

studied is provided by a “spectroscopy ion” while laser cooling and state detection are performed with a different species, called the “logic ion” (see the figure). The two ions of like charge are coupled strongly via the Coulomb force, and at low enough temperature they form a quasi-molecule that is held together by the trap. Laser cooling of the logic ion will sympathetically cool the second ion, and the combined system will fall to the quantum ground state of the vibrational motion in the trap. The spectroscopy ion is now prepared for probing its narrow transition, but how is the success of an excitation attempt registered? A pulse from the spectroscopy laser maps the excitation of the spectroscopy ion to the vibrational mode.

It is here that the conditional aspect of quantum logic comes into play: An excitation of the vibration is produced only if the spectroscopy ion was internally excited.

The procedure reliably transfers even the quantum mechanical coherence from one system to the other. In a second, similar step, the vibrational state is then mapped into two internal levels of the logic ion. The excitation of these levels can finally be read out via laser-induced fluorescence.

In the experiment reported here, Schmidt *et al.* have used $^{27}\text{Al}^+$ as the spectroscopy ion and $^9\text{Be}^+$ as the logic ion. The beryllium ion is convenient for laser cooling and has been used in a number of quantum logic experiments. Aluminum was chosen because it has a very narrow transition between two states with vanishing electronic angular momentum, which makes the transition especially immune to frequency shifts. This property is found in the ions of the third group of the periodic system, such as Tl^+ and In^+ (7), and makes them promising candidates for atomic clocks. The method demonstrated here is

certainly not technically simple, but it is generalizable and makes a wide range of potentially interesting systems accessible to laser cooling and precision spectroscopy. Provided a suitable logic ion of similar mass can be found, the way is open to study any spectroscopy ion, including simple molecules as well as textbook examples such as He^+ with its hydrogen-like spectrum.

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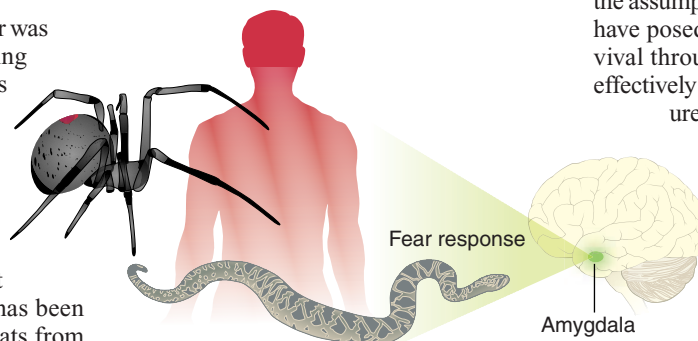
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PSYCHOLOGY

Conditioned Fear of a Face: A Prelude to Ethnic Enmity?

Arne Öhman

For all its absurdity, the Cold War was a political power game adhering to rational rules. However, it has been replaced by less predictable conflicts that give a larger role to emotion than to reason. They are manifested as vicious civil wars fueled by religious conflict and fought through terrorism and “ethnic cleansing.” Thus, an abstract but overwhelming nuclear threat has been replaced by multiple concrete threats from “evil others” in the shape of terrorism. To help cope with this situation, we need a scientific understanding of the emotional dynamics of intergroup conflicts. An important priority is to understand how attitudes between ethnic groups are formed. Not surprisingly, it appears that fear plays an important role. On page 785 of this issue, Olsson *et al.* (1) show that fear conditioning, a simple and well-understood form of learning, results in lasting fear responses to outgroup but not to ingroup human faces. That is, white participants acquired more persistent conditioned fears in response to pictures of



We exhibit a similar fear response to a spider, a snake, and a person of another race.

black faces than to pictures of white faces when the faces were paired with an aversive stimulus, whereas the opposite was true for black participants.

Fear has more insidious effects than to produce fright in response to a specific stimulus. Once we feel fear, we focus on escaping the situation rather than on in-depth evaluation of the real danger involved. Eventually, avoidance of not only the specific fear stimulus, but also of things associated with the dangerous situation, becomes based on anticipated rather than felt fear. In this way, avoidance precludes learning about a feared individual, making that person a blank slate for projections that serve to justify the fear. Hence, we are

likely to demonize a feared person by thinking of the individual as dangerous, evil, and worthy of despise.

The research reported by Olsson *et al.* (1) was inspired by the notion of “preparedness” (2). It proposes that evolution has predisposed humans to more easily learn some things rather than others. With regard to fear, the assumption is that objects and events that have posed recurrent threats to human survival throughout evolution are rapidly and effectively associated with fear (see the figure). This mediates the evolutionary

primed outcome, escape and avoidance (3). Accepting this theoretical premise, the results reported by Olsson *et al.* indicate that intergroup violence has been as common and damaging in evolution as it is among primates today (4). But claiming a biological basis for ethnic tension is contrary to the current emphasis on social learning. Indeed, the data reported by Olsson *et al.* (1) cannot distinguish between an evolutionary and a social learning origin of intergroup conflict. As the authors point out, their results may as easily be seen as effects, rather than causes, of a cultural climate that promotes interracial fears. Nevertheless, the pattern of findings is consistent with views stressing the social nature of human evolution in relatively small groups whose members are bound together by reciprocal altruism and a unique dialect or language. Thus, group cohesion may have been assisted by skepticism toward strangers and a readiness to develop fear of them.

This does not make racial conflict inevitable. The point of the preparedness

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concept (2) may be obvious even though it is not part of current common sense: Biology channels us in some directions rather than others, but learning is required to produce a definite outcome. And what is learned can be unlearned. Indeed, the fear conditioning effect observed by Olsson *et al.* was attenuated by the experience of interracial dating (1).

Fear conditioning appears to result automatically from pairing a neutral stimulus with an aversive one. In humans, it does not require conscious mediation (3). For example, human fear conditioning has been demonstrated in response to faces that were blocked from awareness by backward masking (5–7). This is consistent with contemporary analyses of attitude formation that stress the distinction between implicit (nonconscious) and explicit (conscious) attitudes (8). Implicit racial prejudice has been demonstrated in participants who do not endorse explicitly prejudiced statements about another group but who never-

theless show a negative bias in an implicit evaluation task. For example, without realizing it, white participants more readily associate negative features with black than with white stimulus persons (9, 10).

Brain imaging studies show that both fear conditioning (6, 7) and implicit negative attitudes to outgroup faces (9) correlate with activity in the amygdala even when the faces are masked from conscious recognition. Thus, negative emotional responses to members of a different race are independent of conscious mentation, which may make such responses relatively immune to rational persuasion. However, there is a consistent finding that indices of interracial contact show inverse relationships to both fear conditioning (1) and amygdala activation (9) in response to outgroup faces.

The findings of Olsson *et al.* show that negative attitudes to other races partly derive from consciously inaccessible emotional processes that may be difficult to affect by rational deliberations and deci-

sions. However, these processes can be counteracted by interracial exposure and contact. Furthermore, understanding the ease of associating negative emotions with features defining an outgroup may help combat the development of emotionally charged stereotypes of outgroup members.

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CHEMISTRY

Oxygen Vacancies and Catalysis on Ceria Surfaces

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Chemistry that occurs at the surfaces of metal oxides is critical in a variety of industrial applications including catalysis, optical display technology, solar energy devices, and corrosion prevention. Defects such as oxygen vacancies and step edges are the most reactive sites on the surfaces of metal oxides. Understanding metal-oxide reactivity thus requires an understanding of the nature of surface oxygen vacancies, and their number, distribution, and diffusion across the surface. On page 752 of this issue, Esch and co-workers report an exciting study that clearly elucidates the structure, distribution, and formation of oxygen vacancies on a cerium oxide surface (1).

CeO₂ is one of the most interesting oxides industrially because oxygen vacancy defects can be rapidly formed and eliminated, giving it a high “oxygen storage capacity.” It is this capacity that makes modern automotive exhaust treatment catalysts containing CeO₂ much more effective than their predecessors without CeO₂.

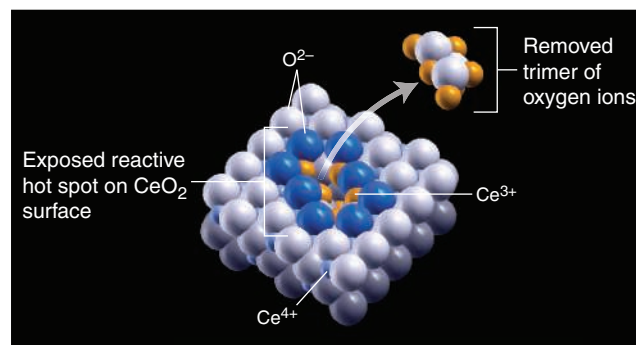
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Relative to other oxide supports, ceria also enhances the performance of transition metal catalysts in a variety of other reactions including water-gas shift, steam reforming of oxygenates, and PROX (preferential oxidation of CO) (2–6), all of which hold promise for enabling a hydrogen economy (2). Surprisingly, using some less reducible oxides, such as zirconia (ZrO₂), as additives enhances the “oxygen storage” property of CeO₂.

To gain new insight into CeO₂ surfaces, Esch and co-workers elegantly combine beautiful, atomic-resolution imaging using scanning tunneling microscopy (STM) on a ceria surface with state-of-the-art quantum mechanical calculations using density functional theory (DFT). They show that surface oxygen vacancies on CeO₂(111) are immobile at room temperature, but linear clusters of these vacancies form at higher temperatures. These vacancy clusters expose exclusively Ce³⁺ ions to gas-

phase reactants. Thus, exposed Ce³⁺ ions are grouped into large ensembles, whereas the sites immediately adjacent to these vacancy clusters remain as pure Ce⁴⁺ ions (see the figure). The authors further show that one subsurface oxygen vacancy is required to nucleate each vacancy cluster. Guided by this knowledge, they performed DFT calculations that suggest an exciting new explanation for the role of Zr promoters in ceria-based catalysts: to enable growth of the linear vacancy chains without the need for a subsurface vacancy, which is energetically more costly than a surface vacancy. Namai *et al.* (7, 8) also recently reported such linear vacancy clusters on CeO₂(111), for which Esch *et al.* now provide much needed atomic-level structural detail.

Surface oxygen vacancies are proposed to participate in many chemical reactions catalyzed by metal oxides. For example, when an adsorbate is oxidized at the surface, the oxidant is often a surface lattice oxygen



Reactive defect in a ceria surface. Coordinated Ce⁴⁺ ions in a dimeric surface vacancy cluster are reduced to reactive Ce³⁺ when the trimer of oxygen ions (surface dimer plus a subsurface oxygen) is removed.