TIME VALUE OF KNOWLEDGE
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TIME-BASED FRAMEWORKS FOR VALUING KNOWLEDGE

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TIME-BASED FRAMEWORKS FOR VALUING KNOWLEDGE

Abstract

To survive and flourish in a changing and unpredictable world, organizations and people must maintain strategic power over necessary resources - often in the face of competition. Knowledge contributes to that strategic power. Without vigilance to maintain its currency and accuracy, the value of knowledge depreciates as circumstances change over time. Karl Popper's evolutionary epistemology and Maturana and Varela's concept of autopoiesis provide a paradigmatic framework for considering the roles and importance of time in constructing knowledge and using it to maintain strategic power. Following Popper, knowledge is constructed, used and evaluated via cyclically-iterated processes. We introduce nine time-based frames of reference based in this Popperian autopoietic paradigm to explore the relationships between time and a utility-based valuation of knowledge as it is constructed and applied. We believe this framework and associated paradigmatically consistent vocabulary provide useful tools for analysing organizational knowledge management needs.

Introduction

The discipline of knowledge management is confronted with several paradigms of organization [1],[2],[3] and the nature of knowledge itself [4],[5],[6] that have led to conflicting approaches to knowledge management, e.g., via Sveiby [7],[8], Nonaka [9],[10], Zeleny [12], Choo [13],[14], Firestone and McElroy [15] and others [16]. This profusion of paradigmatic approaches has also led to considerable terminological confusion [17],[18]. The present paper is part of a larger program attempting to build a coherent understanding and terminology relating to the roles and management of knowledge in organizations based on a common paradigm of organizational autopoiesis [1],[2],[3] combined with Karl Popper's evolutionary epistemology [6] and extended by Hall and colleagues [19],[20],[21],[22],[23],[24].

Here we continue a focus on the impact of time on knowledge as it is used in building and sustaining strategic power that organizations must maintain to access and control resources for survival and growth [25],[26],[27]. Strategic power is achieved through superior knowledge of the world; but without vigilance, over time the utility of that knowledge depreciates. In this paper we identify a number of time-based parameters affecting that depreciation that organizations should seek to monitor and improve.

The paper is organised as follows: First we summarise our previous work on time, organizational epistemology and bounded rationality. Next we explore the cyclic construction of knowledge in organizations and develop a vocabulary for time-related aspects of the construction, evaluation and depreciation of knowledge. We then consider how knowledge can be valued in relationship to time, and conclude by discussing relationships between knowledge cycle times and strategic power.

Time

Dalmaris et al. [25] sought to improve knowledge-intensive organisational processes used to solve problems over different time horizons. That paper introduced the "*time-value of knowledge*" – to suggest the value of knowledge is some function of the duration between its acquisition and its use; and "*temporal convergence*," which is when one's perceived "now" state can be plausibly linked via a chain of actions to an intended or desired endstate ("*goal-state*") in the future. Martin et al. [26], and Philp and Martin [27], respectively explored probabilistic and philosophical positions relating to temporal

convergence, and highlighted different ways to consider the future. A "*stochastic future*" anticipates that after some interval of time from "now", the future state of the world resembles and is derived from the present and recent past. However, as the duration between anticipation and realisation increases, the actual realised future (a new "now") will increasingly diverge from the reality that existed at the original "now." Some changes that happen as this future unfolds are predictable; some are imperceptibly slow (or at least nearly so) but may be highly significant; and some are unexpected and possibly even catastrophic. The "*intentional future*" is based on a belief that one has the ability and opportunity to influence the unfolding world to achieve a preconceived or desired but not yet achieved goal-state. There are also key differences in the way we think of time with respect to a stochastic future versus an intentional future: (a) "*Calendar time*" measures the inexorable progression into the future as events unfold from the past to present and as limited by our mental ability to process and understand the microcosm of cause and effect (our *event-horizon*). In this case, the progressively experienced "now" is referenced to clock or calendar time. (b) "*Event-relative time*" addresses time as relative to a key future event in an envisaged future goal-state seen as a possible configuration of the future world. How might we act as time and events unfold to constrain the world to achieve that event? In this case, time is mostly considered relative to the unfixed time of a key event (e.g. lift-off minus 8 hours). *Temporal convergence* is progressive and affirming. By contrast, "t*emporal divergence*," is where we cannot see a path from where we are "now" to achieve the goal-state. *Temporal divergence* may result from insufficient capability/ capacity to navigate with any confidence toward any goal. Also, one may not know if one is in a state of temporal divergence. Such a knowledge gap can be critical.

Whether in business or in the domain of military command and control in network centric warfare, one must understand epistemological and cognitive aspects of time in knowledge and information management. We continue here from our previous works to discuss what an organization is and what constitutes knowledge over a span of time, and add to the vocabulary for some difficult and often unexpressed issues relating to time, organisations and the valuation of organisational knowledge over time [28],[29]. These concepts are developed here in a biologically-based theory of organisation that treats enterprises and other self-sustaining economic organisations as complex adaptive (i.e., "living") entities that maintain their identity and exist independently of any particular individual belonging to an organisation at any given time. The present work is informed by the authors' practical experience in the worlds of military affairs, industry and commerce, and is grounded in a paradigm of organisational epistemology combining Maturana and Varela's concept of autopoiesis [30][31][32] with Karl Popper's evolutionary epistemology [6].

Organisational epistemology

Zeleny [11],[12], Von Krogh and Roos [1], and Magalhaes [2],[3] suggested organisations might be autopoietic. Autopoietic entities are identified by the following criteria (after Varela et al. [32], as abbreviated by Hall):

- *Bounded* (distinguishably demarcated from the environment)
- *Complex* (individually identifiable components within the boundary)
- *Mechanistic* (system driven by cybernetically-regulated energy fluxes or metabolic processes)
- *Self-referential* (system boundaries internally determined)

- *Self-produced* (system intrinsically produces own components)
- *Autonomous* (self-produced components are necessary and sufficient to produce the system).

Hall agrees and argues [19],[20],[21],[23] that organisations represent a higher order of autopoiesis than people, and have emergent properties and forms of knowledge that transcend the sum of their individual members. By surviving, autopoietic systems establish imperatives, ultimately to maintain their individual existences. For their autonomy to continue, such entities must maintain enough control (i.e., strategic power) over the world and its resources to maintain and produce their boundaries and components against competition and entropic tendencies to disintegrate. Initial survival is due to chance, but natural selection and conscious criticism favour the evolution of goal-directed (i.e., strategically-oriented) processes and behaviours to solve problems of survival [20],[23]. Biggiero [33] reviews the opposite point of view—that organizations are not autopoietic, based on the observation that organizations readily adapt to changing circumstances. However, when autopoiesis is examined in a framework of evolutionary epistemology [23], we choose to treat organizations as autopoietic entities.

Following Popper [6], these evolved solutions are "knowledge". Compared to the subjective concept that knowledge is "justified true belief" (e.g. [4]), Popper's epistemology is founded on lived experience in the real world. Our use of the Popperian definition of knowledge is defended in several works [20],[21],[23]. Popper [6] also divides the world into three ontological domains to discuss the creation and growth of knowledge that we interpret as follows:

- *World 1* (abbreviated here as 'W1') is uninterpreted physical reality.
- *World 2* ('W2') is the domain of the cybernetics of life or the dynamics of subjective experience, and thus, "dispositional" and "subjective" knowledge—where "*cybernetics*" means the regulation, communication and application of control information, beginning at the biophysical level [23].
- *World 3* ('W3') comprises the objective products of knowledge (e.g. the logical contents of DNA molecules, books and libraries, computer memories).

Popper's "subjective" and "dispositional" knowledge in W2 resemble Polanyi's [4],[5] "tacit" knowledge. Popper argues that all claims to know are subjectively constructed and can never be proven to be "true" (i.e., to correspond exactly to reality). Unlike some Knowledge Management (KM) practitioners who assert that knowledge can only be held in peoples' heads—mostly in tacit forms [7],[8]—Popper argues at length that knowledge claims can be codified into persistent objects able to exist independently of the cognitive entity that created them; therefore, knowledge claims can be objects in W3 able to be cognitively transformed back into living knowledge by other cognitive entities and at other times and places.

Simon [34],[35] recognised that humans' mental capacity to assimilate and process information to make decisions is limited both in terms of the volume that can be perceived and attended to and by the time required to reach a decision based on that information. It is impossible to take all the necessary time to make totally rational decisions based on all available information. Rationality is thus "bounded," and people and organisations should "satisfice" decisions (i.e., do just enough work to make minimally satisfactory decisions and go on to the next thing). Arrow [36] and Else [37]

extended Simon's ideas to organisations and identified factors causing organisational decisions to be even less rational. Time was identified as a major factor limiting both individual rationality and the rationality of group decisions at the organisational level.

Knowledge Cycles in Organisational Systems

Learning and knowledge creation for adaptive problem solving is a cyclic process of self-reference between embodied functions of the autopoietic entity and its dynamic interactions with the world. Maturana and Varela [30],[31],[32] equated "*cognition*" with the "semantically closed"[38] cybernetics of autopoietic self-regulation and self-maintenance/production, whereby the entity homeostatically maintains its continued existence through actions that respond to perturbations (i.e., problems) that might otherwise cause it to lose control and eventually "disintegrate".

Popper argued that all knowledge is subjectively constructed, and is forever separated from external reality and can never be proven to be true. However, Campbell [39] and Popper argued that constructed knowledge approaches truth through an iterated evolutionary process where tentative theories are made and tested against reality to eliminate errors. Popper [6] called this a "general theory of evolution" (pp 241-244), summarised as the "tetradic schema": $\mathbf{P_n \rightarrow TT/TS \rightarrow EE \rightarrow P_{n+1}}$. $\mathbf{P_n}$ is a problem, **TT/TS** are tentative theories or tentative solutions to that problem, **EE** is an error elimination process that removes those theories or attempted solutions that fail to solve the problem, and $\mathbf{P_{n+1}}$ is the remaining, somewhat changed, problem faced after solving $\mathbf{P_n}$. Several other similarly cyclic organisational learning/adaptation processes have been proposed: SECI [9],[10],[12]; single and double loop learning [16]; the knowledge life cycle [15]; and a variety of others [13],[14],[40],[41]. Boyd's OODA loop is a straight-forward depiction and facilitates discussing the construction of experiential knowledge ([42],[43],[19],[20],[21],[22],[23] - Figure 1).

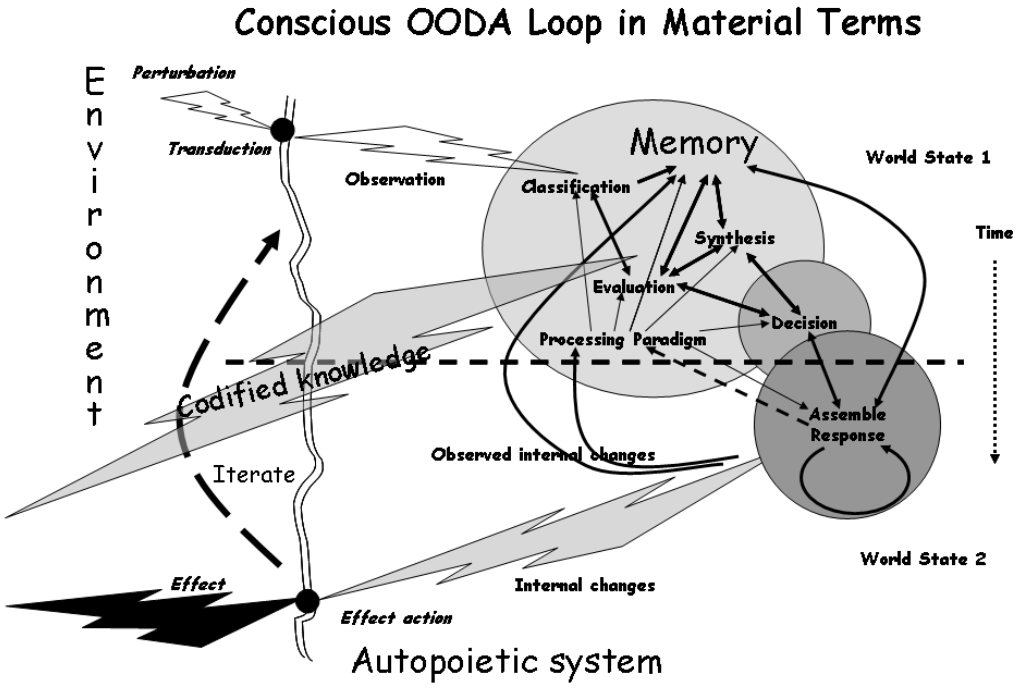

Figure 1. Graphical representation of an OODA cycle [42] in autopoietic cognition (from [21]). For an animation of this graphic see: http://tinyurl.com/3cxnw3.

Boyd resolved the iterated OODA cycle into four segments:

- *Observation*: perturbations from the environment (or internally) are transduced into cognitive "*signals*" (i.e., *sense* "*data*"), as enabled by the entity's structure and organisation. This includes sense data about effects of the entity's prior actions on the world.
- *Orientation*: cognitive processing where signals are classified and evaluated against a "memory" of history (e.g. conscious, unconscious, genetically programmed) via processing paradigms as determined by learning and inheritance to synthesise a picture of the world and possible actions (with associated, forecasted consequences).
- *Decision*: process of selecting/or rejecting possible actions for execution (or deciding to do nothing) in the cycle.
- *Action*: process of implementing a decision. Grant and Kooter [41] explicitly add "*sense-making*" and "*planning*" to Boyd's picture, although these are already implicitly present in the processes of "destruction and creation" that Boyd included in the orientation phase.

Where orientation, decision and action are insufficiently powerful to maintain autopoiesis, the entity dis-integrates (i.e., dies). In a conscious entity, critical feedback loops in each cycle of the cognitive processes should improve the match between the world and the constructed understanding of it by detecting and deciding between more and less effective processes and actions. However, the cognition required to transform perturbations from external reality into a constructed model of the world is not effortless or instantaneous and the world is dynamic and continually changing, both as a consequence of blind, entropically-driven processes, and active interventions by other autonomous actors.

Boyd loops in time

Boyd loops are iterated in time (Figure 2) to continuously update knowledge. In a relentlessly unfolding world, four points in time can be defined for a single Boyd loop (heavy black spiral in Figure 2): "$\mathbf{t_1}$" - time of observation, "$\mathbf{t_2}$" - completion of orientation and sensemaking processes using observations at $\mathbf{t_1}$ to update the model of the world, "$\mathbf{t_3}$" - completion of planning and decision making processes to decide go/no go action, "$\mathbf{t_4}$" - effecting action on the world. The then state of the world including results of action at $\mathbf{t_4}$ is observed in the next OODA loop (in grey) at "$\mathbf{t_{1+i}}$", where "**i**" is the overall duration or cycle time of the previous OODA loop process.

Observations relate directly to the state of the world only at $\mathbf{t_1}$, when external stimuli or perturbations are transduced into the internal 'sense data' of observations (Figure 1). These sense data idiosyncratically and fallibly represent external reality [44],[45]. Cognitive processes then filter, classify and evaluate sense data against memories of prior observations (i.e., to detect change) to construct a cognitive model at $\mathbf{t_2}$ of what was observed. This takes more time. Further delays are introduced in deciding and acting. To compensate, people consciously and unconsciously build dynamic world models in their minds for themselves and for their organisations that project regularities and trends through time, so as to anticipate what the world might be like at $\mathbf{t_4}$, when an action is decided at $\mathbf{t_3}$ [46].

Each activity in the OODA loop has time-based frames of reference. We define nine time-based frames of reference to facilitate discussing how cognising entities dynamically orient, act and navigate through time and space to achieve goals:

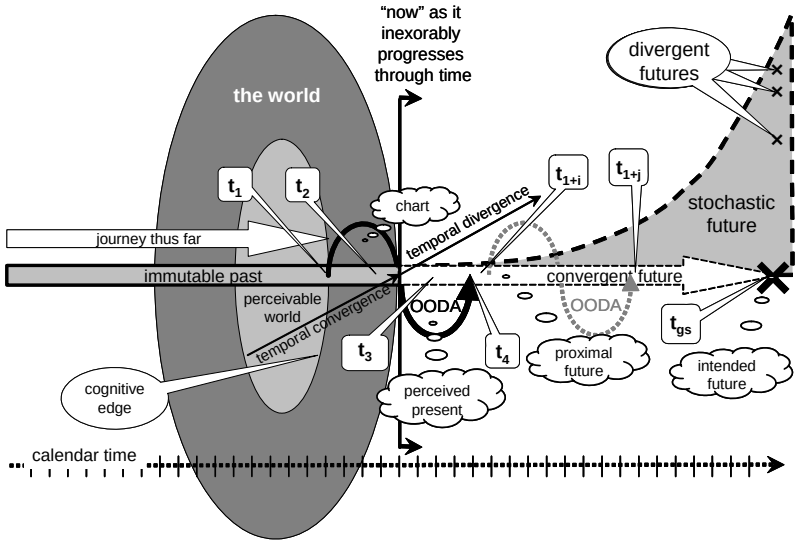

Figure 2. Boyd loops in time. In this figure, the OODA cycle is stretched out in time as a spiral. (See http://tinyurl.com/2twutf for an animation).

- *chart*: the part of the entity's received and constructed world view that remains extant and authoritative for the purposes of a single OODA cycle. The chart is constructed in W2 and W3 to map locations, events and chronology in the perceived world. One of the actions of an OODA cycle should be to amend the chart for the next OODA cycle. For organisations of people, the "chart" can reference intersubjectively shared constructs or W3 knowledge objects.
- *perceivable world*: the part of the world that the entity can observe at $\mathbf{t_1}$ in relationship to the chart. This is the part of external reality (W1) the entity has the sensory capability and cognitive capacity to observe and understand in W2 (i.e., within its "*cognitive edge*" [40]), compared to the journey thus far.
- *journey thus far*: the memory of history (who, why, what, where, when and how) as it exists at $\mathbf{t_2}$ as progressively constructed and embodied in the entity's W2. Some aspects of memory can also be articulated and preserved as objects in W3 (see *chart*) to build understanding as observed prototypes for sense-making, from which the changing world can be extrapolated. Memories tend to focus on prospective and retrospective associations with events (*event-relative time*) and can also be chronological in nature (*calendar time*).
- *recent past*: recent sensory data in *calendar time* concerning the perceivable world at $\mathbf{t_1}$ (i.e., observations) the entity can project forward to construct a concept of the present situation (i.e., at $\mathbf{t_3}$), or some future situation. Recent past is constructed in W2 based on what existed in W1 leading up to $\mathbf{t_1}$.
- *Present*: *calendar time* an action is executed.
    - *perceived present*: the entity's constructed understanding in W2 of its situation in the world at time $\mathbf{t_3}$;
    - *actual present*: the entity's instantaneous situation in W1 at time $\mathbf{t_4}$.
- *Proximal future*: the entity's anticipated future situation in the world (W2) at $\mathbf{t_4}$ as a consequence of its actions at $\mathbf{t_{1+j}}$, where **j** is a time-step unit—typically on

completing the next OODA cycle. This anticipation is based on observed recent past, perceived present and forecasting of the future up to $\mathbf{t_4}$.

- *Intended future*: the entity's intended goal or situation in the world farther in the future (at $\mathbf{t_{gs}}$, where **gs** is a goal-state and $\mathbf{t_{gs}}$ is the moment when that goal is realised). Intentions are not necessarily time specific but are always associated with an event or goal-state (i.e., the arrival of a set point in calendar time can also be considered to be an event).
- *convergent future*: the entity's mapping of the proximal future against an intended future in which $\mathbf{t_{gs}}$ can be specified. $\mathbf{t_1}$ and $\mathbf{t_{1+j}}$ can also be mapped to $\mathbf{t_{gs}}$ and then $\mathbf{t_{gs+1}}$ forecasted in the form of some subsequent goal.
- *divergent future*: a world state where the entity's actions in the proximal future ($\mathbf{t_{1+j}}$) failed to achieve the world state of the intended future at $\mathbf{t_{gs}}$.

In organisational entities, people involved in the OODA loop risk getting "stuck" with no decision or action while trying to agree on what the observations mean [45] (i.e., "*analysis paralysis*" [50]), while competitors are continuing to progress. The choices are losing ground to competitors or making possibly bad decisions by "running out of time" or having them dictated by "fiat" from a superior [44]. Individuals can also waste time dithering. However, time is relentless. Given the boundedness of cognition in the OODA cycle, increasing cycle time can have positive or negative impacts. More observation time captures more detail, to extend the cognitive edge [40]. More orientation time allows processing more detail for a larger, more accurate model of the perceivable world. Without other considerations, more accurate world models should enable more effective control information to support actions. However, striving too long to reduce uncertainty gives more time for random events and other actors to create a *stochastic future* diverging from the *intentional future*, leading to less relevant world views and less effective control information.

Valuing knowledge

We do not seek to establish a subjective or economic value for knowledge, as do most works on valuing knowledge, although our approach should help determine these kinds of value. Our focus values knowledge in terms of its utility to address specific needs or problems, where utility is defined as the quality of being of practical use. The "*utility value of knowledge*" to its possessor equals the sum of its beneficial consequences minus the sum of its detrimental consequences from applying that knowledge. The principle of utility says whatever course of action (or solution) has the most utility—the best overall outcome—is the preferred (i.e., the most "valuable") choice. Cornejo [51] gives two types of utility values for addressing personal needs:

- *Objective utility*: when the utility of a particular bit of knowledge can be directly compared with the utility benefits derived from other personal activities, e.g., when the knowledge improves the person's economic situation or job performance. Examples include methodologies, precedents, tools for professional growth, etc.
- *Subjective utility*: the knowledge isn't seen to have direct economic benefit, but is valuable because it satisfies personal curiosity or sustains a felt need for belonging or appreciation.

Similarly, Cornejo [50] recognises two kinds of utility values for organisations:

- *Direct utility*: leading to perceivable and measurable improvements to processes and operations, usually derived from personal knowledge.
- *Indirect utility*: when it is clear the organisation benefits from acquired knowledge, but doesn't understand the mechanism so lacks a reliable measure for valuing it.

Therefore, in the case of the direct or indirect utility value of particular knowledge, value will be some function of (a) the claim's applicability to particular circumstances and (b) its accuracy in terms of the degree to which it reflects the true state of existence when applied (i.e., the degree that rational actions based on the knowledge produce predictable results). Pattee [38] clearly adopts a utility valuation of knowledge: "Knowledge is potentially useful information about something. ... By useful information or knowledge I mean information in the evolutionary sense of information for construction and control, measured or selected information, or information ultimately necessary for survival". See also [52].

Alberts and Hayes [53] (pages 66 & 84) describe this in the stark terms of a military command and control environment. The utility value of current knowledge is measured by the "quality" and "effects" observed when that knowledge is enacted, as (1) a function of the action, (2) the time and conditions surrounding the action, (3) the quality of execution and (4) other related factors. The selection of the action and its timing are normally part of sensemaking, and is often a collective decision.

Command and control are particularly knowledge-intensive processes in military and commercial organisations for controlling various aspects of information processing and action to achieve convergence on an intended future. "Quality" measures the effectiveness (i.e., value to the entity) in maximising positive results and minimising negative ones to converge on the intended future. As noted by Boyd, Alberts and Hayes and others, the value of the knowledge involved in all of these processes is assessed by some measure of quality (or utility value).

Surviving in a variable world depends on the ability to control the world's threatening aspects. In conscious entities, this is the ability to achieve temporal convergence on goals relating to their imperatives. "*Strategic power*" is this ability to achieve temporal convergence through control. In a world where different entities compete, strategic power is relative—where the strategically more powerful entity can directly control other entities or resources needed by them, and thus prevent competitors from accessing those same requisites. Control is based on knowledge of the world and is achieved by applying control information developed from that knowledge. The degree to which an entity's actions achieve their intended effects depends on the quality and currency (i.e., the utility value) of the knowledge on which they are based.

Cycle times and the achievement and maintenance of strategic power

As identified in Dalmaris et al. [25], a factor often overlooked in organisation and KM studies is that the value of knowledge may depend strongly on the passage of time—the time when the knowledge was created, the time when it was last validated, and the time when it is actually applied in organisational actions. The utility of any knowledge based on past learning—that is not routinely updated—will tend to depreciate as time increases

between the circumstances of the learning and its application. In the case of temporal convergence, where the entity works towards an intentional future, convergence is achieved through periodically updating knowledge and controlling unfolding events to stay within the narrowing zone of convergence as the time of the present “now” approaches the intended future. However, as the interval increases between observation and action in the OODA cycle, the world may diverge so much that executed actions at $\mathbf{t_4}$ no longer achieve intended effects, thus depreciating the value of knowledge generated during the cycle. Where the world includes other entities directly competing for strategic power, as Boyd [42] stresses many times, substantial strategic advantage accrues to an entity that can complete its OODA cycle and act to change the world before competitors can also act to make their changes. By changing the world before others complete their OODA processes, faster actors create worlds of temporal divergence and stochastic futures for slower competitors. In organisations, continued temporal divergence producing stochastic futures leads to irrationality and loss of morale. Even apparently rational forecasts of the proximal future deviate from charts of perceivable worlds. This has certainly been recognised in the area of military affairs, where a major driver for concepts of network centricity has been to minimise the interval between $\mathbf{t_1}$ and $\mathbf{t_4}$.

The importance of time has been less well-realised where non-military organisations are concerned. In reasonably symmetric competition or combat, the competitor with the fastest OODA cycle time has the opportunity to greatly depreciate the value of a competitor’s knowledge, possibly leading to misinformed decisions, "*strategic paralysis*" [50], with "stuck" OODA processes [44] and/or “magical thinking” [42]. Entities with faster OODA processes have the strategic power to shape circumstances. Entities whose OODA cycles take too much time between observation and acting are increasingly at the mercy of the world.

We have shown here that current world-knowledge doesn’t age well, but we also recognise that some kinds of knowledge can become more valuable with time. Some of the most valuable knowledge is in fact “old” knowledge that has survived testing in *many* OODA loops as cultural heritage or “formal knowledge” [24]. Rapid decision also benefits from cultural paradigms [42] that don't have to be revisited often, whereas at the tactical level, one needs to deal aggressively with latency issues.

Conclusions

Whether in business or warfare, the longer decision and action are delayed without new observation and orientation, the more the knowledge on which they depend will depreciate. Such depreciation is reflected in increasing unpredictability of the results of actions based on the knowledge. Ullman [44] observes, "Competitive advantage comes from quickness over the entire loop, and, as with each iteration the changes are smaller (as they are modifications to an understood situation) and can be more easily managed, therefore staying ahead of the competition." Fadok ([54], p. v) is even more explicit about how time depreciates knowledge in competition:

> [Boyd] speaks of folding an opponent back inside himself by operating inside his observation-orientation-decision-action (OODA) loop. This severs the adversary's external bonds with his environment and thereby forces an inward orientation upon him. This inward focus necessarily creates mismatches between the real world and his perceptions of that world. Under the menacing environment of war, the initial confusion and disorder degenerate into a state of internal dissolution which collapses his will to resist.

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