

Seeing through the face of deception

Thermal imaging offers a promising hands-off approach to mass security screening.

We have developed a high-definition thermal-imaging technique that can detect attempted deceit by recording the thermal patterns from people's faces. This technique has an accuracy comparable to that of polygraph examination by experts and has potential for application in remote and rapid security screening, without the need for skilled staff or physical contact.

There is an urgent need to devise technologies that can be used for automated, high-throughput screening to identify individuals intending to perform acts of terrorism. At present, practicalities dictate that we rely on subjective assessment of responses to brief questions such as "Did you pack your own bags?" and "Why are you entering this facility?"

Although polygraph examinations, which have high precision when applied by experts¹, are good at identifying liars, they are impracticable for mass screening because skilled operators are needed, subjects have to be attached to instrumentation for several minutes, data analysis is time-consuming and the interpretation of data is delayed.

We explored the possibility of using high-definition thermal imaging of the face for detecting deceit² because it enables rapid automated analysis of changes in regional facial blood flow to be quantified^{3,4}. We have shown previously² that auditory startling is associated with a specific facial 'thermal signature', in which there is instantaneous warming around the eyes — probably as part of a fright/flight response mediated by the sympathetic nervous system^{5,6}. Although the psychophysiology of startling differs from volitional deception, the nonspecificity of this facial thermal signature is reminiscent of the nonspecific variables monitored during a polygraph (respiration, pulse, relative blood pressure and electrodermal response). Were this thermal signature to accompany lying, independently of startling, it could be used for instantaneous lie detection without the subject even being aware of the test.

We therefore asked volunteers to commit a mock crime and then testify to their innocence under experimental conditions at the US Department of Defense Polygraph Institute (DoDPI; <http://www.dodpi.army.mil>)⁷. Twenty individuals were randomly assigned to stab a mannequin, rob it of \$20 and then assert their innocence of the 'crime'. Control subjects had no knowledge of the crime or of the crime scene. The thermal imaging system correctly categorized 83% of these subjects (Fig. 1); three-quarters (6 of 8) of the guilty individuals were correctly

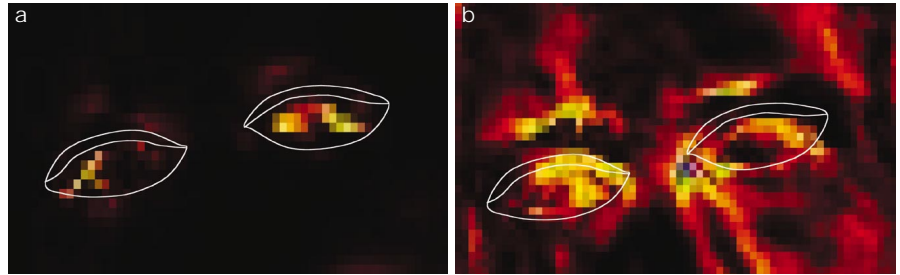


Figure 1 Periorbital, high-resolution thermal images of the face of a 'guilty' subject. Images were obtained before (a) and after (b) lying in reply to the question "Did you steal the \$20?" Images were obtained at 30 frames per second with a cooled thermal camera with a thermal sensitivity of 0.025 °C. The camera was calibrated daily to $T_{min} = 29.00$ °C (black) and $T_{max} = 38.00$ °C (cyan) with an external black body; red, orange and yellow represent progressively warmer temperatures in between. White lines indicate eye contours.

identified as guilty and 90% (11 of 12) of the innocent individuals were correctly categorized as innocent. Traditional polygraphs, performed by experts at DoDPI on the same subjects, correctly categorized 70% of the subjects: 6 of 8 subjects were correctly identified as guilty and 8 of 12 were correctly identified as innocent. Under these experimental conditions, the accuracy of the thermal imaging system was comparable to that of the traditional polygraph.

High-definition thermal imaging of the face is therefore a promising technology that should allow psychological responses to be detected and analysed rapidly and without physical contact, in the absence of trained

staff and in a variety of different situations. **Ioannis Pavlidis***, **Norman L. Eberhardt†**, **James A. Levine†**

*Honeywell Laboratories, 3660 Technology Drive, Minneapolis, Minnesota 55418, USA

†Mayo Clinic, Endocrine Research Unit, Department of Medicine, Minnesota 55905, USA
e-mail: levine.james@mayo.edu

1. Kircher, J. C., Horowitz, S. W. & Raskin, D. C. *Law Hum. Behav.* **12**, 79–90 (1988).
2. Levine, J. A., Pavlidis, I. & Cooper, M. *Lancet* **357**, 1757 (2001).
3. Gratt, B. M. & Sicles, E. A. *J. Orofac. Pain* **9**, 255–265 (1995).
4. Barrett, A. H. & Myers, P. C. *Science* **190**, 669–671 (1975).
5. Fendt, M. & Fanselow, M. S. *Neurosci. Biobehav. Rev.* **23**, 743–760 (1999).
6. Otake, K., Ruggiero, D. A. & Nakamura, Y. *Brain Res.* **697**, 17–26 (1995).
7. Holden, C. *Science* **291**, 967 (2001).

Satellite tagging

Expanded niche for white sharks

Until the advent of electronic tagging technology^{1–4}, the inherent difficulty of studying swift and powerful marine animals made ecological information about sharks of the family Lamnidae^{5,6} difficult to obtain. Here we report the tracking of movements of white sharks by using pop-up satellite archival tags, which reveal that their migratory movements, depth and ambient thermal ranges are wider than was previously thought.

White sharks (*Carcharodon carcharias*) are globally distributed, and have been reported to inhabit primarily continental-shelf waters in temperate seas⁶. Most tracking studies, however, have been limited to seasonal investigations around coastal pinniped colonies^{7–9}. We have extended these over much wider ranges by retrieving data from pop-up satellite archival tags applied to the dorsal musculature of six adult white sharks (3.7–5.0 m in length) caught off the

coast of central California. The tags collected pressure, temperature and light-level data at 2-min intervals over a cumulative 650 days (see supplementary information). Light-level data were used to estimate local midnight or noon for longitude calculations^{10,11}. At a pre-programmed date, the tags detached from the fish and transmitted a summary of stored data through the *Argos* satellite system.

We tagged six sharks in 1999–2000 and tracked them for periods ranging from 0.5 to 6 months (Fig. 1a). All sharks underwent a near-shore phase immediately after tagging. Diving patterns and ambient-temperature preferences during the coastal-residence period were similar for all sharks, who spent most of their time between the surface and a depth of 30 m, with the deepest dives reaching 75 m (Fig. 1b, c). During this period, the sharks experienced a narrow ambient water-temperature range of 10–14 °C.

Four sharks, which we tracked for 4–6 months, then moved offshore, where they remained exclusively pelagic. One individual (shark 5) travelled 3,800 km to waters off the western coast of the Hawaiian island of

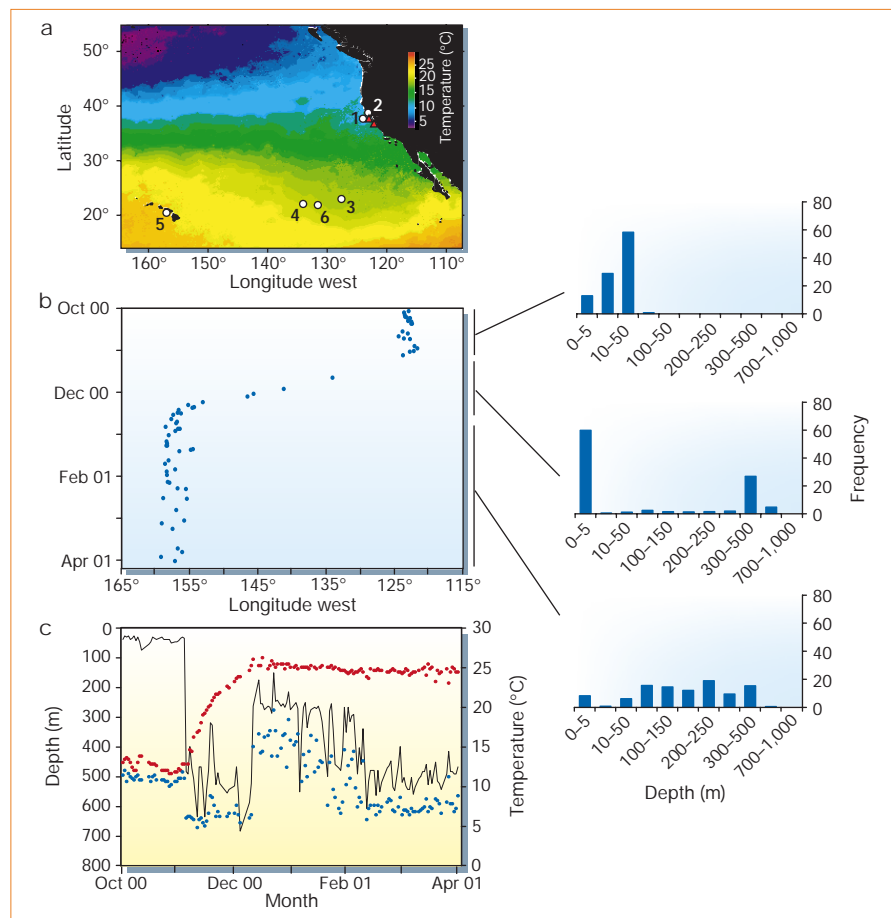


Figure 1 Movements, diving and temperature preference of white sharks. **a**, Deployment (red triangles) and end-point locations (white circles) for sharks tagged with pop-up satellite archival tags. Deployment dates are given first, followed by pop-off dates. 1, 19 October 1999; 2, 30 October 1999; 25, 25 November 1999. 3, 16 October 2000; 19 February 2001. 4, 10 December 2000; 9 April 2001. 5, 16 October 2000; 16 April 2001. 6, 5 November 2000; 8 May 2001. Sea-surface-temperature image is a weekly composite for 21–28 February 2001. **b**, Longitude and depth distribution of shark 5 over the course of its 182-day tracking period. **c**, Data for shark 5 over the course of the tracking period: black line, maximum daily depth; red points, sea-surface temperature; blue points, minimum daily temperatures. Coastal residence is indicated by shallow maximum depths (which correspond to the shark's position over a continental shelf), low sea-surface temperature and narrow ambient temperature range.

Kahoolawe; three others (sharks 3, 4 and 6) moved to a region of the subtropical eastern Pacific (Fig. 1a). All four sharks showed a period of bimodal preference for depths of 0–5 m and 300–500 m, spending up to 90% of the day in these depth ranges and little time at intermediate depths (Fig. 1b shows representative data for shark 5). As the sharks moved southwest, they increased their maximum diving activity and experienced a broader range of ambient temperatures. Sea-surface temperatures rose to 20–26 °C, and the minimum temperatures at maximum depths (650–680 m) dropped to 4.8 °C (Fig. 1c), suggesting that white sharks can tolerate a broad temperature range.

The shark that travelled to Hawaii crossed 32° of longitude in 40 days at a minimum velocity of 71 km per day (Fig. 1b). Although sightings of white sharks in Hawaiian waters are rare¹², this individual remained in the vicinity for almost 4 months, primarily staying between the surface and 300 m throughout this period (Fig. 1b).

These data provide the most extensive

record so far of the ecological niche of white sharks. Our results indicate that their range is more pelagic than was previously thought, comprising an inshore continental-shelf phase as well as extensive oceanic travel. The offshore phase lasted for at least 5 months, suggesting that it is an important period in the life history of white sharks in the North Pacific. It is unclear whether these offshore movements, which include extensive deep dives, represent feeding or breeding migrations. Increased tracking using electronic tagging should provide more data about the movement patterns, habitat usage and potential fishery interactions of white sharks, as well as critical information needed for the conservation of this species.

Andre M. Boustany*, **Scott F. Davis†**, **Peter Pyle‡**, **Scot D. Anderson‡**, **Burney J. Le Boeuff†**, **Barbara A. Block***

*Tuna Research and Conservation Center, Stanford University and Monterey Bay Aquarium, Hopkins Marine Station, Pacific Grove, California 93950, USA
e-mail: bblock@stanford.edu

†Institute of Marine Sciences, University of California at Santa Cruz, Santa Cruz, California 95064, USA

‡Point Reyes Bird Observatory, Stinson Beach, California 94970, USA

1. Metcalfe, J. D. & Arnold, G. P. *Nature* **387**, 665–666 (1997).
 2. Block, B. A., Dewar, H., Farwell, C. & Prince, E. D. *Proc. Natl Acad. Sci. USA* **95**, 9384–9389 (1998).
 3. Block, B. A. *et al. Science* **293**, 1310–1314 (2001).
 4. Eckert, S. A. & Stewart, B. *Environ. Biol. Fish.* **60**, 299–308 (2000).
 5. Carey, F. G. & Teal, J. M. *Comp. Biochem. Physiol.* **28**, 199–204 (1969).
 6. Compagno, L. J. V. *FAO Fish. Synop.* **125**, 1–249 (1984).
 7. Klimley, A. P. *Mem. South. Calif. Acad. Sci.* **9**, 15–40 (1985).
 8. Goldman, K. J., Anderson, S. D., McCosker, J. E. & Klimley, A. P. in *Great White Sharks: The Biology of Carcharodon carcharias* (eds Klimley, A. P. & Ainley, D. G.) 111–120 (Academic, San Diego, 1996).
 9. Klimley, A. P. *et al. Mar. Biol.* **138**, 617–636 (2001).
 10. Hill, R. D. in *Elephant Seals: Population Ecology, Behavior, and Physiology* (eds LeBoeuf, B. J. & Laws, R. M.) 227–236 (Univ. California Press, Berkeley, 1994).
 11. Welch, D. W. & Everson, J. P. *Can. J. Fish. Aquat. Sci.* **56**, 1317–1327 (1999).
 12. Taylor, L. *Mem. South. Calif. Acad. Sci.* **9**, 41–48 (1985).
- Supplementary information accompanies this communication on Nature's website (www.nature.com).

Carnivorous plants

Mass march of termites into the deadly trap

Carnivorous pitcher plants of the genus *Nepenthes* are not usually very selective about their prey, catching anything that is careless enough to walk on their slippery peristome, but *Nepenthes alboburginata* is an exception. We show here that this plant uses a fringe of edible white hairs to lure and then trap its prey, which consists exclusively of termites in enormous numbers. This singular feature accounts for the specialization of *N. albo-*

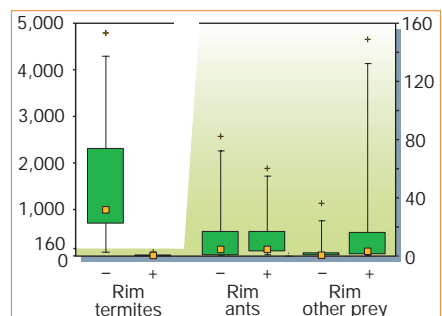


Figure 1 Comparison of prey composition for pitchers with intact and with grazed-down rim hairs (box plot; rim condition: minus sign, grazed down; plus sign, intact). The prey groups 'ants' and 'other prey' (right) are presented on an extended scale. For statistical analysis, we used the non-parametric Mann–Whitney *U*-test. There is a significant difference in the number of termites ($P > 0.02$), but no significant difference for the prey-group ants. The difference in the number of the group 'other prey' was significant ($P > 0.02$) but in our opinion this was too heterogeneous to allow any conclusions to be drawn. Details are available from the authors. Plus signs, maximum values; hollow squares, medians; error bars, limits; green boxes, 25th to 75th percentiles.

where the only two species that showed increased mortality at depth (*Diploria strigosa* and *Acropora cervicornis*) were very rare. Baker's "acutely stressed" corals, however, recovered under the higher light levels of a shallow-water site (2–4 m). From this experimental design, we cannot unequivocally conclude that the improved survival of the acutely stressed corals was due to their adoption of a new mix of dinoflagellates after bleaching, or to improved recovery conditions at the shallow site. As light energy is critical to the survival of reef-building corals⁶, stressed corals might be expected to survive better when transplanted to a more sunlit site and less well after transfer to deep water, irrespective of bleaching.

The ABH assumes that bleached corals favour new host–symbiont associations that optimize survival, necessitating rapid evolutionary adaptation (that is, genetic change) by populations of reef-building corals and their symbionts³. Although Baker claims that bleaching offers an ecological opportunity for reef corals to rid themselves rapidly of suboptimal algae and to acquire new partners¹, he relies on a molecular technique that is unable to distinguish newly invading genotypes from other rare genotypes that are already present in the host and which simply increase in proportion after conditions change. The latter is a phenotypic change (acclimatization) and, as such, is restricted in its provision of new genetic combinations for evolution.

We consider that the evidence in favour of the ABH remains scant in the absence of observations that the genotypes of symbionts in corals become more thermally robust during and after mass bleaching. Baker's finding that corals adopt a different mix of symbiont genotypes when moved from one light environment to another is an interesting addition to the well-known acclimatory responses of corals and their symbionts to changes in light quality and quantity⁷, but we cannot conclude that bleaching favours new host–symbiont combinations that guard populations of corals against rising sea temperature.

Ove Hoegh-Guldberg, Ross J. Jones, Selina Ward, William K. Loh

Centre for Marine Studies, University of Queensland, Queensland 4072, Australia
e-mail: oveh@uq.edu.au

1. Baker, A. C. *Nature* **411**, 765–766 (2001).
2. Buddemeier, R. W. & Fautin, D. G. *BioScience* **43**, 320–326 (1993).
3. Ware, J. R., Fautin, D. G. & Buddemeier, R. W. *Ecol. Model.* **84**, 199–214 (1996).
4. Jones, R. J. & Hoegh-Guldberg, O. *Plant Cell Envir.* **24**, 89–100 (2001).
5. Hoegh-Guldberg, O. *Mar. Freshwat. Res.* **50**, 839–866 (1999).
6. Muscatine, L. & Cernichiaro, E. *Biol. Bull. Mar. Biol. Lab. Woods Hole* **137**, 506–523 (1969).
7. Falkowski, P. G. & Dubinsky, Z. *Nature* **289**, 172–174 (1981).

Baker replies — Hoegh-Guldberg *et al.* suggest that corals that were transplanted downwards died more frequently than those transplanted upwards because they were deprived of critical sunlight energy at depth. My argument went a step further by explaining why this energy is so critical for these transplanted colonies.

Because corals that were transplanted downwards did not bleach in response to reduced irradiance, they failed to exchange their 'high-light' algal symbionts for the more suitable 'low-light' algae that were already found in the deep-water colonies at this site (and/or at other sites nearby). As a result, they contained inappropriate algae for their new environment, which led to chronic stress and eventual mortality.

In contrast, corals that were transplanted upwards experienced severe bleaching as a result of increased irradiance. Consequently, suboptimal low-light algae were removed, allowing high-light algae to become dominant in the newly vacant hosts. Such corals survived well as a result, despite their initial bleaching. This explanation is particularly powerful because it unifies coral bleaching, symbiont change and host mortality.

Hoegh-Guldberg *et al.* suggest that my findings fail to support the ABH because they do not provide evidence of 'new' symbionts in transplanted corals. The ABH is not limited to this constraint. Regardless of the origin of replacement symbionts (which, as I pointed out, may "colonize" and/or "proliferate inside" hosts) or the proximate environmental causes of bleaching (for example, light or temperature), if bleached reef corals change the composition of their symbiont communities faster than unbleached corals, and if more rapid symbiont change proves beneficial, then bleaching has adaptive value. Even if adult colonies are unable to form symbioses with unusual or new algae (which is unlikely, given the recent discovery of some scleractinian coral colonies containing symbionts that are usually found in foraminifera¹), cryptic populations of diverse symbionts may still occur at low abundance in many coral hosts².

There is no field evidence that symbiont genotypes change after bleaching events because the necessary molecular investigations have not yet been undertaken. Despite this, one of the best available long-term data sets on mass coral bleaching and mortality reveals that far fewer corals in the far-eastern Pacific Ocean died after the 1997–98 El Niño event (0–26%) than after the 1982–83 El Niño event (52–97%; ref. 3), even though the magnitude and duration of sea-surface temperature anomalies in the region in 1997–98 exceeded those of 1982–83 (ref. 4). These observations indicate that surviving reef corals may be more

resistant to recurrent thermal stress through having experienced earlier episodes of severe bleaching and mortality, as predicted by models of symbiont change⁵.

Furthermore, field experiments with bleached corals⁶ and laboratory studies of model invertebrate–algal symbioses⁷ support some of the assumptions of the ABH. We should not mistake an absence of evidence for evidence of absence, and instead need to document worldwide patterns of coral–algal associations and their response to mass-bleaching events. The real question is not whether coral–algal associations can adapt by recombining, but rather how, and over what timescales, they do so.

Although episodes of mass coral bleaching and mortality will occur in the future, my findings suggest that they may not recur with the frequency and severity predicted by some studies⁸. This should stimulate efforts to protect the remaining three-quarters of the world's coral-reef ecosystems⁹ by reducing the compounding effects of anthropogenic factors that are still under our influence.

Andrew C. Baker*†

*Marine Conservation Programs, Wildlife Conservation Society, 2300 Southern Boulevard, Bronx, New York 10460, USA

†Center for Environmental Research and Conservation, Columbia University, New York 10027, USA

e-mail: abaker@wcs.org

1. Rodriguez-Lanetty, M., Cha, H. R. & Song, J. I. *Proc. 9th Int. Coral Reef Symp.* (in the press).
2. Goulet, T. L. & Coffroth, M. A. *Proc. 8th Int. Coral Reef Symp.* **2**, 1331–1334 (1997).
3. Glynn, P. W., Maté, J. L., Baker, A. C. & Calderón, M. O. *Bull. Mar. Sci.* **69**, 79–109 (2001).
4. Enfield, D. B. *Bull. Mar. Sci.* **69**, 7–25 (2001).
5. Ware, J. R., Fautin, D. G. & Buddemeier, R. W. *Ecol. Model.* **84**, 199–214 (1996).
6. Toller, W. W., Rowan, R. & Knowlton, N. *Biol. Bull. Mar. Biol. Lab. Woods Hole* **201**, 360–373 (2001).
7. Kinzie, R. A., Takayama, M., Santos, S. R. & Coffroth, M. A. *Biol. Bull. Mar. Biol. Lab. Woods Hole* **200**, 51–58 (2001).
8. Hoegh-Guldberg, O. *Mar. Freshwat. Res.* **50**, 839–866 (1999).
9. Wilkinson, C. (ed.) *Status of Coral Reefs of the World: 2000* (Austral. Inst. Mar. Sci., Townsville, Queensland, 2000).

errata

Seeing through the face of deception

I. Pavlidis, N. L. Eberhardt, J. A. Levine
Nature **415**, 35 (2002)

It was not intended to convey the impression that this thermal-imaging technique is already suitable for mass security-screening purposes: indeed, the false-positive rate identified in this small study might preclude large-scale application.

Laterality in tool manufacture by crows

Gavin R. Hunt, Michael C. Corballis, Russell D. Gray
Nature **414**, 707 (2001)

The tool held in the beak of the bird shown in Fig. 1 of this communication was wrongly described as a crochet tool, whereas it is a simple leaf-stem tool that happens to be hooked.