joint centers, on the one hand, between elbow joint and wrist joint centers, on the other hand, the length l_3 is defined by the following relationship:

$$l_3 = \sqrt{l_A^2 + l_G^2} \quad (3)$$

where l_A is the distance between the distal tip of the atlatl and the center of hand grip and l_G is the distance between wrist center and hand grip center. Although four joint variables are considered, our robotic system is not a redundant system since the θ_4 -angle is a passive angle whose value depends on the other active joint trajectories. Actual atlatlists generally insist on the role of the wrist motion for giving the right orientation to the atlatl: "When your arm is almost completely extended, snap your wrist downward hard. "The atlatl should end up pointing at the target", says Hrdlicka [7]; "Then as the hand passes the head, give a vigorous snap of the wrist, swinging the atlatl up to vertical and flicking the dart away", also says Whittaker [13]. However, these advices are relatively vague, suggesting that the control of the atlatl's orientation is relatively easy and, additionally, this control is not prejudicial

to the speed summation of moving links in which is engaged the wrist motion. In this same practical note, Whittaker claims: “The throwing motion with an atlatl is the same as in throwing a ball or rock”. For the roboticist, this remark is surprising because the location of a ball, supposed to be perfectly spherical, is entirely characterized by its Cartesian position, while the spatial location of a dart or a spear, supposed to be not flexible, must be specified both in position and in orientation. All seems to be like the passive θ_4 -joint facilitated spatial orientation of the dart, without preventing the summation of speeds of shoulder, elbow and wrist, in same direction, as a baseball pitcher does.

Let us see how our very simple robotic model can help us to estimate the velocity of the dart leaving the atlatl. From Equ. (2), we derive the well-known velocity equations of vector $\dot{P} = [\dot{x} \ \dot{y}]^T$ as follows:

$$\begin{cases} \dot{x} = -(l_1 S_1 + l_2 S_{12} + l_3 S_{123})\dot{\theta}_1 - (l_2 S_{12} + l_3 S_{123})\dot{\theta}_2 - l_3 S_{123}\dot{\theta}_3 \\ \dot{y} = +(l_1 C_1 + l_2 C_{12} + l_3 C_{123})\dot{\theta}_1 + (l_2 C_{12} + l_3 C_{123})\dot{\theta}_2 + l_3 C_{123}\dot{\theta}_3 \end{cases} \quad (4)$$

where $\theta_1, \theta_2, \theta_3$ are respectively the joint 1 to 3 velocities. From the sequence of positions proposed by Raymond [8] in Fig. 2.b – as also from other technical documents [13] – we can consider that the time at which the dart leaves the atlatl corresponds to a joint configuration in which arm and forearm are aligned. Moreover, in such release configuration, the atlatl appears to be perpendicular to the forearm, and the dart roughly perpendicular to the atlatl, as illustrated in Fig. 6.a. Assuming, for simplicity reasons, that the dart is released in the X -direction, the speed of the dart, in absolute value, noted V_{atlatl} , corresponds in our model to the x -component of Equ. 4 with: $\theta_1 = \theta_2 = 0$, $\theta_3 = \text{atan2}(l_G, l_A)$. It follows: $S_1 = S_{12} = 0, S_{123} = l_A/\sqrt{l_A^2 + l_G^2}$, and then:

$$V_{atlatl} = l_A(|\dot{\theta}_{1ra}| + |\dot{\theta}_{2ra}| + |\dot{\theta}_{3ra}|) \quad (5)$$

where $\dot{\theta}_{1ra}, \dot{\theta}_{2ra}, \dot{\theta}_{3ra}$ are respectively the joint 1 to 3 velocities at the release time supposed to be all negative according to the joint directions imposed by our model. This very simple expression can be compared to the expression of the velocity reached in the X -direction by a 3R-planar robot – i.e. our robotic model deprived of the passive joint 4 with $l_3 = l_G$ – put in the joint configuration: $\theta_1 = +\pi/2, \theta_2 = \theta_3 = 0$, which is a singular configuration maximizing the Cartesian velocity, as shown in Fig. 5.b. The hand-velocity in magnitude, noted V_{hand} , is therefore given by:

$$V_{hand} = l_1|\dot{\theta}_{1rh}| + l_2(|\dot{\theta}_{1rh}| + |\dot{\theta}_{2rh}|) + l_G(|\dot{\theta}_{1rh}| + |\dot{\theta}_{2rh}| + |\dot{\theta}_{3rh}|) \quad (6)$$

where $\dot{\theta}_{1rh}, \dot{\theta}_{2rh}, \dot{\theta}_{3rh}$ are respectively the joint 1 to 3 velocities at the release time of the spear. From comparison between Equ. (5) and Equ. (6), it results that, at dart release time, the atlatl would work like a substitute of the thrower’s hand, put in the so-called elbow singularity ($\theta_2 = 0$) for giving to the dart the greatest Cartesian velocity along a direction orthogonal to the atlatl. If we assume similar joint release speeds i.e. $\dot{\theta}_{ira} = \dot{\theta}_{irh} = \dot{\theta}_i$, for $i=1$ to 3, it is clear that a same Cartesian release speed would require an atlatl-length equal to:

$$l_A = l_G + \frac{l_1|\dot{\theta}_{1r}| + l_2(|\dot{\theta}_{1r}| + |\dot{\theta}_{2r}|)}{|\dot{\theta}_{1r}| + |\dot{\theta}_{2r}| + |\dot{\theta}_{3r}|} \quad (7)$$

At our knowledge, accurate joint velocity data during spear throwing like during dart throwing with an atlatl are missing. In the absence of such data, we propose to use available data in a hammering task: although generally helped by the force of gravity, such task has a certain similarity with atlatl use due to its performance in a vertical plane, supervised by the worker’s gaze. According to Côté *et alia* [14]: peak velocities have been recorded for healthy non-fatigued people: 196°/s in shoulder extension (our $|\dot{\theta}_{1r}|$), 645°/s in elbow extension (our $|\dot{\theta}_{2r}|$) and 357°/s in wrist ulnar deviation (our $|\dot{\theta}_{3r}|$). Moreover, from *The Naval Biodynamics Laboratory* [15], we can consider: $l_1 = 28.6$ cm, $l_2 = 27.9$ cm and $l_G = 6.7$ cm. As a consequence, we deduce: $l_A \approx 31$ cm. Although atlatl lengths are generally a bit more higher, between 40 and 60 cm, the result appears to be rather deceptive since a relatively long tool would be necessary to get the same performance than a short distal link.

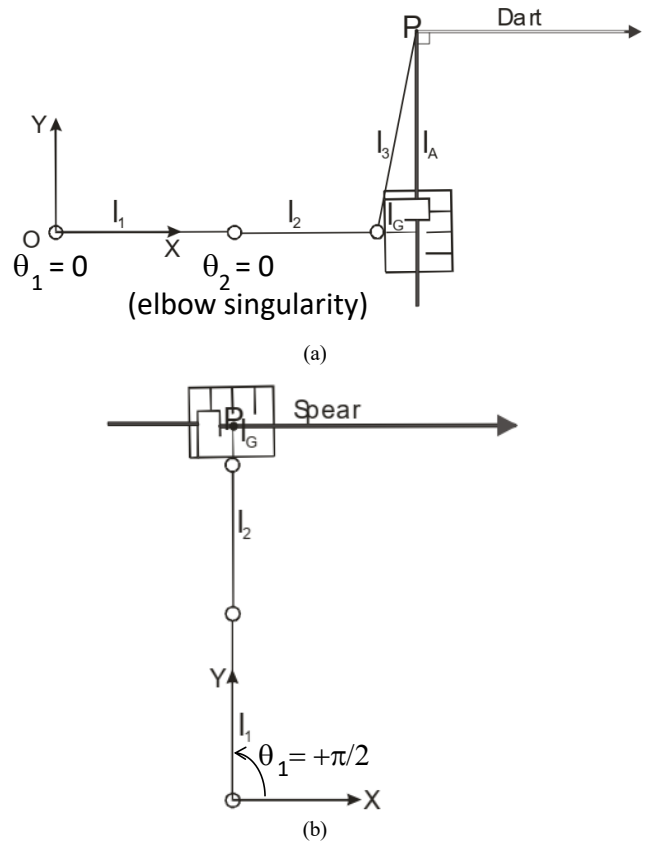


Figure 6. Release configuration of the dart by the atlatl (a) compared to an equivalent release configuration by the hand holding a spear (b) – see text.

But, in the case of the human upper-limb, and this is a key point for understanding the atlatl’s invention, such configuration for throwing a hand-held spear appears to be very badly adapted for getting high Cartesian speeds due to the limitation in shoulder extension: the considered angle $\theta_1 = +\pi/2$ indeed corresponds to a mechanical stop for the shoulder in the sagittal plane. If we limit ourselves to the vertical plane, only the elbow and wrist can then participate to the production of a Cartesian speed in the joint configuration shown in Fig. 6.b. As a consequence, to be in accordance with human shoulder joint range in flexion-extension, it is necessary to

impose: $\dot{\theta}_{1rh} = 0$. Let us put: $k_A = l_A/l_G$. If we continue to assume: $\dot{\theta}_{2ra} = \dot{\theta}_{2rh} = \dot{\theta}_{2r}$ and $\dot{\theta}_{3ra} = \dot{\theta}_{3rh} = \dot{\theta}_{3r}$, we deduce the following ratio between corresponding release speeds – please note that $\dot{\theta}_{1r}$ is now the sole release speed for shoulder extension during dart throwing with an atlatl:

$$\frac{v_{atlatl}}{v_{hand}} = k_A \left(\frac{|\dot{\theta}_{1r}| + |\dot{\theta}_{2r}| + |\dot{\theta}_{3r}|}{\left(\frac{l_2}{l_G}\right)|\dot{\theta}_{2r}| + (|\dot{\theta}_{2r}| + |\dot{\theta}_{3r}|)} \right) \quad (8)$$

Using the same data as before, the release speed with the atlatl is twice this produced by the spear throwing by hand for a k_A -factor equal to about 6.15 leading to an atlatl length of about 41 cm, highlighting the great interest of the atlatl for increasing the squared velocity term of the dart kinetic energy¹.

Moreover, if a baseball pitcher can flex hard his/her wrist for giving the maximum speed to the ball, as illustrated in Fig. 2.c, this is not so easy for a thrower delivering his/her spear by hand, if he has also to control the spear orientation towards the target. As a consequence, the previous assumption $\dot{\theta}_{3ra} = \dot{\theta}_{3rh}$ is without any doubt too optimistic leading to underestimate the positive effect of the wrist movement in the dart throwing with an atlatl.

Recently, Kortkandtn [18], criticizing the assumption of hunting by thrusting in the time of Neanderthals, reported an old photography, ill-dated, showing a hunting scene in secluded areas we took the freedom to reproduce in Fig. 7.



Figure 7. Mandari men hunting an elephant – reproduced from Kortkandtn [18] who specifies that the picture is attributed to a French book on hunting by Molloy dating from before World War II.

On this picture, the man on the right hand side is clearly at the all beginning of his throwing, in some typical initial joint configuration for a thrower aiming the expected prey with his spear, which clearly limits final shoulder and elbow high joint velocities at release time. Trunk rotation generally compensates the limitation in shoulder movement making more complex the look for a precise throw. By comparison, the atlatl overcomes these drawbacks. First, because the release of the dart occurs when the extended arm is roughly at the horizontal, the shoulder can extend along a much greater joint range. Secondly, although the wrist joint has to participate to the final orientation, realized by the passive hook-joint, in coordination with shoulder and elbow movements, it also participates to the whole-body throwing movement as a baseball pitcher does. It is also, according to us, interesting to oppose the spear throwing of the typical

¹ In their recent studies, Jessop and Pain [16] report much higher velocity peak values, especially in shoulder extension (about 1071°/s) and elbow extension (about 1598°/s) but these movements are performed in unrestricted conditions without hand-held tool and without a task to be performed. However, by using these data combined with the maximal ulnar deviation

hunting scene shown in Fig.7 with javelin throwing: while the throwing of a spear by the hunter aims to reach his/her expected prey, the throwing of a javelin by an athlete aims to reach the maximum range. But, as noted by Mont and LeRoy [19]: “In the javelin, as in all other throwing events, the range depends uniquely on the state (position, velocity, attitude, angular velocity) of the instrument at the instant of release by the thrower” (page 583). A typical body posture for getting this maximum release speed is illustrated in Fig. 8: according to Brown, Sing and Webb [20], “Rather than a throw, the javelin is an over-arm, whip-and-flail motion that uses the entire body”. And it is true that some pictures look strange for the neophyte ([19], page 587, for example), when he/she notices the head movement at the release time towards an opposite position with respect to the javelin’s direction. It is all as if the javelin’s thrower forgot where the javelin must go. In an opposite way, the hunter must combine his/her throwing with the look at the game and, before the invention of the bow, in a more efficient way than a hand-held spear throwing, the atlatl made that possible.



Figure 8. Typical release position in javelin throwing (redrawn from Bartonietz [21], Fig. 20.2, page 405) – see text.

Moreover, it is interesting to note that, in this quest of the highest release speed, without losing sight on the game, the grip of Fig. 1.b seems to be more efficient than this of Fig. 1.a because, as reported by Schoenmarklin and Marras [17], wrist flexion leads to higher peaks of velocity (1049°/s) and acceleration (16092°/s²) than ulnar deviation (respectively 436°/s and 7640°/s²). In his own experiments, Raymond [8] reports a mean velocity peak of 21.6 m/s got with an atlatl deprived of weights, whose full length is 48 cm with a grip adapted to wrist flexion and a dart weight of 70 g. Hutchings and Brüchert [22] have therefore shown that the use of heavier darts can lead to much higher release speeds, until 64 m/s for a dart weight of 273.4 g. Data are curiously missing about release speeds of hand-delivered spears for hunting, but it is clear that such speeds are quiet less than these reached in world-class javelin throws, around 30 m/s with a 800 g javelin for men [23]. Although the weight of hand-delivered spears can be higher than darts thrown by atlatls, the gain in speed squared in the computation of the kinetic energy is primordial.

velocity (about 436°/s) measured by Schoenmarklin and Marras [17], we get, with same Equ. (8), an atlatl length equal to about 37.5 cm for a dart release speed twice the spear release speed, close to the previous computed value.

IV. CONCLUSION AND DISCUSSION

The atlatl is not a spring but, according to us, to say that “an atlatl acts as a lever arm, allowing a light spear to be thrown much more forcefully than by hand alone” [2] does not fully express the very original way it derives advantage of being included into the upper limb kinematic chain. Similarities can be found between the successive positions of a baseball pitcher and a thrower with an atlatl. It could be said that the atlatl and dart-machine make possible a throwing so natural than a ball throwing and even more efficient, not due to the atlatl as a lever, but due to the atlatl as a cyborg device, understood as a substitute of the hand. By means of the cyborg concept, we are therefore led to highlight the major role of hook in the atlatl functioning. As a passive joint, it does not extend the joint range, especially limited in the radial-ulnar deviation but, in some way, it shifts the zero of the corresponding joint – i.e. when forearm and hand are aligned – making possible a dart release in the most profitable upper-limb joint configuration – i.e. the singular configuration with arm and forearm aligned. As a consequence, a summation of shoulder, elbow and wrist speeds results, leading to dart release velocities much greater than these of a hand-delivered spear, while throw accuracy is kept.

According to Neil Thomas Roach, “humans are the only species that can throw objects both incredibly fast and with great accuracy. This unique throwing ability may have been critical to the survival and success of our hominin ancestors, helping them to hunt and protect themselves” [24]. Such ability would be due to what Roach calls “elastic energy”, a kind of potential mechanical energy stored in tendons, ligaments and muscles, especially inside the shoulder complex [25]. It is clear that throwing with an atlatl derives benefit from this elastic energy but, according to us, it does so differently from the act of throwing a hand-held spear. While shoulder extension is limited when the upper-limb is raised, preventing to take advantage of the optimal joint configuration with elbow fully extended in the vertical plane for maximizing the throwing speed, the atlatl would shift this optimal joint configuration a 90°-angle lower. Such an ability of modifying the natural optimal kinematic configuration for throwing makes the atlatl, according to us, a very original and efficient cyborg device.

Beyond this purely technical analysis attempt, we would like to highlight two points in relation with our actual thinking about cyborg development.

1. The atlatl as a typical example of easy-to-learn cyborg device.

Archeologists still debate about the shift from spear-thrower to bow, resulting, as explained by Brigid Grund [26] either from diffusion (“bows are superior to atlatls in all respects”), subsistence (“bows are better for handling smaller, faster prey”) or warfare (“bows are better equipped for handling situations of human-on-human conflicts”). As a consequence, atlatl would be a typical example of an outdated technology whose study can only interest archeologists. However, Grund highlighted, by experimenting the two technologies, some unexpected property of this old technology: the bow would be more difficult to learn than the atlatl with, as a consequence, that “spear thrower can be wielded effectively by larger segments of human populations

than bows” ([27], page 114). It is not clear why “maximum spear thrower skill is approached more rapidly than maximum bow skill” (*ibid.*, page 114) whereas the two technologies do not seem to differ in complexity. Such amazing result suggests that spear-thrower, as a cyborg device, can directly derive advantage from the skill gesture, on which its use is based, whereas to master a bow is a non-natural activity. According to Rausing [28] – cited by Grund [27] – “Each type of bow and even each individual bow has its own characteristics, and nothing less than many years of training is sufficient to produce perfect cooperation between the archer and his weapon” (page 12). We could so say that atlatl technology is an easy-to-learn cyborg technology because its use is directly based on our natural motor skills. This is, in some way, confirmed by Whittaker when he is talking about “high-scoring atlatlists [reaching their] current level of consistency after only a few years” ([29], page 103). But, as suggested by an anonymous reviewer, it seems that “the hook of the atlatl limits controlling the dart” and, according to Whittaker: “In a general sense, bows are more accurate than atlatl” ([29], page 108). However, as still emphasized by the same author, “despite the general superiority of bow accuracy over atlatl accuracy, at actual hunting ranges, atlatls in skilled hands were probably as accurate as many prehistoric bows”. (*ibid.* page 108).

In a broader manner, we could therefore compare the actual easy-to-learn cyborg technologies: on the one hand, the j-shaped artificial limbs named “cheetahs”, which are an amazing success for making running people deprived of a foot or even both of them, with the unexpected failure of the Google glass. The reasons of such miserable failure are still debated [30] but, according to our ecological approach of cyborg technologies, it is clear that Google glass failed because it attempted to modify the relation of the person with his/her environment. Human eyes are made to see and not to record, whereas the atlatl tends to make easier the relation of a person with its environment: human arm is, in other things, made to throw. It could also be said, in a more Darwinian perspective that, as emphasized by Kobrinsky, father and son, in their robotic treatise [31] that the human body is optimal without we can know with respect to which criteria. According to this approach, any cyborg technology is supposed to respect this hidden optimal nature of the human body, otherwise there is a risk to be rejected by disturbing the equilibrium of the body as a whole with the environment who made it optimal.

2. The atlatl as a typical example of a nongendered cyborg device.

Hunting is generally considered as a male activity and most of artistic views of prehistoric hunting scenes show adult men. However, prehistoric female burials include tools whose functionality can be associated with hunting activity. Very recently, Randall Haas and his team discovered, at the Andean highland site of Wilamaya Patjxa, a young female burial with undoubtable hunting tool kits [32]. According to the authors, “The findings are consistent with nongendered labor practices in which early hunter-gathered females were big-game hunters”, in full accordance with Grund’s hypothesis about the easiness in the atlatl’s use by females before reaching reproductive age. Such a nongendered use of the atlatl is still in accordance with our interpretation of the atlatl as a

kinematic cyborg. While the efficiency of a bow is based on the muscular power transmitted to the bow, the efficiency of the atlatl is based on a kinematic transformation between joint space and Cartesian space along a trajectory during which velocity is progressively increased until the dart leaves the atlatl. Whereas the throwing of a hand-held spear is performed after a short trajectory of the hand requiring, to be the most efficient possible, high joint torques and therefore high muscular power, the throwing of a dart by an atlatl is more progressive due to the longer hand trajectory before release. As emphasized by Doucette, “the mechanics of the atlatl are such that throwing a spear with more power and accuracy is easier” with, as a conclusion: “There are no reasons why a woman could not have used an atlatl for hunting” ([33], page 171). The atlatl would so illustrate what could be expected from cyborg technologies for erasing the differences between male and female activities. My paper is unusual and to finish on some unusual note, I will cite Dona Haraway and its *Cyborg Manifesto* about which we seriously can think that it is doing much to reintroduce the term cyborg into our scientific community. She ends her manifesto by the so powerful statement: “Cyborg imagery can suggest a way out of the maze of dualisms in which we have explained our bodies and our tools to ourselves. This is a dream not of a common language, but of a powerful infidel heteroglossia. It is an imagination of a feminist speaking in tongues to strike fear into the circuits of the supersavers of the new right. It means both building and destroying machines, identities, categories, relationships, space stories. Though both are bound in the spiral dance, I would rather be a cyborg than a goddess” ([34], page 182). Rather than an Amazon or a goddess, the 17-to-19-year-old female called WMP6 whose burial has been located at the Andean highland site of Wilamaya Patjxa was already a cyborg in Haraway’s meaning.

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