Boyd's Real OODA Loop and Fencing

By

Nicholas J. Johnson

Introduction

In a previous article (Johnson 2012), the OODA loop was presented and discussed in the context of a game theoretical model of stimulus and response actions. This is useful because elite level fencers are studied in great detail in film footage and detailed probability models of their reactions to different stimulus movements can be developed. It also offered specific training suggestions.

Several observations were made that are worth repeating. They are:

Observation 1: In a system with uniformly distributed probabilities across its nonzero responses, the greater uncertainty (entropy) is always associated with the greater number of choices.

Observation 2: The fencer that fences with the most evenly distributed probabilities creates the maximum amount of entropy (uncertainty) for his opponent in determining what movement the fencer will select in response to the opponent's initial action.

Observation 3: The system as represented by the system stimulus response table affects the fencer's perception of the fencing environment and hence their ability to orient to it.

Observation 4: A fencer's perception of the fencing environment, as determined by his training in a system, determines how he perceives the uncertainty of the situation and hence can affect the entropy he faces in reading an opponent. (Johnson, 2012)

These observations were to act as guides in training fencers and constituted a different way of thinking about the fencing environment. More specifically, it drives home the fact that fencers perceive the fencing environment through their training. Also the fencer should seek to manipulate the opponent's information uptake and not just go through movement and countermovement. The real goal should be to modify the entropy in the fencing environment to one's advantage. This meant that the fencer seeks to ramp up the opponent's entropy so that it is higher than one's own.

The concepts of information theory were used to increase the understanding of the fencing environment. This was done by adopting an information model of the fencing environment. In this paradigm the fencers are seen as part of a communication system that involves the transmission and reception of fencing movements. This allows one to use the idea of entropy. In information theory entropy is a measure of how much information one needs to resolve the uncertainty in a given message. Essentially it is a measure of uncertainty. Using the concept entropy it was possible to show how entropy changes depending on the situation. (Johnson, 2012)

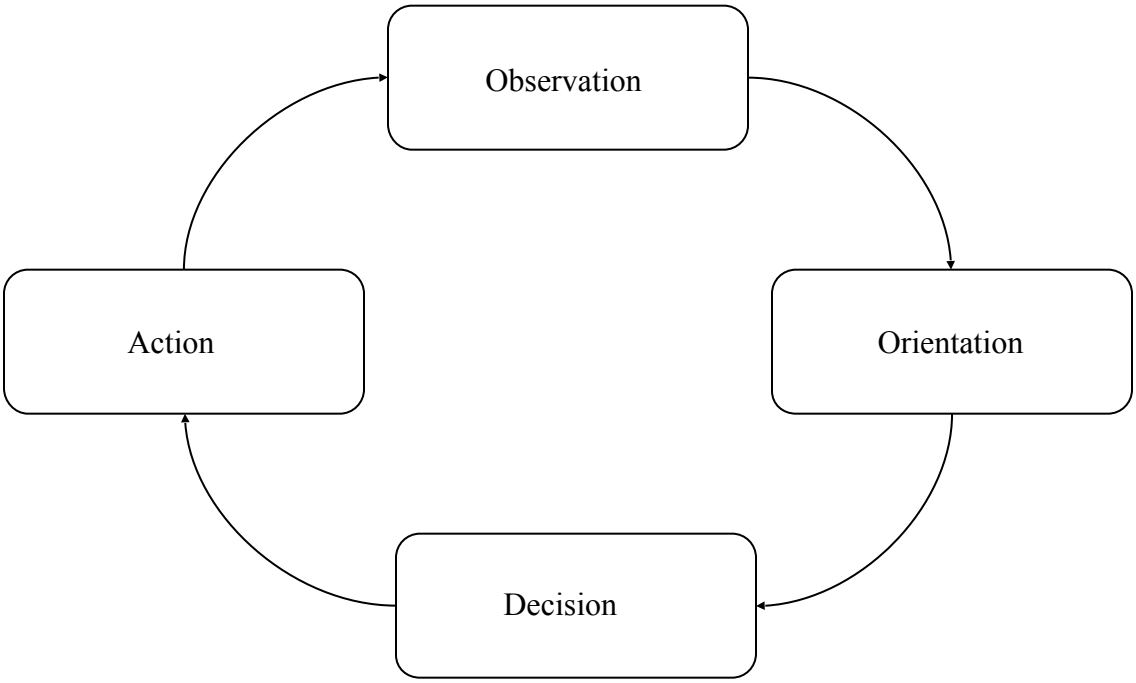
The above observations, while useful, seemed to indicate a one way pattern of a bout, where the main goal is to increase the entropy by a simple movement and counter movement scheme. Another issue was the OODA loop was overly simple. Upon

discussion with gentlemen that worked closely with John Boyd for several years (on whom, see below) and further reading and study it became evident to the author that the OODA loop deserved more detailed consideration than was presented in the article. Thus through this endeavor a further and very important additional observations can be made and added to the above. The development and explanation of the full OODA loop and these observations are the topics of this article. This shall start by revisiting the simple versions of the OODA loop.

Simple OODA

In the previous article, the OODA was taken as a model of how a fencer resolves the uncertainty in the fencing environment. This was necessary in order to explain how uncertainty was developed and resolved in the communication system consisting of the two fencers. This loop is shown in Figure 1.

Figure 1



Boyd used the OODA loop to describe how a fighter pilot operates in a combat environment. From the previous the loop gave a brief explanation of the OODA loop from that perspective as follows:

> *In the first phase the pilot observes the situation around him and takes in data about the environment around him. He then goes through an orientation phase that creates and/or modifies a mental model of the world around him via a process of analysis and synthesis of the data in context of previous experience, cultural beliefs, genetic heritage, and of course, new data…So orientation is important to place the new data into some kind of context from which meaning can be extracted and a mental model created that allows one to make predictions about what our opponent is likely to do next. From these predictions in the mental model certain decision paths arise and this leads to the decision phase. In the decision phase a specific decision path is chosen from all the others and that leads to the final phase. The action phase is where the person carries out the physical action that was decided on in the decision phase. This action phase changes the environment and causes new data to be taken into the observation phase and the cycle repeats.* (Johnson, 2012 p.24)

This is of course a very beguiling explanation. It draws fencers in because of its immediate application to fencing. To make the above explanation apply to fencing one need only replace the term “fighter pilot” and “pilot” with the word “fencer” and the explanation practically completes itself. But is this model really the best?

The OODA loop depicted in Figure 1 has been criticized in military circles. One of the best criticisms of a sequential OODA loop was written by Maj. Jim Storr (2001). His arguments deserve especial consideration because they have great applicability to fencers.

Criticism

Storr begins his criticism of the OODA loop depicted in Figure 1 by describing it as follows: "The OODA Loop suggests that the process of Observation, Orientation, Decision and Action is a circular, iterative process." (Storr, 2001 p. 39)

He continues by stating that advantage stems from completing the loop faster than one’s opponent. He then proceeds to point out that the loop cannot be circular in nature by using an example. He describes it as follows:

> However, the OODA process is not circular. It apparently takes 24 hours to execute a divisional operation. Planning takes a minimum of 12 hours. Thus, a divisional OODA loop would have to be at least 36 hours long. Yet the Gulf War and other recent operations show divisions reacting far faster. Military forces do not in practice wait to observe until they have acted. Observation, Orientation and Action are continuous processes, and decisions are made occasionally in consequence of them. There is no OODA Loop. The idea of ‘getting inside the enemy’s decision cycle’ is deeply flawed. There is considerable advantage in reacting faster than one’s opponent, but the OODA Loop does not adequately describe the process. (Storr, 2001 p. 39)

His point in the above is that the idea of a military unit operating in a combat environment waiting for 36 hours after taking action to observe the opponent's reaction to their initial action is unrealistic in the extreme. Storr's point is absolutely correct in that the OODA loop cannot be a circular reiterative process only and adequately explain what happens on a military level. But does a simple OODA loop work in a one-on-one situation such as fencing? Storr offers an argument that this loop does not by using the example of a fighter pilot ace as follows:

> Biographies of aces such as General Robin Olds, who was an ace in Korea and also in both the Second World War and Vietnam, display no evidence of iterative behaviour. Their effectiveness centres on rapid, decisive decision and action; based on superlative, largely intuitive, situational awareness. (Storr, 2001 p. 39)

His implication is that the OODA loop model breaks down even at the level of individual one-on-one combat. His main problem with the OODA loop is that for aces there is no evidence of iterative behavior. Iterative behavior here is meant as taking action and then observing its effect on the environment before taking another action. He continues on in his criticism on iteration. His main point is that militaries try to minimize the loss of life on the part of their soldiers for both pragmatic and moral reasons (Storr, 2001). This is a particularly appt criticism of the OODA loop for fencing since a fencer can scarcely afford to give up too many touches. In short a fencer can ill afford to take an action and wait and see what happens before taking another action.

So the above begs the following question. How did Boyd envision the OODA loop? This seems like a straight forward question. In a typical scholarly endeavor one would research what Boyd wrote about the OODA loop and one would then surmise his

meaning. This is somewhat difficult to do with Boyd since most of his writing is in the form of briefings. The slides that constitute the briefings and one unpublished (in his life time and is now readily available on the internet) paper titled "Creation and Destruction" are all we have on Boyd's OODA loop. Fortunately Boyd's briefings were epic in nature and so each briefing contained many slides. But still one must sometimes work from secondary sources to fill in gaps. Fortunately many of these the secondary sources worked closely with Boyd for years and are intimately familiar with his ideas and understanding of the OODA loop. One of these people is Chet Richards.

The Full Loop and Nothing but the Full Loop

> In an online article Richards writes as follows:
>
> > The acronym "OODA" stands for "observe, orient, decide, act," and it is often depicted with the four elements arranged in a simple sequence, as if the acronym stood for "observe, then orient, then decide, then act," as shown in Figure 1 (Osinga 2005; Richards, 2004). (Richards, 2012)

Richards is stating the popular loop that is shown at the beginning of this article and is shown in Figure 1. A direct consequence of this simple view is that of completing the OODA loop more rapidly than your opponent. This in turn leads to cumulative and irresistible advantages and eventual defeat of one's opponents. This is referred to as "rapid OODA looping" (Osinga, 2007). Richards is also hinting that this is not entirely correct. His article then goes on to quote Storr in showing why such a simple loop concept is unworkable in actually combat. Namely that it is not a circular process (Richards, 2012).

Richards also refers to examples where drawing a conflict out may lead to tactical advantages. He cites sources ranging from business to guerilla warfare to make his case. He goes on by referring to Boyd's briefings. Several of the statements he quotes are useful to give some context for Boyd's understanding of the OODA loop. The following statements from Boyd's briefing "Patterns of Conflict" are given below:

> Observe, Orient, Decide and Act more inconspicuously, more quickly and with more irregularity...
> or put another way
> Operate inside the adversary's Observation-Orientation-Decision-Action loops or get inside his Mind-Time-Space. (Boyd, 1986 p132)

> Operate inside adversary's observation-orientation-decision-action loops, or get inside his mind-time-space, to create a tangle of threatening and /or non-threatening events/efforts as well as repeatedly generate mismatches between those events/efforts adversary observes, or anticipates, and those he must react to, to survive; (Boyd, 1986)

Evidently Boyd was trying to develop a far more comprehensive idea than what is suggested by the simple loop given in Figure 1. But this begs the question what did Boyd mean? This is made more evident in his briefing "The Essence of Winning and Losing". The author has decided to reproduce the entire first slide titled "Key Statements" here. The statements below represent some of Boyd's clearest writing on his ideas and the OODA loop in general. These are taken from a version of the briefing that has been updated and edited by Richards (2010). All bolding conforms to Boyd's earlier version from 1995.

From the "Essence of Winning and Losing" reproduced here:

- **Without our genetic heritage, cultural traditions, and previous experiences,** we do not possess an **implicit** repertoire of psychophysical skills shaped by environments and changes that have been previously experienced.
- **Without analyses and synthesis** across a variety of domains or across a variety of competing/independent channels of information, we cannot evolve new repertoires to deal with unfamiliar phenomena or unforeseen change.
- **Without a many-sided, implicit cross-referencing process of projection, empathy, correlation,** and **rejection,** (across these many different domains or channels of information), we cannot even do **analysis** and **synthesis**.
- **Without OODA loops**, we can neither sense, hence observe, thereby collect a variety of information for the above processes, nor decide as well as implement actions in accord with these processes.

Or put another way:

- **Without OODA loops** embracing all of the above and **without the ability to get inside other OODA loops**(or other environments), we will find it impossible to comprehend, shape, adapt to and in turn be shaped by an unfolding evolving reality that is uncertain, everchanging, and unpredictable.

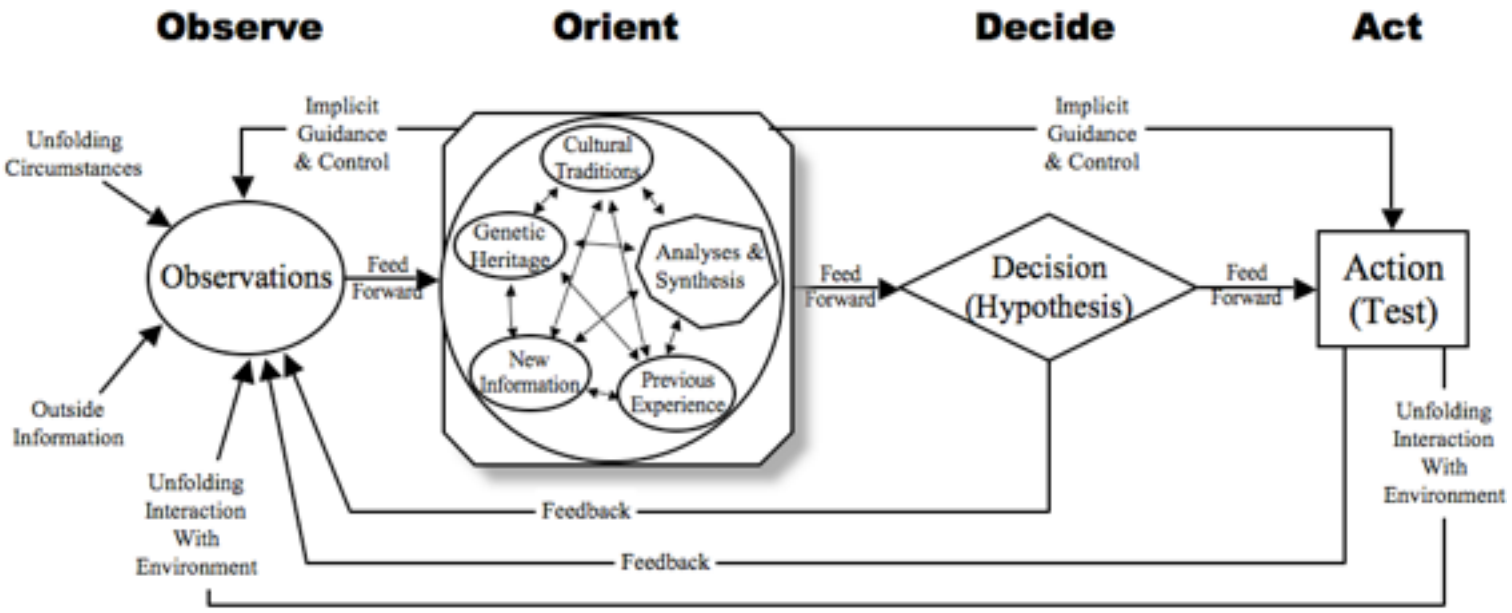
(Boyd, 1995)

What Boyd was trying to convey was more a theory of learning. In the first point he is saying that we rely on a variety of factors genetic, cultural, and past experience (training if you will) in order to deal with a chaotic environment. He emphasizes the implicit nature of how we do this. This implies that not all of this occurs at a conscious level. In the second bullet he points to the necessity of an analysis/synthesis process of learning where ideas and experiences are broken down and put back together in new and novel ways that lead to new or different ideas/actions that allow one to deal with the unfamiliar and unpredicted. This is akin to fencers breaking down a fencing phrase to understand it and then developing counters to the actions at different points in time in the phrase. He also stresses that a person must be open to competing and independent channels and sources of information. This would mean a fencer should not spend all of his time using

his visual field and should broaden out his sensory uptake to include tactile and auditory as is appropriate. Certainly he should not spend all his time focusing on just one part of the opponent's body. The third point of Boyd's gives an insight to his understanding of the OODA loop. It is not necessarily a conscious process but it does allow one to compare mental models to the changing reality around him and accept and reject models as needed. This comparison is done by cross-referencing different sources of information from the environment and comparing it to the projections of the mental model. This is similar to a fencer performing an action and changing it in midflight because of an opponent's action or inaction. In the fourth point Boyd states that the OODA loop is essential to performing the tasks of information uptake, decision making, and action execution in a way that is in accord with the changes happening in the environment. In the final point Boyd clarifies that OODA loops are essential if one is going to survive in a dynamic changing environment.

Richards, after citing some of the above, goes on to state that a simple OODA loop that operates as shown in Figure 1 does not capture the essence of what Boyd was trying to convey. Boyd seemingly realized the need for a better rendering of what he meant and it is far more subtle and involved than the simple loops that everyone knows. Boyd's loop is shown in Figure 2 and is taken from the same edited version of "The Essence of Winning and Losing" (Boyd, 1996)

Figure 2



At the bottom of the diagram in Boyd's briefing is box titled "Insights:" It contains the following two statements:

> Note how orientation shapes observation, shapes decision, shapes action, and, in turn, is shaped by the feedback and other phenomena coming into our sensing or observation window.
> Also note how the entire "loop" (not just orientation) is an ongoing many-sided implicit cross referencing process of projection, empathy, correlation, and rejection. (Boyd, 1996)

The full loop is far from being a simple loop and looks more like a complex circuit where some of the wiring is in series and some of it is in parallel. This is one of the interesting aspects of the full loop. It implies that it does not have a cyclical nature where one must go from observation, then to orientation, etc. *ad infinitum* in step-by-step method. Rather as Boyd states above it is an ongoing process. In other words one does not move step by

step through each stage of the loop but rather they are in every stage simultaneously at all times (if one considers a null response, meaning one simply carries on the action or lack of action they were previously performing, as an action then one can be thought of being in a state of action at all times) where via an implicit process all the aspects of orientation affect observation, decision, and action. This means how one understands his environment (orientation) affects what he looks for in the environment (observation), what he decides to do (decision), and how he acts (action). Notice though how decision and action feed back to observation in turn affecting orientation. So this model shows how the main elements of observation, orientation, decision, and action affect one another and interact. This is the cross-referencing Boyd talked about throughout "The Essence of Winning and Losing". Finally, one should notice how outside information enters in to the decision making process via unfolding interaction with environment, unfolding environmental interaction, unfolding circumstances, and finally outside circumstances. All of which serves to remind one that they are part of the environment their actions have consequences and that circumstances may change and one needs to be aware of more than just what their opponent is doing. To better comprehend the loop, Richards makes the following observation:

> To get a handle on it, begin with the centrality of orientation and imagine that when we are engaged with opponents—or in the case of business, with competitors and customers—our actions will flow from it directly and implicitly, that is, without explicit (e.g., written or detailed verbal) commands or instructions, most of the time, something which is difficult to model with the loop of Figure 1. Orientation is an ancient idea, embodied in the concept of mindfulness, but it is as modern as fighter pilots, who talk about maintaining "situation awareness." (Richard, 2012 pg. 11)

This shows the importance of orientation in the OODA loop and basically it changes conflict to a "learning contest" (Richards, 2012 p. 12).

In the full loop implicit guidance and control is of absolute importance. Without it Storr's argument that a simple loop that passes through stages is far too slow and easy to disrupt. By using implicit guidance and control from orientation to action, one can act directly and rapidly in an almost reflexive manner. It is this aspect of Boyd's full loop that accounts for and counters Storr's argument. Implicit guidance and control bypasses the need to go through the stages in a step by step fashion. Again Richards states an important observation:

> If, on the other hand, action can flow rapidly from orientation directly via an implicit guidance and control (IG&C) link, then any pattern of actions becomes possible. In particular, abrupt shifts, which Boyd (1986) called "asymmetric fast transients," from *cheng* to *ch'i* are straightforward. Just fire the *ch'i* when the time is right. The jarring transition jerks opponents off balance mentally (sometimes physically) and sets them up for the exploitation to follow. (Richards, 2012 p.12)

Here Richards is saying that by using Boyd's idea of implicit guidance and control one can rapidly transition in the environment. These fast transitions from one state to the next are called fast transients. These allow one to adapt and throw the opponent off balance.

Consider the above in a fencing context. Consider a fencer begins by making a feint direct followed by disengage. The opponent attempts a time thrust. If the opponent is able to change his state rapidly enough the fencer cannot adapt in time and runs into the opponent's point. This is an example of a fast transient on the part of the opponent. The fencer could create his own fast transient by performing a feint in time, counter

thrust or transitioning to a parry riposte strategy. These are all forms of a fast transient in reaction to an opponent's attempt to counter.

The above is fine but misses the point of Boyd's entire thesis. Boyd more than once discussed the necessity of becoming the uncertainty in environment. This increased ambiguity makes one harder to read and understand and in turn allows for manipulation of the opponent's perception of the environment. This is accomplished by performing fast transients to induce mental hesitations that in turn can be exploited.

With the preceding discussion completed it is clear to see that Storr's criticisms of the simple OODA loop are correct as affirmed by Richards (2012). But the simple loop was not the final version of the process as envisioned by Boyd. By using implicit guidance and control Boyd was able to avoid the pitfalls of a sequential simple loop. Indeed Richards states that the part of loop termed implicit guidance and control that connects orientation and action is how one should use a repertoire of actions. Whereas the part along the bottom of the loop feeding back to and through observation, orientation, decision (hypothesis), and action is how one goes about expanding the repertoire of action by creating new and novel actions in an explicit manner (Richards, 2012).

Using this implicit guidance and control method Boyd was able to harness the ability of orientation to permeate aspects of observation, decision, and actions taken by an individual. In turn orientation is affected by those actions, observations, and decisions in terms of how they modify and fit the environment. This is basically saying that the

OODA loop is happening in real time and not in a sequential "wait and see" iterative approach.

A Quick Aside: System 1, System 2 Psychodrama

While the above comments are useful, it is interesting to note that there is an analogy to this implicit guidance and control of the full loop and the direct, sequential, and iterative control of the simple loop. This is found in the work of Kahneman, a psychologist who won the Nobel Prize in economics. In his book, *Thinking, Fast and Slow*, he describes the interactions of two different types of decision making systems in the mind, which he describes as a psychodrama with two participants. He terms these participants System 1 and System 2. System 1 is fast rapid and requires very little effort. It is used for tasks that require rapid decisions. It is highly associative in nature. System 2 is used when the decision requires effort and concentration and is very deductive in nature. For example System 1 would be used for sorting laundry and System 2 would be used for doing a math proof. He notes that one of the great features of the mind is that System 2 is used for figuring things out and can in fact train System 1. Since System 1 is highly associative, it tends to look for associations that may not exist. (Kahneman, 2011)

The connection with the full OODA loop is that the System 2 is analogous to the observation then orientation then decision then action sub loop found in the center part of the loop. Richards even notes that this part of the loop is used for creating new and novel actions to use in dealing with the environment (2012). Meanwhile, System 1 is akin to the orientation then action by implicit guidance and control pathway which Richards

mentioned as being the primary way actions are carried out in the environment in real life conditions (2012).

The connection to fencing is clear. During a bout, System 1 is used when actually performing fencing actions. It is the primary decision making system under real fencing conditions. But when trying to figure out new tactics and strategies and training regimens, System 2 is the primary system. By using System 1, the fencer is able to execute action and respond to changes in the fencing environment rapidly without a great deal of mental effort, but the mind is more susceptible to following patterns and imposing false patterns on the observed information in the environment. This tendency toward following or creating false patterns is something that can be exploited.

Returning to the Full Loop

This broader understanding given by the full loop moves one away from a "rapid OODA loop" approach where the game becomes about always moving faster than one's opponent (Osinga, 2007). Instead it becomes about modifying the opponent's understanding of events. This allows a fencer to lead an adversary to a false impression of his intentions and thus create opportunities that emphasizes fast transients to induce pauses in what fencing coaches call mental tempo. This means that success and speed of execution are not necessarily entwined. In fact it can even be useful to prolong a fencing phrase so as to probe and test the opponent's reaction and observe any patterns and tendencies he may have.

This leads to another observation. Let a fencer have a pattern of favoring a particular response to a given action. This says something about the fencer; namely that he is predictable. Any clever opponent facing him will discern the pattern. Now it is obvious that the opponent could devise a counter movement to the habitual response action, but this is a limited game because the opponent may not be shocked by the action and as a result the action failed as a fast transient. Also the clever opponent has several options. The opponent could try to counter the action within the duration of the fencer's preferred action by using actions that can be completed while the fencer is performing the action that results in the fencer receiving a touch. An example of this would be a counter attack or in-time action depending on what the favored action is. The other option is to neutralize the favored action and then perform an action to touch the fencer like a parry/ riposte combination. All of these options focus on the fencer performing the preferred action and the opponent taking advantage of them after the fact.

Throughout the above discussion one must ask if there is another way to look at this. The previous discussion was really focused on a predicted-response/ countermovement paradigm. That paradigm must be altered in order to find different ways of dealing with the fencing environment. This is when Boyd's ideas come in to the fore front of this discussion. What Boyd is encouraging people to do is to consider what a fencer's preference says about how he views the fencing environment and then exploit and or modify his orientation accordingly.

Rather than focusing on the fencer with the preferred response pattern actions or outputs one looks at the inputs. Basically this means switch roles. Entice the fencer to

perform the stimulus movement and then deliver a very different response movement. To clarify this, say the fencer performs movement B when presented with movement A. Rather than figuring out a counter to movement B, instead get the fencer to perform A and then perform a movement other than B. This is more likely to act as a successful fast transient. The reason why is given by the full loop. Since orientation is guiding all aspects of the fencer's loop that means the fencers preference to perform B when presented with A implies that this is his normal orientation. By getting the fencer to perform A so that one can perform a different action, one is more likely to catch the opponent off guard and open up mental tempo. The paradigm that is suggested by the above is one of enticed-stimulus/least-preferred-response. This leads to the following observation:

Observation 5: The fencer's preferences can be used against them by predicted-response/countermovement but also by enticed-stimulus/least preferred response.

This works because the existence of a preferred response implies that there exists a least preferred responses and the use of these against the stimulus action is more likely to create ambiguity and hesitation in the fencer that demonstrates such a tendency. Yet is this all there is? Is it possible to move the stimulus/response action view to a larger more global view? By looking at Boyd's work in a broader context there is. It requires that one note that the opponent's actions indicate a view of the fencing environment. What the opponent is expressing is his view of the fencing game space.

From this perspective a different option emerges. He could avoid the stimulus action that provokes the favored response. In fact the clever opponent will try to shift the

whole fencing bout away from the fencer's favored actions. This is done to try and drive the fencer into more uncomfortable and alien parts of the fencing game space. In this way the opponent forces the fencer to deal with actions that he may not be as familiar with. This increases the likely hood that the fencer with the preferred response action pattern will take longer to orient to the situation and/or run into actions that are completely novel to his experience. This is not a bad tactic but is difficult to do because it does not take advantage of the known response performance. This tactic requires a very clever opponent indeed. This implies the following observation:

> *Observation 6: The fencer who can use his actions to modify the information content of the fencing environment towards areas of the game space that the opponent is least familiar with will create greater ambiguity, confusion, and disorder on the opponent's part.*

Finally, how do fencers avoid falling into this trap? The only way is to practice ambiguity and to train a variety of actions so that they occur at an implicit level. That means the fencer must become as entropic as possible and exhibit no statistical tendency in his fencing. But this must be more than just a percentage view. Indeed, Boyd would have advocated moving away from a statistical view since it breeds predictability. This maybe unavoidable since elite fencers and their coaches spend countless hours studying fencing matches of other elite fencers. So this means the fencer that can create a large depth in terms of the number of response movements to a given stimulus and is as non preferential as possible can create greater ambiguity in the opponent and hence open up greater opportunities for exploitation. But this alone is not sufficient. Fencers must be

trained to look for patterns of behavior and how to exploit them in both a predicted-response/countermovement and by an enticed-stimulus/least preferred response method. Here it is about training the mind. This leads to the final observation:

> *Observation 7: The fencer who can be more ambiguous and is more successful in manipulating the opponent's response patterns most likely wins.*

Conclusion

Boyd's full OODA loop moves tactical thinking far beyond just movement and countermovement. He is advocating for a way of dealing with uncertain situations. To do this he emphasizes implicit guidance and control of actions so that they can be performed quickly. This implies that fencers should use a vast and adaptable repertoire of actions to create opportunities by embracing ambiguity. In a highly competitive environment, the fencer must look and exploit patterns observed in the opponent and do this in multiple ways. Rather than just thinking in terms of movement and counter movement, Boyd would advocate for a view of ambiguity and transient actions to bring about hesitation and interruptions in opponent's mental tempo. The fencer must do this and not develop statistical tendencies himself. Speed also is not the paramount criteria for success, rather it is manipulation of the opponent's uncertainty. At every turn the fencer must seek to work inside the opponent's loop by using uncertainty as an ally.

Bibliography

Borysiuk, Z., Waskiewicz, Z., (2008)
"Information processes, stimulation and perceptual training in fencing." *Journal of Human Kinetics* 19, 63-82. doi: 10.2478/v10078-008-0005-y

Boyd, J. R., (1964, August)
Aerial Attack Study (Monograph). USAF.

_____, (1976)
Destruction and Creation. Unpublished manuscript. Retrieved from http://globalguerrillas.typepad.com/JohnBoyd/Destruction%20and%20Creation.pdf Accessed 02/15/2014

_____, (1976, August 4)
A New Conception of Air to Air Combat. Briefing presented at NASA.

_____, (1986, December)
Patterns of Conflict. Briefing presented at various places.

_____, (1987, May)
Organic Design for Command and Control. Briefing presented at various places.

_____, (1987, June)
The Strategic Game of ? and ? Briefing presented at various places.

_____, (1987, August)
A Discourse on Winning and Losing. Briefing presented at various places.

_____, (1992, July/August)
Conceptual Spiral. Briefing presented at various places.

_____, (1996)
The Essence of Winning and Losing. Accessed 03/02/2014 http://slightlyeastofnew.com/439-2/

Brumley, L., Koop, C., & Korb, K. (n.d.)
The Orientation step of the OODA loop and Information Warfare [Data file]. Retrieved from http://pdfcast.org/pdf/the-orientation-step-of-the-ooda-loop-and-information-warfare Accessed 10/12/2012

Casile, A., Giese, M., (2005)

"Critical features for the recognition of biological motion." *Journal of Vision*, 5, 348-360. doi: 10.1167/5.4.6

Casile, A., Giese, M., (2006)
"Nonvisual motor training influences biological motion perception." *Current Biology*, 19, 69-74. doi:10.1016/j.cub.2005.10.071

Chaterjee, S. H., Freyd, J.J., &Shiffar M., (1996)
"Configural processing in the perception of apparent biological motion." *Journal of experimental Psychology: Human perception and Performance,* 22, 916-929

Crossley, J. N., Ash, C. J., Brickhill, C. J., Stillwell, J. C., & Williams, N. H., (1990)
What is Mathematical Logic? (1990 ed.). New York: Dover Publications. (Original work published 1972)

Czajkowski, Z., (2005)
Understanding fencing: The unity of theory and practice. (1st ed., pp. 108-149). Staten Island, New York: SKA Swordplay Books.

Decety, J., Grèzes, J., (1999)
"Neural mechanisms subserving the perception of human actions." *Trends in Cognitive Science*, 3(5), 172-178.

Diaz, G., Fajen, B., Phillips, F. (2012)
"Anticipation from biological motion: The goal keeper problem." *Journal of Experimental Psychology: Human Perception and Performance*, 38(4), 848- 864. doi: 10.1037/a0026962

Gaugler, W. M., (1997)
A Dictionary of Universally Used Fencing Terminology. Bangor, Maine: Laureate Press, Lance C. Lobo.

_____, (1997)
The Science of Fencing: A Comprehensive Training Manual for Master and Student; Including Lesson Plans for Foil, Sabre and Épée Instruction. Bangor, Maine: Laureate Press, Lance C. Lobo.

_____, (1998)
The History of Fencing: Foundations of Modern European Swordplay. Bangor, Maine: Laureate Press.

_____, (2010)
"Aldo Nadi: His Method for Success in Competition." *The Sword*, (7), 18-20

Gödel, K., (1992)
On formally undecidable propositions of Principia Mathematica and related systems (B. Meltzer, Trans., 1992 ed.). New York: Dover Publications, Inc. (Original work published 1931)

Hagemann, N., Schirer, J., Bruland, R., Lotz, S., & Strauss, B., (2010)
"Visual perception in fencing: Do the eye movements of fencers represent their information pickup?" *Attention, Perception, & Psychophysics*, 72 (8), 2204-2214. doi: 10.3758/APP.72.8.2204

Hall, N., (1994)
Exploring chaos: a guide to the new science of disorder. New York: W. W. Norton & Company.

Holland, J., (1992)
Adaptation in natural and artificial systems: an introductory analysis with applications to biology, control, and artificial intelligence. 1st MIT Press ed.

Holland, J., Holyoak, K., Nisbett, R., Thagard, P., (1986)
Induction: process of inference, learning, and discovery. 1st ed. MIT.

Jacobs, A., Pinto, J., & Schiffrar, M., (2004)
"Experience, context, and the visual perception of human movement." *Experimental Psychology: Human Perception and Performance*, 30(5), 822-835.

Johansson, G., (1973)
"Visual perception of biological motion and a model for its analysis." *Perception & Psychophysics*, 14(2), 201-211.

Johnson, N., (2012)
"Uncertainty in the fencing environment stemming from the choice of time and line in various types of actions." *Point In Line*, 4(3), 15-45.

Jordan, H., Reiss, J., Hoffman, J., & Landau, B., (2002)
"Intact perception of biological motion in the face of profound spatial deficits: Williams syndrome." *Psychological Science* 13(2), 162-167.

Kahneman, D., (2011)
Thinking, fast and slow. (1st ed.). New York City, NY: Farrar Straus & Giroux.

Kibele, A., (2006)

"Non-consciously controlled decision making for fast motor reaction in sports-a priming approach for motor responses to non-consciously perceived movement features." *Psychology of Sport and* Exercise 7, 591-610.

Michels, L., Lappe, M., & Vaina, L., (2005)
"Visual areas involved in the perception of human movement from dynamic form analysis." *NeuroReport*, 16(10), 1037-1041.

Richards, C., (2012)
"Boyd's OODA Loop: It's Not What You Think." Accessed 02/15/2014, http://slightlyeastofnew.com/439-2/

Osinga, F. P., (2007)
Strategy and History: Science, Strategy and War: The strategic theory of John Boyd (C. Gray & W. Murray, Eds.). London: Routledge Taylor & Francis Group.

Peterson, K. (n.d.)
"Notes on Shannon's Information Theory." Accessed 07/01/2011 http://www.math.unc.edu/Faculty/petersen/Coding/info.pdf

Pierce, J. R. (1980)
An Introduction to Information Theory: Symbols, Signals, and Noise. Mineola: Dover Publications, Inc.

Salczenko, I.N., (1980)
Dwigazjellnyje wzajmodijestwija sportsmienow. Kijew

Schechtman, G. M. (1996)
Manipulating the OODA Loop: The overlooked Role of Information Resource Management in Information warfare (Master's thesis, Air University, Montgomery, Alabama). Accessed 07/01/2011 http://www.au.af.mil/au/awc/awcgate/afit/schec_gm.pdf

Schmidt, F., Haberkamp, A., & Schmidt, T., (2011)
"Dos and don'ts in response priming research." *Advances in Cognitive Psychology*, 7 (special issue), 120-131. doi: 10.2478/v10053-008-0092-2

Shannon, C. E., (1948)
A Mathematical theory of Communication, Bell Systems Tech. J., 27, 379-423, 623-656

Shiffrar, M., Blake, R., (2007)
"Perception of human motion." *Annual Review of Psychology*, 58, 47-73.

doi: 10.1146/annurev.psych.57.1020904.190152

Starkes, J.L., Ericsson, K.A., (2003)
Expert performance in sports. Human Kinetics. Champaign. IL

Stevens, J., Fonlupt, P., Schiffrar, M., & Decety, J., (2000)
"New aspects of motion perception: selective neural encoding of apparent human movements." *NeuroReport*, 11(1), 109-115

Storr, J.
"Neither art nor science-towards a discipline of warfare." Accessed 02/15/2014
http://www.rusi.org/downloads/assets/JA00115.pdf

Szilágyi, T., (1992)
Examination of a fencing lunge. 10 International Symposium on Biomechanics in Sports. Milan, Italy. June 15-19, 1992
Editors: Rodano, R., Ferrigno, G., Santambrogio, G. C., Accessed 07/08/2011
https://ojs.ub.uni-konstanz.de/cpa/article/view/2824

Thurman, S., Grossman, E., (2008)
"Temporal "Bubbles" reveal key features for point-light biological motion perception." *Journal of Vision,* 8(3):28, 1-11. doi:10.1167/8.3.28

Urgesi, C., Maieron, M., Avenanti, A., Tidoni, E., Fabbro, F., & Aglioti, S., (2010)
"Simulating the future of actions in the human corticospinal system." *Cerebral Cortex*, 20(11), 2511-2521. doi: 10.1093/cercor/bhp292

Winter, D., (2009)
Biomechanics and motor control of human movement. 4th ed. Hoboken, New Jersey.