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To appear in Roberto Casati (ed.), *The Sailing Mind*

Situation Awareness in Racing Sailors

The history of working sail, from its beginning in the far distant past until its general demise in 20th-century, is fundamentally the history of sail-driven speed: building competitively fast sailing vessels for specific purposes and then, when the need arose, wringing from these vessels every last bit of speed, often at the risk of both boat and crew. Naval warfare was from its very beginning a matter of attempting to bring overpowering destructive force to bear on an enemy, but this often required speed, speed to gain a tactical advantage or to close with an outmatched enemy who is doing everything possible to escape, or sometimes speed to escape certain defeat. Clipper ships (the word 'clip' meaning speed) were developed in the late 18th century to speed the delivery of goods, notably tea from China, but they quickly became used for other purposes that demanded exceptional speed, such as blockade running during wartime. The extremely over-canvassed 'sandbagger' sloops that plied the waters of New York harbor during the 19th century would meet much slower, deeper draft ocean-going fishing vessels off the mouth of New York harbor, load these vessels' catches aboard, at the same time casting overboard their sandbag ballast, all the while being careful not to turtle the boat in the process, and then run full-speed to the Fulton Fish Market in lower Manhattan, where the first arrivals fetched the highest prices for their cargo. Sailboat racing emerged out of this

obsession for speed, first in the form of wagering on competitions between working vessels, but eventually in the form of vessels designed, built, and crewed solely for racing.

The allure of sailboat racing has much in common with all sports: it is competitive, and it is necessarily practiced at the very limits of human perceptual, cognitive, emotional, and physical abilities. But the fact that sailboat racing is practiced on sailboats, against other sailboats, adds greatly to the challenges, which gives sailboat racing its allure. There are all the challenges associated with designing, building, and equipping a racing boat that is faster than one's competitors, these three elements themselves invariably constrained by cost, safety considerations, and by agreed-upon rules of racing. And to this must be added what is arguably most unique from a sporting perspective, namely, that sailing competition takes place in a very challenging environment where wind and sea test both boat and competitors -- the design, construction, equipping, and maintenance of the boat, and the perceptual, cognitive, emotional, and physical skills and limitations of the competitors. And if this were not enough, most sailboat racing is conducted on crewed boats, where in addition to all the other challenges, there is the complex challenge of assembling, and for skippers, leading a crew that must act in concert to move the boat across a designated race course faster than one's competitors.

In this essay I focus on a crucial cognitive component of sailboat racing that in human factors engineering has come to be called 'situation awareness'. In the present context, situation awareness is an awareness of the opportunities afforded by the situation in which one finds oneself for actions that are likely to result either in gains over one's competitors or to avoid or minimize threats to one's race performance, sometimes even to the safety of both

boat and crew. I discuss not only the perceptual/cognitive skills and capacities that underpin and make possible situation awareness, but also the role of training and experience in the acquisition of situation awareness. I draw most of my examples from small-boat, one-design around-the-buoys racing, both because that is the sort of racing with which I am most familiar, but also because it in this sort of racing in which most offshore ocean racers invariably first develop and hone their situation awareness skills. My discussion of situation awareness is from the perspective of the skipper, focusing on the opportunities and threats afforded to the racing boat as a whole, though clearly situation awareness is no less essential to crew members in the conduct of their specific jobs on the boat. I will not have much to say about non-racing sailing, though situation awareness is important there, too, especially as regards safety of boat and crew.

I begin my discussion of situation awareness by explaining just how I understand this notion. From there I move on to the two cognitive aspects that I take to underpin situation awareness: (i) recognition of *the possibilities for action afforded by a situation*, and (ii) recognition of *the attendant risks and rewards of these possible actions*. My talk of the actions afforded by a situation is intended to harken back to the work of James J. Gibson (1966, 1977, 1986), who coined the term 'affordance', because, in my view, this is exactly the right way to conceive of situation awareness, viz., as an awareness of the action affordances of a situation. But in taking on Gibson's notion of affordances, specifically, the perception of affordances, I am not endorsing Gibson's (1986) ecological approach to perception. I especially want to remain neutral on the issue of whether, as Gibson claims, the perception of affordances is direct, viz., that requisite information for perception of affordances is fully present in the stimulus array, or

whether, as Fodor & Pylyshyn (1981) claim, it is indirect. This issue is not relevant here, though I am inclined to believe that affordance perception is not direct in the manner Gibson claims, but includes what most philosophers and psychologists would consider cognitive elements. I should add that I do not presume here any particular way of drawing the distinction between perception and cognition, as this will not be pertinent to anything I have to say here.

1. Situation Awareness

Situation awareness can be defined simply as knowing what is going on around you, knowing well enough, that is, to be able to complete satisfactorily whatever task faces you. Situation awareness became a hot research topic in the 1980-90s when human factors engineering became focused on the problem faced by individuals operating, controlling, or directing complex dynamic systems in domains where failure to take into count multiple situational inputs, including previous operator actions, can lead to disastrous outcomes. Of particular interest has been such domains as commercial and military aircraft piloting, aircraft traffic control (ATC), military battlespace command and control, law enforcement, and the operation and control of large-scale manufacturing facilities, utilities and refineries, all domains of high-stress for operators, where operators are routinely required to make rapid, often split-second decisions, where failure to consider relevant situational factors can have disastrous consequences. The basic aim of such research has been to understand the determinants of, and obstacles to, operator situation awareness and then to propose general guidelines for both the design of the complex dynamic systems with which operators are interacting and the training of operators themselves so as to enhance requisite situation awareness. The classic example of situation awareness-driven equipment design is the instrumentation and layout of the modern commercial aircraft cockpit,

along with the checklists and flight manuals that pilots carry and consult. The knobs, for example, on manual controls such as throttles, flaps, and landing gear are all of standardized, but different shapes, so pilots can know without looking down that they have gotten hold of the intended control. On the training side, besides the training and experience required for certification, there are the many hours in flight simulators for specific aircraft, where pilots can practice specific critical piloting skills.

Focused as they typically are on the determinants of situation awareness, researchers disagree to a surprising extent on just how precisely to understand situation awareness,[1] even on the seemingly crucial question as whether to count as constitutive of situation awareness the decisions or actions that flow from it.[2] There is even less agreement as to whether situation awareness is primarily or exclusively perceptual, or whether it is also cognitive, a question the answer to which would seem important in deciding how to think about the determinants of situation awareness as well as how to design complex systems and train operators so as to enhance their situation awareness. For our purposes here, I shall take situation awareness to be primarily perceptual and *not* to include the decisions and actions that flow from it, regardless of how automatic or unconscious these may be. I shall take situation awareness to be the perception of *the possible actions afforded by the situation* an individual finds himself in, something that effectively closes the conceptual distance between perception and action, but without collapsing one into the other. As we will see, the actions that an individual perceives as afforded by a situation will depend both on the perceiver's knowledge of the sorts of situations in

[1] For an enumeration of the different definitions of situation awareness, see the unattributed online report of the Human Factors Group of the Royal Aeronautical Society at https://www.raes-hfg.com/crm/reports/sa-defns.pdf.
[2] Endsley (1995: 36) defines situation awareness as 'the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future', but she notes that the U.S. Air Force construes situation awareness as including the decisions and actions that flow immediately from it.

which these affordances present themselves, the perceiver's skills in exploiting these affordances, and any limitations that inhibit the perceiver's performance of the particular actions afforded.

Situation awareness in sailing demands keeping one's head out of the boat, but that is not enough. Any normally sighted person who is looking can see the approach of a dark squall line, often when it is still several miles away, but it is another matter whether this person sees this squall line as requiring certain actions, perhaps certain immediate actions, e.g., shortening sail, or perhaps even going to bare poles. It takes knowing what one is seeing in order to appreciate the situation one faces, one that depends on the speed with which the squall line is approaching, the presence of dark fingers tumbling off its front, etc. Similarly, in around-the-buoys racing, one may see that the boat immediately ahead is rounding a leeward mark wide, but it is quite another matter to see this as affording an opportunity to achieve an inside overlap and gain a competitive advantage, because whether the wide rounding affords such an opportunity depends on the inherent maneuverability of both boats as well as on the sailing skills of the boats' respective helmspersons and crews. Or to take yet a third example from offshore racing, a navigator may be aware from daily weather models of an approaching front, or perhaps a developing meander or eddy in the Gulf Stream, but to be truly aware of the possible actions afforded by the situation, this navigator must know a lot both about the sailing characteristics of their boat and the disposition of the fleet.

Finally, situation awareness is not only visual, especially when it comes to boat performance, where the indicators are as much kinesthetic or auditory as they are visual. Sailors, for example, often speak of having 'a feel for the boat', and they mean this literally: to have a feel for a boat is to be able to sense kinesthetically whether the boat is being driven and trimmed

in a way that maximizes VMG (velocity made good) [3]; and when it's not, the perception typically presents itself as affording certain possibilities for spontaneous remedial action, such as bearing off slightly to gain speed and point, making small changes to sail trim, or redistributing crew weight: one simply senses the situation as affording, indeed demanding, some particular action. Sometimes the affordance perception is auditory, as for example while sleeping off watch one is jerked awake by the groan of the rigging and winches and realizes that the on-watch crew needs to reduce sail. The point of all these examples is that situation awareness is not simply looking and seeing (or attending and sensing), but it is also, crucially, a matter of recognizing what one is seeing (sensing). Of course, there are also times when the boat simply isn't moving, it feels sluggish, it isn't pointing well, it labors through the tacks, and yet one can't figure out why or what to do. The actions one takes in these situations are nothing like the ones that flow spontaneously and unreflectively from affordance perception: here one invariably falls back on conscious analytic deliberation about the possible cause of the problem, such deliberation only occasionally it seems, leading to action that resolves the problem.

Situation awareness presents itself phenomenologically to its possessors not as a passive, disinterested awareness of the situation in which these individuals find themselves, that is, as an awareness with no attached action potential, but as the perception of certain possible actions that the situation affords, specifically possible actions that promise to advance the perceiver's goals (e.g., 'The boat ahead is rounding wide; I can squeeze in there and gain an inside overlap'; 'there's a big puff coming down the left side of the course; I can tack, get into it, and "make trees" on boats on the right side'). To think of situation awareness as an awareness of the possible goal-advancing actions afforded by a situation is, I think, exactly the right way to think

[3] VMG is the actual speed towards some intended destination. Because sailboats are rarely able to sail directly towards their intended destination, a boat's VMG is only rarely identical to its speed along its heading.

of it. For thinking of situation awareness in these terms captures three important features: (i) it is primarily perceptual in nature; (ii) it tightly couples perception to action, though without collapsing the one into the other, by taking the perception to be a perception of the possible actions afforded by the situation; and (iii) it identifies the relevant possible actions as likely or promising to advance the goals of the perceiver. This construal effectively treats situation awareness as the exercise of a perceiver's capacity, however developed or undeveloped it may be, for what James Gibson called 'affordance perception', where the affordances of a situation are the goal-advancing possible actions afforded by the situation.[4] That situation awareness is such an exercise of affordance perception entails, we will see, that (iv) situation awareness is perceiver-relative, not simply to the perceiver's goals, but also his or her perceptual, emotional, cognitive, and physical abilities and limitations; moreover, (v) situation awareness is something that can be developed through training and experience.

2. Recognition of Affordances for Action

In the late 1990s, we were racing in the J/24 Midwinters Championships in Biscayne Bay, Miami. My tactician was Eric Leitner, a terrific small-boat sailor who had been slated to represent the U.S. in 470s at the 1980 Moscow Summer Olympics, until the U.S. boycotted the games in protest of Russia's invasion of Afghanistan. About half-way up the first leg of an early afternoon race, we were sailing up the middle of the course on port tack in a strengthening sea-breeze, when the usually taciturn Eric turned to me and said firmly, 'we've got to get to the left

[4]Donald Norman (1988) first emphasized in a way that Gibson had not that affordances are affordances for possible actions, using 'affordances' in the context of human-machine interaction to refer to just those possible actions that are readily perceivable in a situation by an actor, effectively linking perception and action in precisely the way that I am suggesting perception and action are linked in situation awareness. Michaels (2003) identifies affordances with possible actions. For a general discussion of the ontology of affordances, see Vetter (2018).

side of the course immediately; there's a big left shift off the tip of Key Biscayne'. We tacked and sailed almost to the port lay line, where we tacked back onto port and reached into the windward mark well ahead of the fleet. I was of course happy with the leg, but I was astounded by Eric's call: the tip of key Biscayne was some 3 miles off when we tacked off to the left, and when I had looked to where Eric was seeing the shift, I had seen only the collection of wooden shacks built on stilts on the sand shelf south of the tip called 'Stiltsville' by locals. As the regatta wore on, I came to realize that Eric had vision for wind shifts that I simply didn't have: it was as if the shifts on the course, indeed shifts far upwind of the course, announced themselves to him on a big flashing billboard floating above the shift. I couldn't help but wonder just how the entire course on which we were racing appeared visually to Eric. Maybe he saw shifts in somewhat the way better baseball batters claim to see pitched balls, as unusually big (Witt & Proffitt 2005). Maybe the telltale signs on the water looked to him bolder and better delineated; maybe the changed sailing angle of boats already in the shift look more dramatic. However the course appeared to Eric, I also wondered how he came to have such vision.

Over the years, I have come to realize that Eric's visual skills are fairly widespread among top racing sailors: many have what I have come to think of as 'affordance perception', by which I mean that when racing they spontaneously and without reflection perceive possibilities for action afforded by the situation they find themselves in, actions that are likely to result in gains over their competitors, or at least to avoid or minimize losses. In describing such perception as 'affordance perception', I want to call attention to what I take to be a very salient feature of these sailors' perception of the situation in which they find themselves, one that Gibson's ecological theory of perception emphasized, namely, that these sailors' perception of the situation is not some value-neutral registration of the possible actions afforded by the situation, but is an

inherently value-rich registration: it is not only a perception of what the situation affords to the sailor by way of possible actions, but it is also a perception that captures the beneficial/injurious aspects of what the situation affords for that sailor. Affordance perception, then, is not simply action-oriented in that it is perception of the possible actions afforded by the situation, but it is also a perception of possible actions that are positively *valenced* relative to the goals and needs of the perceiver, whether it be an action that promises to secure a material advantage of some sort (say an advantage over a competitor) or an action that promises to avoid calamity or danger.

Numerous experimental studies have shown that the affordances of a situation are relativized in yet another way, in particular, to the perceiver's ability to perform the actions afforded. Thus whether a subject perceives a particular set of stairs as climb-able, a particular chair to be sit-on-able, a particular aperture, say a doorway, to be pass-through-able, depends, as the experimenters put it, on subject's 'body-scale', which is indirectly a measure of the ease or difficulty that the subject would have performing the actions in question – thus, e.g., a short person will not perceive as (easily) climb-able the set of stairs that a tall person will.[5]

As suggestive as these body-scale affordance studies are, establishing as they do that affordances are perceiver-relative, body-scale affordances are generally static, not at all characteristic of the affordances that racing sailors perceive on the race course, which are often very transient, quickly appearing and just as quickly disappearing. Somewhat more relevant are studies of affordances such as for the catch-ability of tossed balls, where subjects are asked to judge visually whether they could catch tennis balls thrown in their vicinity (Oudejans et al., 1996). Their judgments turned out to accurately predict their actual catching skills. Such studies do not come close to modeling dynamic activities such as baseball hitting and fielding, where the

[5] See, e.g., Warren, 1984, on climb-ability; Mark, 1987, on sit-on-ability; Warren & Whang, 1987 on pass-through-ability; Ishak et al., 2008. on for whether a subject's hand can pass through an aperture.

affordances for players are constantly changing as they run to get under and catch a fly ball or to move bat and body so as to hit a pitched ball, but they do establish a sort of perceiver-relativity different from body-scale, namely a relativity to the perceiver's perceptual and motor skills and abilities.[6] The general point is that anything that affects a subject's abilities to perform the action, including not just skills, but physical disabilities[7] or even lack of confidence, can affect a subject's affordance perception. Moreover, and importantly, it turns out that subjects can perceive the affordances of a situation not only for themselves, but also for others, as is evidenced of course by everyday unsolicited helping behavior, though not surprisingly, subjects' perception of affordances for others is less precise than for themselves (Stoffregen et al., 1999).

The takeaway from these studies for situation awareness in sailing, one that is abundantly confirmed by observation, is that the affordances of a situation, as perceived by a skipper/helmsperson, are specific to boat and crew. What is an affordance for one boat and crew may not be for another, if the latter lacks the maneuverability or skills to execute the afforded action. A skilled sailor may perceive the gap left between a leeward mark and the boat ahead as affording the opportunity to gain an inside overlap, where a less skilled sailor would perceive no such affordance, inasmuch as the required boat-handling is beyond the abilities of a less skilled sailor. I recall just such a situation in a local J/24 race. Approaching a leeward mark I was forced by heavy traffic very close to the front side of the mark, causing me unavoidably to leave a wide gap on the backside. The boat immediately behind was helmed by a relatively inexperienced skipper who had onboard two paid, professional crew. Seeing the backside gap that I was going to leave, a gap through which these two professionals could themselves have

[6] See, e.g., Cesari, et al., 2003, for the dependence of stair climb-ability not simply on body-scale but also on limb strength and flexibility.
[7] See Randerath and Frey, 2016, for discussion of affordance perception in stroke victims.

comfortably sailed in the prevailing fresh breeze, they directed this skipper to shoot the gap, which he did, … but poorly. Failing to release the mainsheet and call for easing the jib, he was unable to turn the boat sufficiently and struck me hard on the port quarter. The force of the collision bounced him back a good boat length or so, and at the same time spun my bow to port, closing the backside gap. The wind quickly refilled his sails, driving him forward into the now closed gap, causing him to hit me hard yet a second time, this time just ahead of the port chainplates. I came out of the rounding holed both fore and aft, and he disqualified from the race. One of the two professionals on the boat, a friend, apologized, saying, 'I should have realized that what I saw as doable was not doable for my skipper'. An obvious corollary to the conclusion that better sailors perceive affordances that less skilled sailors do not is that the more skilled the crew, the more affordances of a given situation, and also the more opportunities to make gains or avoid loses.

Thinking about cases where what is an affordance for one sailor is not for another raises an interesting question, namely, whether there might be something akin to affordance *mis*perception, where what appears to a particular individual to be an affordance does not in fact exist, at least not for that individual. Certainly there are racing sailors, typically in the bottom of the fleet, that are forever getting themselves into situations, most often at starts, mark roundings, or crowded finishes, from which they cannot extricate themselves without fouling, sometimes damaging, other boats. These skippers, in my experience, are not unusually aggressive; rather they appear to see affordances where there are none, at least none for someone with their skills. Thus, along the lines of the previous example, they may see as an opportunity to gain an inside overlap at a leeward mark rounding a situation that is such only for a more skilled sailor. Maybe they lack a clear understanding of their limited sailing skills, thinking that they are better than

they are. Or maybe they don't recognize the perceiver-relativity of affordances, much like the rotund man in a Hollywood slapstick comedy, maybe a Laurel & Hardy skit, who sees the skinny man he is chasing run through a very narrow doorway and tries to follow, only to become stuck in the doorway, arms and legs flailing. More interesting, though, are cases where there *is* a gap sufficiently wide to fit in on the front side of a leeward mark, but where a more experienced racing sailor would see what the less experienced sailor might not, namely, that the boat ahead will be able to close this gap on the backside of the mark, forcing a boat that attempts to shoot the gap to foul either the mark or the boat ahead. In effect, the less experienced sailor fails to grasp the presented situation in its entirety, focusing exclusively on the clearly visible gap on the front side of the mark but neglecting likely developments on the backside of the mark, developments to which the more experienced sailor will be sensitive, inasmuch as the presented situation affords an opportunity to gain an advantage over the boat ahead only if the contemplated action will carry one safely past the mark without fouling mark or boat ahead.

I am not sure how common affordance perception is in human perception. Gibson thought that it was predominant, maybe exhaustively so, but that seems dubious. Perhaps it is predominant with respect to the perception of basic human needs, perhaps innately so.[8] It is clearly common in those domains where by long experience or by training, individuals come to respond spontaneously in specific ways to the circumstances of the situation they find themselves in. The typical sort of case are emergency situations for which someone is trained, e.g., in law enforcement, where police officers are taught to respond immediately in specific ways to someone pointing a gun at them. Affordance perception is considerably more common, maybe even dominant, in other species, where their perceptual world seems to be almost

[8]Anderson et al. (2002) found that merely looking at an object primes the human brain to perform the action the object affords.

exclusively a world of affordances for specific actions. Virtually all non-human animals spend some amount of time exploring their environment, especially when they are first thrown into it, and arguably the perception associated with such exploratory behavior cannot easily be subsumed under affordance perception. But such exploratory behavior aside, much of these animals' perception fits comfortably under affordance perception: their perception seems exquisitely tuned to environmental affordances that address their basic needs, and the causal link between perception and action is immediate. Of course, a situation may sometimes afford incompatible possible actions, forcing the animal to pursue one action at the expense of another (e.g., when the presence of a predator at a waterhole forces a potential prey to choose between water and safety), sometimes only after some hesitation, at other times with no delay whatsoever. The same is true with affordance perception in sailing, where incompatible affordances of a situation are generally resolved spontaneously, at least by experienced racing sailors, in favor of the higher valued option given the competitive goal of sailboat racing.

The fact that the possible actions afforded by a situation can be incompatible, such that acting on one precludes acting on another, with perceivers choosing the higher-valued option calls attention to an important feature of perceived affordances: they come to an individual, a sailor in our case, with an attached positive valence for action, even in situations fraught with danger. That is to say, the actions delivered by affordance perception are ones that offer, or promise to offer, some material advantage or good to the perceiver. Actions that don't, like ramming a nearby competitor, are simple non-starters. This, of course, is compatible with a situation affording incompatible possible actions, these actions usually differing in their attendant risks and rewards, a matter to which I now turn.

3. Recognition of Attendant Risks and Rewards

Read or hear any first-hand accounts of sailboat races, whether grand round-the-world ocean races like the Vendée Globe or Volvo Ocean Race, or local around-the-buoys races, and you can't help but be struck by the significant risks and rewards invariably attendant to decisions about possible courses of action. In a recent digital interview for the Storm Trysail Club, fellow member and famed navigator Stan Honey described a call he made in the 2005-2006 Volvo Ocean Race aboard *ABN AMRO I*, a call that secured their overall victory. The call involved splitting from the entire fleet and giving up considerable ground, all in order to catch a distant, strong cold front that might, and in fact did, allow the boat to ride out well ahead of the fleet. Asked in Q&A, how did you make the decision, Honey said, 'I looked at the weather models and calculated that the rewards of catching the front well before our competitors outweighed the risk of sailing off to catch the front, missing it, and falling behind the entire fleet. My only concern was preparing the crew for the fact we'd lose ground to the fleet as we reached away towards the front; I didn't want them to become despondent over what might seem like a flier'. Honey had the time to deliberate consciously about the risks and rewards of splitting with the fleet to catch the front before making his decision. But in many situations that face racing sailors, there isn't time to deliberate: the window for taking an afforded action is so fleeting, one simply acts or doesn't. But even when not consciously attended to, attendant risks and rewards nevertheless always shape the better sailor's response to perceived affordances. They don't take high risk/low reward actions, and they take low risk/high reward actions without hesitation. They have learned through experience, often painful experience, the risks and rewards attendant to specific sorts of actions, maybe specific to this boat and crew (e.g., that a gybe-set spinnaker hoist at a windward mark is high risk for this particular boat and crew), and this acquired knowledge of attendant

risks and rewards shapes their behavior, regardless of whether consciously or not. The risks and rewards attendant to certain actions can also be taught, at least to the extent that sailors can be taught the risks and rewards that generally attend certain actions (e.g., that coming into a windward mark on port, right at the mark, in a big fleet, is a very risky proposition, unless you are in the very top of the fleet). Of course, there are cases where a situation affords a number of possible actions, where anticipated risks and rewards don't dictate the action. In these cases, you choose one of the afforded actions, feel good if the chosen action pays off, feel bad if it doesn't, and try not to take much credit or blame for the outcome. But the important point that I would like to emphasize here is that in many situations the attendant risks and rewards are so obvious that low risk/high reward affordances are taken without a second thought, while high risk/low reward affordances never present themselves as live possibilities.

4. Learning Through Doing

Situation awareness, including a recognition of both the possible actions afforded by a situation and the risks and rewards attendant to each of these possible actions, can be acquired through experience, through the repeated experience of finding oneself in a given situation, performing one or another specific action afforded by that situation, and observing the consequences, good or bad. But it's not just a matter of doing a lot of racing, because the stress and tensions attendant to racing are not conducive to unsupervised learning, unless the consequences of an action are especially dramatic, like costing you the race. Rather situation awareness, as well as the proper execution of the afforded actions, is something that is learned mostly through instruction. By instruction here I include both formal instruction, where sailors are taught by coaches, first in a classroom setting and then on the water, what to look for in certain situations

and how to react to what they see, but also informal instruction where sailors learn from other sailors what to watch for and how to react. Most amateur racing sailors do not receive any formal instruction or coaching beyond a junior sailing program or college sailing, but there is a surprising level of informal instruction conducted on the boat during racing or practice sessions, in after-racing debriefs, or over drinks at the bar. On-the-boat instruction is by far the most prevalent informal instruction, ranging from quite explicit instruction from the more experienced sailors on the boat as to what to look for and how to respond (e.g., 'if you see the luff of the spinnaker breaking first high, lower the pole until the luff breaks uniformly from top to bottom') to general discussion about proper sail trim and helming technique, these discussions invariably focused on what to look for and how to react. In after-sailing debriefs and over drinks at the bar, sailors invariably discuss either what they saw going on across the course and how they reacted to what they saw, or what they did at critical junctures in the race, why they did it, and whether it worked. Frankie Egan, my spouse and long-time sailing companion, has a charming photo of a bunch of Viper 640 sportboat sailors from our yacht club standing around in a circle after a day's racing talking about what had worked and hadn't worked; one of the Viper sailors is down on hands and knees moving borrowed sailing shoes and flip-flops around to show the tactics he had employed to gain an advantage at a mark. These after-racing debriefs often take the form of an explicit discussion of three important elements of situation awareness: what was the situation, what actions did it afford, and what were the risks and rewards attendant to each action.

5. Memory for Situations and Afforded Actions

Besides their capacities for affordance perception and recognition of attendant risks/rewards, good racing sailors invariably have a detailed memory of races they have just sailed (where on

the starting line they and their principle competitors started, what were the prevailing conditions across the course, what side of the course paid on different legs and why, what they and their nearby competitors did at crucial points in the race, etc.), something I have noticed less skilled sailors generally don't have. It's hardly surprising that at after-racing debriefs, sailors want to hear from the day's winners, not simply because they were the winners, but because they invariably have the clearest understanding of what happened on the course. Differences in the memories are also very evident in protest hearings, where less skilled sailors very often have only the fuzziest memory of the situation that led to the protest, even to the extent of not having a clear idea of the disposition and movement of the boats involved, including their own.

Better sailors, by contrast, also have a surprisingly detailed memory of many of their past races, particularly of crucial situations they found themselves in, the actions they took, and whether those actions paid. It may be an open question what role if any memory plays in affordance perception acquisition, but at very least these better sailors' memories do suggest that they pay selective attention to those elements of situations that are relevant to the perception of the actions afforded by a situation and the risk and rewards attendant to these actions. At very least these sailors' selective memory for relevant elements of the situations in which they have found themselves tells us something about what elements they have learned to attend to, which tells us something about the end point of acquisition, if not the acquisition process itself. And if, as Eleanor Gibson (1969) argues, much of our ability to react spontaneously to perceived affordances is the result of experience and training that has taught us how to react in response to such affordances, then the experiences to which these memories testify, if not the memories themselves, provide a storehouse of data for learning, both about strategies and tactics that work and don't work in particular conditions, and about the particular conditions that are characteristic

of different racing venues. Most sailors who have raced on the Foxtrot Course of Kingston, Ontario's Portsmouth Olympic venue know, for example, that the left side of that course is favored in a building sea-breeze, as the building southerly sweeps around the southwestern tip of Simcoe Island before eventually settling in the southwest. It is instructive to read the many books on sailboat racing and racing venues by well-known sailors/writers such as Stuart Walker or Paul Elvstrom: they invariably illustrate the conclusions that they wish to draw using specific examples from their own long racing experience. Some like Walker tend to focus on the mistakes they made, so much so in Walker's case that a sailing wag summarized the recurring theme in all Walker's books as 'how I managed to lose that race', a focus that calls attention to the importance of learning from mistakes.

6. Acquiring the Relevant Perceptual and Cognitive Skills

Most good racing sailors begin sailing at a very early age, and they invariably come out of sailing programs at their local yacht or sailing clubs where they received formal classroom instruction and extensive on-the-water coaching. In this respect sailboat racing is no different from ski racing, golf, or tennis, indeed no different from any sports that are practiced at a very high level. The crucial aspect of these sailing programs is not the classroom instruction, which serves primarily to acquaint the learner with the racing skills that the on-the-water sessions aim to develop, but the on-the-water sessions, where racing skills are practiced *ad nauseum* under the eye of a coach until such point as the learner knows how and when to deploy these skills. The on-the-water training sessions largely implement the Navy adage 'Fight the ship the way you train, and train the ship the way you fight', which in the present context means race using the particular skills you have learned in training, and focus in training on the critical skills you need

in racing. In around-the-buoys small-boat racing, this means practicing such things as helming, sail trim, roll-tacks, roll-gybes, starts, mark-roundings, boat-on-boat tactics, and recognizing shifts and puffs, while for offshore racing this means practicing some of these same small-boat skills, but also such big-boat skills as safety procedures, navigation, weather prediction and analysis, sail changes and reefing, and emergency boat repair, with the important difference that not everyone on a big-boat crew will be practicing each of these skills, inasmuch as there is a significant division of labor and hence of requisite skills, with the consequence that crew members generally practice only those skills that they will exercise while racing, unless for safety, as in offshore racing, one wants to build in redundancy.

The question in this section is whether the training described above, viz., classroom instruction followed by coached on-the-water practice, does in fact develop situation awareness, specifically, does it develop affordance perception along with a grasp of the risks/rewards generally associated with particular actions? I address this question in the context of a necessarily brief discussion of experimental studies of affordance perceptual learning and the role that practice and experience has been shown to play in such learning. There is, of course, a significant gulf between these experimental studies and real-world coached sailboat racing instruction, but these studies can nonetheless lend credence to the presumption within sailing that coached sailing instruction facilitates the affordance perception learning that situation awareness requires (though, of course, few sailors, if any, would put the presumption in these terms). For present purposes, following Eleanor Gibson's (1963:29) general definition of perception learning, I shall understand *affordance perception learning* as any relevantly permanent and consistent change in the perception of affordances brought about by perceptual exposure to the affordances in question, the change in question improving the learner's response to those

affordances.[9] I shall presume here without further argument that there are affordances (for possible actions), some of which can be readily perceived, and focus then on affordance perception learning.

Affordance perception learning does not necessarily give you the skills necessary to take advantage of what is afforded by one's environment. One has to learn the skills, and this is typically done in sports through coaching. But it is equally true that the point of most coaching in sports is to develop as a package ***both*** the perceptual ability to recognize the relevant affordances ***and*** the skills needed to take advantage of them. And there is, as we have noted, reason to think that in the normal case affordance perception and action are so closely intertwined, one perceives only those affordances for which one has the requisite skills or abilities to execute. There are, of course, examples of unsupervised affordance perception learning (in the learning-theoretic sense of 'unsupervised') without attendant skill learning, e.g., learning that hot stoves afford pain, but maybe these are all cases where the response does not involve a learned skill or the learned skill is pre-existing. But the cases of interest here are invariably cases of supervised learning, where learners are taught (in sailing, through on-the-water coaching) a single perception-action routine that incorporates both the affordance perception and the afforded action ('Jones, the boat ahead has left you more than enough room to gain an inside overlap; take it'; 'Jones, here comes a left shift, sail well into it, then tack')**.**

A number of experimental studies have looked at the role of practice and experience in affordance perception learning. Franchak et al. (2010: 2758) investigated the effect of permitting subjects to pass through doorways of various widths before asking them to judge perceptually

[9] I have added to Gibson's definition Goldstone's (1998: 587) insistence both that the changes in perception have to be caused by the environment and that these changes improve the learner's response to that affordance. This definition does not rule out changes in affordance perception that are unlearned, say the result of maturation, but it does take in all changes in affordance perception caused by that affordance to be learned.

whether for a particular doorway they could pass through that doorway. They found that subjects who had been permitted to practice passing through doorways of different widths were more accurate in their judgments than those who were not. Fanchak et al. attribute this to action feedback that facilitated scaling of doorway widths to their bodies, finding that judgments in this 'action-first group' were strongly related to height, weight, and torso-size, whereas judgments in the other group were not. A number of other studies have looked at subjects' ability to determine visually whether an object they were carrying would fit through a doorway. Again, practice carrying large objects of different dimensions through doorways of various widths improved the accuracy of subjects' judgments. There is, of course, nothing surprising in all this: experienced movers are very good at recognizing visually whether the furniture they are carrying has to be maneuvered to fit through a doorway. And more pertinent to our interests here, truck drivers, as those of us who live in crowded cities can attest, are quite skilled at being able to judge visually, and without slowing significantly, whether they can squeeze by a double-parked car on a narrow city street, a skill that experienced racing sailors sailing a familiar boat exhibit at starts and roundings, where the distance between boats is often quite minimal, yet typically without contact.[10]

The foregoing studies establish both that subjects can perceive affordances (for themselves and others) and that these affordances are relative to the perceiver's ability to execute the actions afforded. These studies, specifically Franchak et al. 2010, also establish the crucial point here, namely, that through experience and practice subjects become more adept at recognizing

[10] Perceptual learning is not only visual: numerous tactile acuity studies show that the just noticeable distance (JND) at which subjects can discriminate being touched by two pointed objects (say, on their backs) decreases dramatically with practice, up to a neurologically imposed limit (Wong et al. 2013).

affordances.[11] Sailing coaches might be forgiven for thinking that there is little in these studies of perceptual learning that they don't already know. This is clearly right, but that in itself provides some reason for thinking that theories of perceptual learning are onto something. But more importantly in the present context, these studies provide some experimental support for conceptualizing situation awareness in terms of affordances. They also provide something of a rationale and explanation for why sailboat racing instruction and coaching has evolved in the way that it has.

If we ask what gets learned in affordance perception learning, we can begin by looking at perception learning more generally, where theorists generally distinguish four varieties of such learning: differentiation, unitization, attention weighting, and stimulus imprinting (see Goldstone 1998), all of which would seem to be instanced in affordance perception learning. *Differentiation*, *where a learner learns to distinguish two properties, or two environmental states*. Differentiation is especially salient in racing instruction, as coaches are forever trying to teach their charges to distinguish true affordances for actions that will provide an advantage over competition, from perceptually similar stimuli that won't, e.g., a puff that brings a left shift rather than one that brings a right shift, both of which are visible on the water as an area of darker, ruffled water, but subtlety different both in the shape of the puff and in the way that they move across the water. *Unitization*, *the converse of differentiation, where one learns that what appears to be two different properties or environmental states are in fact one*. In the simplest case, one learns that what are first perceived to be instances of different kinds are in fact instances of a single kind. In other cases, one learns that what one took to be separate things are

[11] Perceptual learning theories distinguish two sorts of effects from experience and practice: *discovery effects*, which are enhancements to perceivers' ability to discriminate relevant from irrelevant perceptual information, and *fluency effects*, which are enhancements to the ease with which perceivers can extract relevant information, sometimes to the point of automaticity. For a review of relevant findings, see Kellman & Garrigan 2009.

in fact parts of a single thing. Both sorts of unitization have an important role in racing sail training. The first is obvious; it is perceptual generalization over instances. The second is less obvious, but something that sailing coaches emphasize, namely, that what is afforded by a situation is generally not a simple action, but a complex action, and they teach sailors to recognize and exploit the complex action by having them practice first the skills required to execute the component actions and once the components are mastered, coaches have them execute the entire complex action. In their training coaches emphasize the entire complex action, so that the learners come to see the affordance, if in fact there is one, as an affordance for the complex act, thereby preventing sailor from seeing a hole, sailing into it, and then finding that there is no escape. Thus, for example, once sailors have mastered the component skills of both making a tight rounding close to the mark and coming out of the rounding at the proper angle to the wind so as not to stall, they then practice the entire complex action of establishing the overlap, making the rounding, and coming out with speed on the backside, all in the presence of competing boats. *Attentional weighting, where one learns to direct one's perceptual attention to certain things in one's environment and to neglect others*. Racing sailors are forever being told to 'keep their head out of the boat', to focus on what is going on around them and not be distracted by what is going on in the boat. Learning to direct one's attention outward towards the relevant features of one's situation is essential to perceiving the affordances that enable gains over one's competition, but it is a difficult attentional skill to acquire, and especially difficult to deploy if something is going wrong in the boat. And even when a sailor keeps his head out of the boat, it is doubly hard not to be preoccupied with one's immediate environment, neglecting to take into account often obvious changes taking place further up the course. *Stimulus imprinting, where through repeated exposure the learner builds specialized detectors for the stimulus in*

question, allowing the leaner to quickly recognize its presence in a scene.[12] A basic feature of all four varieties of perceptual learning is that they are acquired through learning, through exposure to the right sort of stimuli, often supervised exposure, and a fundamental effect of such learning is the automaticity of perceptual response – with training and practice one sees what the situation affords immediately and without deliberation.

As useful as it may be to think of affordance perception learning in terms of these four varieties of perceptual learning, it is perhaps more illuminating to think of affordance perception learning as consisting of two analytically distinct components, *perception tuning* and *action linking*, i.e., tuning the learner's perceptual apparatus to the environmental stimuli that signal the affordance, and linking these stimuli to the appropriate motor action. These analytically distinct components are in fact inseparable, both in the learning process and in the acquired capacity for affordance perception.

In talking of 'perception tuning' I don't mean to imply that there is a single perceptual stimulus, even a narrow set of such stimuli, that triggers the affordance perception; rather the point is to emphasize that in the course of affordance perception learning learners get progressively better at discriminating the affordance from its embedding environment. In his discussion of what I am calling perception tuning, Fajen et al. (2008: 85) put the point this way:

> Differences between experts and novices reflect, in part, differences in the informational variables upon which experts and novices rely. Indeed, recent evidence from a range of perceptual … and perceptual-motor … tasks suggests that novices rely on variables that do not specify the relevant properties but with practice converge toward specifying variables.

[12] There is neurophysiological evidence that such imprinting involves rewiring of visual cortices. In particular, studies found that learning-induced plasticity occurs in the adult primary sensory cortices much more than researchers had previously thought (Fahle 2002: xii). Neurological evidence of such plasticity provides some evidence that changes in perceptual discrimination can be due to perceptual learning.

Assuming that the relevant information is present in the stimulus array, and reporting studies by Smith et al. (2001) on hitting pitched balls and Jacobs & Michaels (2006) on catching, Fajen et al. take the progress from novice to expert to be a matter of fixing on the variables that are invariant across different presentations of the stimuli that present the affordance. Regardless of the plausibility of this Gibsonian assumption, the basic point seems right: with training and expertise, learners become much better at discriminating the affordance in question under different performance conditions.

The second analytical component of affordance perception learning, what I am calling 'action linking', is crucial to achieving the fundamental goal of affordance perception, namely, perceptual control of action: perception must be tied to action, not in the sense that the relevant perceptual stimuli gives rise to the action, but in the sense that what is perceived is the possibility of action. Nevertheless, action linking is achieved by practice where perception is followed by the afforded action, thereby setting up the required perception-action link that leads the learner to view the relevant stimuli as affording as a possible action that action (or actions) that have become linked through repeated practice.

Construing affordance perception learning as a process of perception tuning and action linking captures a crucial goal of coached instruction, namely, training the learner's perceptual apparatus to detect the distinctive features that signal the presence of the affordance and then, having detected the affordance, to act appropriately in response to that affordance. While some individuals can no doubt acquire, through unsupervised learning, the ability to perceive the relevant affordances and then act appropriately in response, supervised learning is generally more efficacious, as evidenced by the fact both that young sailors (actually, their parents) are willing to pay for coaching and that good coaching demonstrably improves racing abilities.

Proper training welds affordance perception and motor action into a single perceptual/motor skill, where perception of the affordance eventuates in the very action that the affordance is an affordance of that action's valenced possibility in the situation. This way of conceptualizing affordance perception learning addresses an obvious problem with any attempt to construe affordance perception learning in terms of just the four varieties of perceptual learning set out above: they don't link perception to action except in an accidental way.

Construing affordance perception learning in terms of perception tuning and action linking also predicts the perceiver-relativity of affordances, specifically in the case of sailing the dependence of affordances on the perceptual, cognitive, emotional, and physical capabilities and limitations of both boat and crew. It predicts that changes in boat and/or crew may require both perception re-tuning and action re-linking, because what the environment affords a changed boat and/or crew may be quite different, entailing a relearning of the possible actions afforded by the environment.

7. Some Concluding Remarks

Sailboat racing, I have argued, shares with other domains that demand situation awareness the distinctive feature of presenting racing sailors, indeed all sailors, with the challenging task of operating and controlling a dynamic system, in this case a racing sailboat, in an environment where there are multiple inputs that need to be factored into any decision. It is this challenge that gives sailboat racing its cognitive allure. Crucial to situation awareness, I have argued, is a developed capacity for affordance perception, which links perception to possible action in a way that enables immediate action in response to perceived situation variables. The crucial role of

situation awareness in racing sailors, an awareness made possible by a developed capacity for affordance perception, also explains the observed importance of training and experience.

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