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Neuroeconomics and International Studies: A New Understanding of Trust

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Nearly all political choices depend on trust—or a lack thereof. In world politics, successful negotiations, arms agreements, and deterrence postures all depend on trust. This paper reviews recent findings in neuroeconomics that have identified the neuroactive hormone oxytocin as a key brain mechanism that causes people to trust strangers. This research has also identified the physiologic and behavioral effect of distrust. A neurologically informed formal model of trust is introduced and implications are drawn from it for international studies (IS). We contend that findings in neuroscience and neuroeconomics can be used by social scientists to deepen their understanding of processes such as foreign policy decision making.

On August 30, 2009, former Israeli Prime Minister Ehud Olmert was indicted on charges of fraud, falsifying records, tax evasion, and breach of trust. These allegations were so egregious that Olmert had been forced to resign his position as Prime Minister a year earlier (Kersherner 2009). Several years before Olmert resigned, retiring California state senator John Vasconcellos created an organization called the Politics of Trust Network. Their mission is ''to create a whole new Politics of Trust.'' While trust seems essential to nearly every aspect of politics—certainly in democracies—the research done to date by social scientists has only scratched the surface of this important topic (Braithwaite and Levi 2003; Ostrom 2005; Hardin 2006; Kramer and Cook 2007).

Traditionally, a fundamental distinction has been drawn between realist international politics where anarchy rules and domestic politics where trust is essential for governance (Hobbes 1651/1966; Waltz 1981). The exclusion of trust did not fit with the preponderance of peaceful interactions among nations—albeit with some egregious exceptions. War and crisis are the exception rather than the rule. This reality has been recognized by practitioners across the political spectrum. Trust continues to be rejected by proponents of anarchy but it is embedded in major theories of world politics. For example, power transition theories assume ''conditional anarchy'' that requires trust to support the status quo. Trust is used to account for the history of interactions, both positive and negative, between countries (Organski 1958; Organski and Kugler 1980; Kugler and Werner 1993; Tammen, Kugler, Lemke, Stam, Abdollahian, Alsharabati, Efird, and Organski 2000; Lake 2009). Integration theories particularly applied to the European Union model nation-states as yielding portions of their sovereignty, revealing their trust in it, to a

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supra-national organization (Hass 1964; Yesilada 2010). Less integrated alliances and organizations like the United Nations, North American Treaty Organization, World Trade Organization, and the North American Free Trade Association create institutions to build trust and increase cooperation. The willingness to accept international rather than national rules and priorities depends critically on the trust of politicians and citizens in these supra-national organizations and their leaders (Kydd 2005).

A compelling example of creating institutional trust is the United Nations Security Council. The Security Council has a veto on the ''legal'' use of force by major powers in unstable environments. This veto rule was put in place so that none of the major powers (Russia, China, United States, France, and the UK) could use force against an ally of one of these powers without consent by all. Trust is created and enforced by an institutional arrangement.

Classical deterrence theory does not rely on trust, just the fear of credible nuclear retaliation at unacceptable levels. Deterrence theories assume that fear alone can prevent the initiation of war (Brodie 1946; Waltz 1981). Deterrence through fear may be effective in a bilateral one-shot game, but with sequential interactions when three or more parties are involved or risk affects payoffs, instability is the rule (Kugler and Zagare 1987; Zagare and Kilgour 2000). As nuclear proliferation has increased, multilateral relationships based on trust become a central issue. For example, non-nuclear powers that commit not to develop nuclear weapons have to trust that nuclear powers will retaliate against an aggressor if they are attacked. No institution for such an extended collective deterrence has thus far been established (Kang and Kugler 2009). A nuclear strike against Iran by Israel, or in the future a strike by Iran on Israel, could be deterred by insuring a retaliatory strike by China, Russia, or even the United States would be exercised against the nuclear initiator. No institutions now bind these parties, and non-nuclear nations have no institutional trusted guarantee of such retaliation. Instead a nuclear umbrella is offered to allies only. The United States recently provided an extended nuclear umbrella to South Korea and Japan that can be trusted, but a similar benefit is not extended to North Korea. A stable arrangement cannot be unilateral but requires trust on all sides.

There are two primary reasons why trust has not been included in most formal models. First, trust is hard to measure. Surveys of trust are often used, but data from questionnaires suffer from well-known shortcomings, especially the lack of an objective measure of trust. Surveys also suffer from biases induced by who asks the questions. For example, a recent cross-country data set on trust based on the World Values Survey and other data sources, compiled by Uslaner (2002), lists China and Iran as the sixth and seventh highest trust countries in the world, ahead of New Zealand, Switzerland, and Japan (see Figure 1). One should be quite skeptical of these data since they are simply opinions, not behaviors. Indeed, laboratory studies that use monetary transfers to a stranger to gauge trust and trustworthiness call into question such survey measures of trust. When the World Values Survey question ''can most people be trusted?'' is included in laboratory experiments, there is little correlation with the monetary transfer measure of trust (Glaeser, Laibson, Scheinkman, and Soutter 2000; Zak, Kurzban, and Matzner 2005a). We must conclude that the survey measure of trust may not consistently capture the typical meaning of the word.

The second reason trust is usually excluded from models is that in building formal theories, nearly all modelers have assumed that strategic choices are noncooperative (including the Zak and Knack 2001 formal model of trust). And yet, in a variety of interactions with high stakes on the international stage, cooperative solutions are found. While there are some models of trust that permit both degrees of trust and variations in trust over time (Binmore

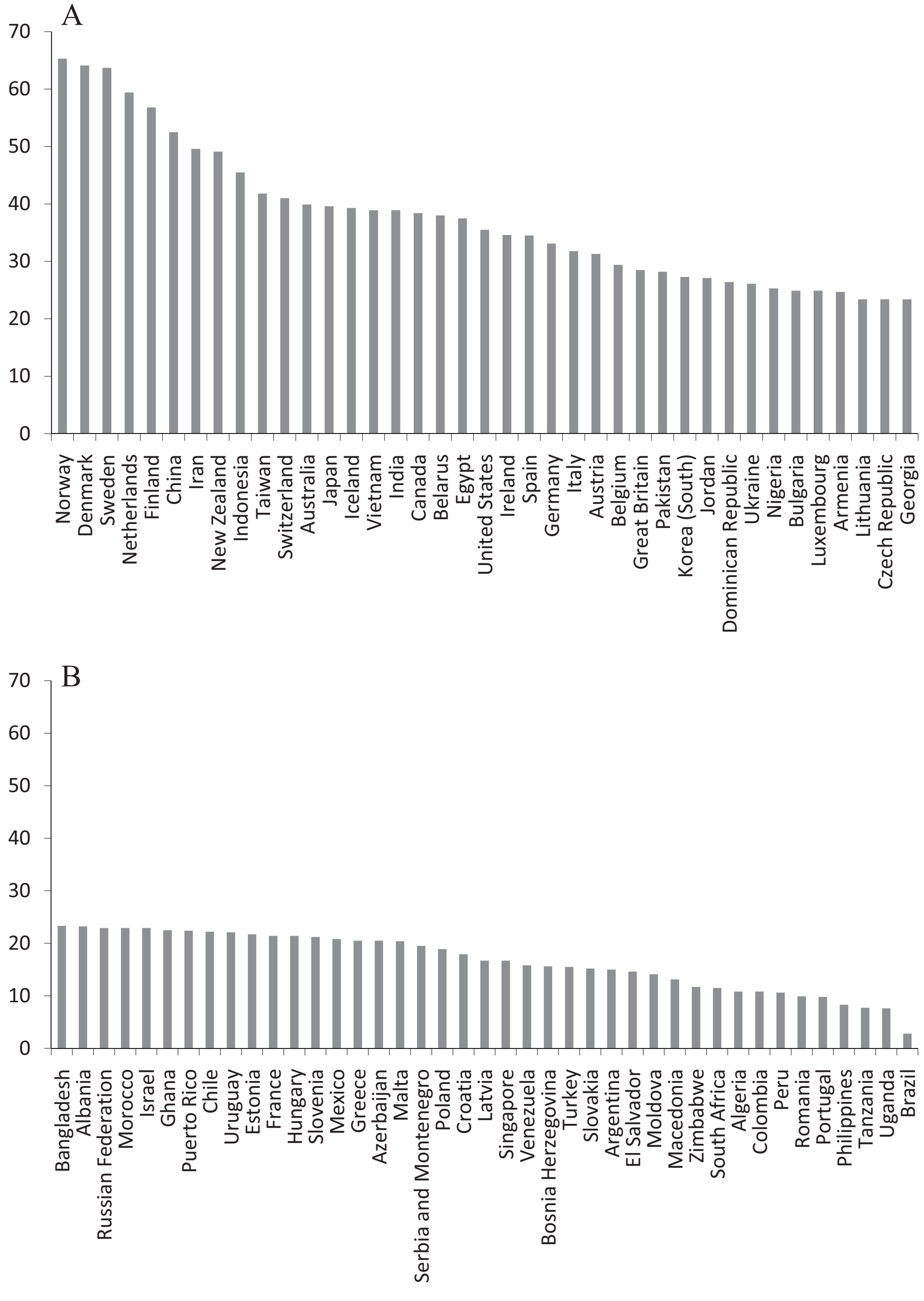

FIG 1. Cross-country Trust Levels from the World Values Survey and its Imitators. Data are the Proportion of People Answering Yes to the Question ''Do You Think Most People Can be Trusted?'' (*Notes*. Data are latest available from 1999 to 2001, with occasional data from 1995 if later was unavailable. These data are stable over time for most countries, but some data are not believable. A: high-trust countries; B: lower-trust countries. Source: Uslaner 2002.)

1994; Sobel 2002; Camerer 2003), and include trust-inducing factors such as reputation and monitoring, most models consider the baseline case to be noncooperation.

The most obvious role for trust is in repeated games. Cooperation in Prisoner's Dilemma-type games can be sustained by repeat play, a finding known as the ''folk theorem'' and shown computationally by Axelrod (1984). The folk theorem shows that cooperation can be achieved provided long-term gains exceed the short-term payoff. Unfortunately, most policy-relevant applications are not Prisoner's Dilemma games and have variable payoffs involving players with known attributes. Attributes of individual actors and countries may be known personally or through a dossier, but the past and the future certainly matter as much as the present. In such cases, understanding the role of trust as an independent element is essential.

For both a lack of solid data and a straightforward implementation, trust has not infiltrated into many formal models. At the same time, it is apparent that countries and individuals often exhibit high degrees of trust in real-world financial decisions and diplomatic negotiations. Moreover, experimental work shows that individuals presented with trust problems frequently act consistent with trust expectations and seldom act as if they were selfish maximizers interacting in an anarchical world (Smith 1998; Zak et al. 2005a; Zak, Borja, Matzner, and Kurzban 2005b; Vercoe and Zak 2010).

This paper will argue for a middle-ground for how trust affects decision making, an approach that admits both trust and defection, and presents a model to illustrate this perspective. The model in this paper differs from standard formal models in two important ways. First, it is an inductive model (Vercoe and Zak 2010). That is, the assumptions are based on years of experiments that have systematically varied conditions until general mechanisms are revealed. This is contrasted with typically deductive models in which the modeler sits down and imagines mechanisms that may produce a particular behavior. Our approach is problem-based rather than imagination-based and follows the typical approach in the natural sciences. The second difference is that the model presented here is based on accumulated evidence on the neurologic basis for trust, much of it from Zak's laboratory. Measuring brain activity while participants in experiments make decisions is a technique now known as neuroeconomics (Zak 2004; Park and Zak 2007). Neuroeconomics studies allow the modeler to directly identify mechanism producing behavior rather than rely on the typical guess-and-verify method of building models. Neurologically based models are based on direct measurement of brain activity. This approach to modeling takes more time and often results in a more complicated model. But we would argue that the value of getting the mechanisms right is offset by these factors.

Neuroeconomics is a recent transdisciplinary field that applies the measurement techniques of neuroscience to decisions that involve money and other people (Zak 2008a,b,c). This field grew from several strains of research in the social sciences, including evolutionary economics and bioeconomics, behavioral economics, and experimental economics. The field has added value to traditional neuroscience that has mostly focused on mechanisms of action rather than objectives and constraints faced by the organism and brain. Neuroeconomics stands as an exemplar for the integrated approach as advocated by Yetiv (2011) because of the way in which it brings the insights of multiple disciplines to bear on topics of wide interest.

The requirement in economic models to identify the objective function and constraints has had a salubrious effect on neuroscience by encouraging neuroscientists to do the same (Sugrue, Corrado, and Newsome 2004). The techniques used in neuroeconomics studies vary from recording signal neurons while animals execute a task, to, in humans, correlating brain activity using a electroencephalogram (EEG) or functional magnet resonance imaging with a decision outcome. Additional techniques used in neuroeconomics studies measure neurotransmitters and hormones in blood or other bodily fluids while experimental participants make decisions, and infuse drugs into the human brain to ''turn on'' or ''turn off'' parts of the brain to demonstrate the causal effect of these substances on decisions. A focused magnet pulse called transcranial magnetic stimulation has also been used to inhibit or magnify neural activity in cortical (outer) brain regions during decision making. Finally, individuals with focal brain regions have also been studied in neuroeconomics to prove the necessity of a particular brain region to doing an economic task. A discussion of these techniques and findings can be found in the survey by Zak (2004).

Neuroeconomists have studied both individual choices (for example, choices between pairs of goods or lotteries) and choices involving other people (strategic decisions). For the former, a primary finding is that the economists' mythical utility function is an actual physiologic entity (Knutson and Peterson 2005; Kuhnen and Knutson 2005). This is where biology is particularly useful to understand human behavior. Every animal must make decisions on how to acquire primary resources like food or a mate. The brain had to have evolved a brain circuit that would value outcomes and balance risk and reward. In the human brain, this involves three fundamental and integrated mechanisms. The first is the motivation to acquire the reward. The second is the cost or risk involved during acquisition. The third is the value of the reward. The primate (human and nonhuman) utility function in the brain integrates these information flows into a unified evaluation that either motivates the creature to seek the reward or discourages it from doing so. This research has also revealed a key role for the emotions during individual choice, both in the motivation to acquire reward and when outcomes are ill-specified and therefore ambiguous.

In the area of social choices, measuring brain activity while participants make strategic choices has shown that cooperation is encoded the same as primary rewards like food (King-Casas, Tomlin, Anen, Camerer, Quartz, and Montague 2005; Sanfey 2007). Far from cooperation being a mystery, as it has been portrayed relative to the limiting case of a purely self-interested rational actor, neuroeconomics studies have revealed that human beings readily cooperate because our social brains motivate and reinforce it. On the other end of the social choice spectrum, costly punishment for a lack of cooperation in one-shot games has been seen as ''irrational.'' Neuroeconomics studies have shown that people, especially men, experience rewards for punishing sharing-norm violators (Seymour, Singer, and Dolan 2007). A recent experiment that infused testosterone into men showed that higher testosterone parametrically increased the likelihood that participants would spend money to punish those who were noncooperative (Zak, Kurzban, Ahmadi, Swerdloff, Park, Efremidze, Redwine, Morgan, and Matzner 2009).

There are two primary takeaways from this overview of neuroeconomics. First, human beings are far from classic *homo economicus*. Neuroeconomics studies have revealed an important role of the brain's cognitive regions in making cost-benefit-type economic choices. But these decisions are informed by evolutionarily older brain regions that mediate emotions, motivation, and attention. We are far from rational actors, but neither are we systematically irrational. Rather, we can characterize people as being ''rationally rational'' (Zak 2008a). Because brain resources are scarce, default pathways in the brain are laid down that bias decisions to similar ones previously made. This manifests as choice heuristics. We can deviate from these heuristics, but do so only when the expected reward is sufficiently high. For a range of decisions, the energetic constraints on the brain produce boundedly rational choices.

Secondly, strategic decisions require a balancing of resources for self and other, while taking into account that our brains evolved to facilitate repeated social interactions and reputation maintenance. Neuroeconomics studies have shown that emotions are especially important in strategic choices. These emotional decisions should be understood in an evolutionary context as guiding appropriate behaviors for a species that is highly social. We examine the neurobiology of trust in this context next.

Oxytocin and Trust

One of the innovative and useful findings that have come from neuroeconomics studies of decision making is an understanding of the chemical basis for trust between strangers. Prior to the dawn of neuroeconomics in the early twenty-first century (Zak 2004), it was known that in the studies of monetary decision tasks between strangers, participants in experiments readily could be incentivized to let others take control of some or all of their resources—a way to measure trust. Of those shown such trust, nearly all would reciprocate and share money with the person who originally trusted them rather than defect and keep all the money for themselves (Berg, Dickhaut, and McCabe 1995; Smith 1998). The question was ''Why?''

Various explanations were offered for the high degree of cooperation of many types seen in the laboratory, from the stakes being too low, to confusion, to prosocial framing (Andreoni 1995; McCabe, Gunnthursdottir, and Smith 2002). After careful experimentation, none of these explanations could account for much of the variation in the observed behavior (Camerer 2003). This led to an explosion of model building, seeking to explain this ''anomaly.'' The favored explanation seemed to be imbuing individuals with a taste for fairness (Rabin 1993; Fehr and Schmidt 1999). Yet these models imposed a preference for fairness, while experiments had shown that unfair behavior also could be easily induced (Hoffman, McCabe, Shachat, and Smith 1994), revealing this explanation as either wrong or nonrobust. Something interesting was happening in the laboratory, but participants in these experiments, when debriefed, had trouble explaining why they were deciding to trust a stranger.

Economists were stuck. By the late-1990s, research had found that cross-country data on trust were highly variable, from around 3% of Brazilians saying that they thought their countrymen were trustworthy to 66% of Norwegians reporting that those in their country were trustworthy. This variation was explained through a combination of biological, institutional, and economic factors built into a formal model and tested extensively (Zak and Knack 2001; Zak and Fakhar 2006). Further, Zak and Knack (2001) showed that trust was among the strongest predictors that economists had ever found to predict the growth in living standards across countries.

At the same time, the existing realist model of international politics was being challenged empirically as the balance of power structure dissipated. The collapse of the Soviet Union should have provided an opportunity for the United States—the single dominant state after 1989—to impose new stringent rules on the international system. Following well-established principles, a major war that secured the dominance of the United States was looming (Mearsheimer 2001). Instead, despite the obvious realization that its preponderance would diminish with time, the United States supported the recovery in Russia, continued to encourage the expansion of the European Union, and sought accommodation with China. This added further urgency to understand trust in the controlled environment of the laboratory so that it could be applied effectively to economic and political reality.

The importance of trust in reducing poverty, and the desire to build a well-grounded model of trust between strangers, led to one of the first neuroeconomics experiments—and certainly the first involving blood draws, in 2001 (Zak, Kurzban, and Matzner 2004). This represented a major technological change that, at the level of individual decisions, created the potential for greatly enhanced knowledge (Fritsch 2011). The hope was that neuroscientific experimental techniques would reveal why people quite regularly trust strangers with their money. These trusters were labeled ''irrational'' by the standard self-interested, game-theoretic solution of the trust game because they did not play the subgame perfect Nash equilibrium. The Nash solution predicted no trust and no trustworthiness. Based on the assumption that any money sent to a stranger would be kept by him or her, a ''rational'' person would not send any money to a stranger. Playing Nash, trust game participants leave the laboratory with only their initial endowment. Yet in these studies, those who initiated trust earned, on average, 40% more than their endowment, while nearly all of those who were trusted with another's money reciprocated and still walked out with 70% higher earnings than predicted by the Nash solution (Zak, Kurzban, and Matzner 2004; Zak et al. 2005a,b). Somehow these participants had found a way to systematically beat the Nash payouts. Participants certainly were not irrational since on average they were earning more money than in the Nash strategy, so something must be wrong with the standard model used by economics and political science to account for their choices.

What these experiments hoped to find was a direct mechanism in the brain that told people who to trust and not trust. But where to look? There was little clarity on the reasons why we trust strangers in the economics, psychology, political science, sociology, or other literatures. The Nobel Prize winner, Vernon Smith, had run the first trust experiments in his laboratory and found that, when asked, participants could not clearly articulate why they had decided to trust a stranger with money on the line. So, one of us (PZ) turned to the literature in biology and found a small and evolutionarily old molecule called oxytocin.

Oxytocin (OT) has classically been associated with peri-reproductive behaviors. Oxytocin comes from the Greek for ''fast birth'' as it contracts the uterus during parturition and also initiates milk flow for breastfeeding. In animal studies, this uniquely mammalian hormone was also shown to facilitate maternal care for offspring. The animal literature had reported a few studies in rodents suggesting that in the 3% of mammals that are socially monogamous, OT sustains attachment between male and female breeding pairs. These animals often live in ''clans,'' with several breeding pairs inhabiting the same burrow, and OT had also been associated with males tolerating other males in their burrow and even allowing other males' access to food. Anthropomorphizing a bit, this could be called emerging trust and cooperation.

There was simply no literature studying the behavioral effects of OT in humans, and the high interspecies variation in OT's effects meant that extrapolation from rodents to humans was unwise. Human OT studies had not been undertaken for several reasons. First, the behavioral effects of OT in animals had only been established in the late 1980s and early 1990s, so the translation to humans had not yet occurred. Second, in humans, OT was considered a ''female hormone,'' simply a concern of OB-GYNs. Being associated with females meant, as one medical doctor related privately, that it could not be very important. There were no serious disease states associated with an excess of OT or a lack of OT (although those with autism have recently been shown to have low OT). Unless a woman was giving birth or breastfeeding, OT could be ignored. Third, OT is difficult to measure. In animals, this is done by sampling cerebral spinal fluid. This approach could be used in humans, but is risky and gives people a wicked headache. Animal studies had shown that OT release to the brain and in the blood targeting peripheral organs coordinated, so measuring blood levels of OT in humans might be possible. Fourth, basal OT in animal studies had been shown to be very close to zero. Outside of behaviors surrounding reproduction (OT is also released during sexual climax), animal studies showed that basal levels of OT were mostly unrelated to behavior. A stimulus was needed to induce the brain to make OT that could then be related to behaviors. How, or if, this could be done in humans outside of reproduction was unclear. Lastly, if a spike in OT could be produced, very precise measurement and handling were needed to capture it because OT has a three minute half-life and degrades rapidly at room temperature.

These were the hurdles Zak faced in 2001. Moving forward nonetheless, Zak hypothesized that a monetary transfer denoting trust might be processed in the brain as a positive social signal and cause measurable OT release. To test this mechanism, Zak's team borrowed refrigerators, clinical centrifuges, laboratory space and brought blood-draw supplies and 25 pounds of dry ice. Through good fortune, our group had the first doctoral student in neuroeconomics who was also a medical doctor. The research team designed a protocol where, immediately after decisions were made in the trust game, we quickly drew 28 ml of participants' blood, kept it cold, and processed it to obtain blood plasma and serum. These were immediately put on dry ice until they could be transported to a −80 °C freezer and stored for later analysis.

Our experiments found that OT spiked when participants were intentionally trusted with another's money. The experimenters compared OT levels in those who were trusted to levels in a control condition in which money was transferred through a random mechanism and did not signal trust. Zak and colleagues found that those who were trusted had OT levels that were 41% higher than controls ($N = 67$; F-test $p = .049$; Zak and Kurzban 2004; Zak et al. 2005b,a). In the trust condition, receiving larger transfers caused a surge in OT, and OT levels predicted how much money participants returned to the person who had shown them trust (one-tailed t-test, $p = .021$). The researchers measured nine other hormones that interact with OT and found no direct or indirect effects on behavior or OT release. The reader is referred to the published papers for the details of the experimental design and analysis.

The trust game was the first nonreproductive stimulus shown to cause OT release in humans. But as in all such experiments, it was possible that Zak and colleagues had made a mistake that some other unmeasured physiologic factor was responding to a signal of trust. So to prove that OT caused trust, Zak designed a protocol that exogenously manipulated OT levels using an OT nasal spray (Kosfeld, Heinrichs, Zak, Fischbacher, and Fehr 2005). In this study, those who received the OT spray sent 17% more money denoting trust compared with those who got the placebo ($N = 58$, Mann–Whitney U-test $p = .029$). More compellingly, the number of people who showed maximal trust—sending their entire endowment to a stranger—increased from 21% in the placebo group to 45% in the OT group. There were no differences in an objective risk-taking task or in mood across conditions, showing that OT narrowly affects positive social behaviors.

The bottom line is this: *trust is chemical*. Social norms, one's developmental history, and even current events affect trust, but these do so by modulating OT release as we discuss below. Because the amount of OT release directly affects trustworthiness, a single pathway through which variations in trust and trustworthiness can be explored and explained. Zak's laboratory and others have replicated these results in a variety of settings, for example, showing that OT infusion in the zero-sum Ultimatum Game increased generosity by 80% ($N = 68$, Mann–Whitney U-test $p = .005$; Zak, Stanton, and Ahmadi 2007). Zak's lab has also shown that 15 minutes of touch (from a massage therapist) primed the brain to release more OT after being trusted by a stranger (not the therapist) relative to untouched controls and increased monetary sacrifice toward the person who had initiated trust by a phenomenal 243% ($N = 33$, two-tailed t-test $p = .006$; Morhenn, Park, Piper, and Zak 2008).

Does OT have any effect on political preferences? Zak's team recently ran an experiment to test this idea by infusing OT or placebo into 88 US citizens during the 2008 primary elections. After the OT loaded for 60 minutes, we asked questions similar to those used in the American National Election survey. For example, we asked ''How much of the time can you trust the government in Washington to do what is right?'' We also asked general trust questions such as ''Do you think people are generally trustworthy?'' We found that, relative to placebo, OT raised generalized interpersonal trust and that greater trust in people predicted greater trust in government and greater satisfaction with government (Merolla, Burnett, Ahmadi, and Zak, in review). These results reveal that OT's effects scale up from the interpersonal to the government as a whole.

These findings are important because knowing the brain mechanism producing trust permits us to identify when trust is expected to be high or low. Familiarity and a history of positive interactions will more easily stimulate OT release resulting in trust, whereas animal studies show that high stress inhibits OT release and is therefore likely to reduce trust. Zak's lab recently showed that OT release is associated with the subjective experience of empathy: we trust more easily when we understand and empathize with others (Barraza and Zak 2009).

OT release activates a brain circuit now called the HOME (Human Oxytocin Mediated Empathy) circuit that makes reciprocation ''sticky'' (Zak 2011). OT release potentiates the release of other brain chemicals that are associated with reinforcement learning and positive effects on mood. We evolved to socialize. Humans are the hypersocial ape, and trusting others utilizes the same brain mechanism that evolved to facilitate care for offspring. At least this is true for most people. Studies of college student participants have found that 2% of them have an OT dysregulation so that they appear immune to its promotion of social intercourse (Zak 2005). These individuals are unconditional nonreciprocators and have unusual psychological and behavioral traits similar to those found in psychopaths. These individuals maximize their own monetary returns as if they were living in an anarchical world. We recently replicated the finding of dysregulated OT in patients with social anxiety disorder (Hoge, Pollock, Kaufman, Zak, and Simon 2008), indicating the crucial role that OT has in sustaining appropriate social behaviors.

Zak's lab has also found sexually dimorphic effects: for every nonreproductive stimulus they have developed, women release OT more than men and are similarly more prosocial in their behavior (Zak 2008b, 2011). There are certainly women who do not release OT after a stimulus, but this is the exception. A recent study examined what happens physiologically and behaviorally when people are distrusted, that is, when they are offered very little in the trust game. This study found that men had a ''hot'' physiologic response, but not women. Men had a spike in the bioactive metabolite of testosterone, dihydrotestosterone (DHT), indicating an aggressive response that was reflected in their lower levels of reciprocity as compared with women (Zak et al. 2005b). DHT inhibits OT uptake by its receptor, acting as an OT antagonist. We recently confirmed this finding by administering synthetic testosterone to men (Zak et al. 2009). Testosterone-infused men were less generous but also more likely to punish others for not cooperating than themselves on placebo. Throughout the range of offers in the trust game, women are proportional reciprocators. Generalizing from these experiments is premature, but they are consistent with findings showing that in some settings women reciprocate more than men (Eckel 2008). Men and women bring different physiologies to interactions that involve trust and distrust, and thus, gender diversity in negotiations can be quite valuable. One implication is that as the representation of women in the political and economic environments increases, greater cooperation may well follow.

A Neurologic Model of Trust

If experimental studies are to inform our understanding of international relations, two criteria are necessary. First, the behavior in the experiment must capture an essential part of out-of-the-laboratory actions. Second, the mechanism producing the behavior should be sufficiently consistent and robust that generalization is reasonable. Knowing the physiology driving behaviors increases the likelihood that generalizability is supportable. The Neurologic Model of Trust (NMT), presented formally in Appendix A, shows how neuroscientific findings can be generalized in a game-theoretic model. The model is based on 10 years of OT experiments and discoveries about the brain circuits involved in trust and distrust. The NMT is fairly complicated, but its value is in its *neurologically grounded assumptions.*

The key innovation in the NMT is the reciprocity function $\alpha(S, E, V)$ that depends on the trust signal received, S, the external environment, E, and the variance, V, in the trust signal. This formulation comes directly from the OT and trust research reviewed above. The NMT reveals, for example, why the US's NATO partner, France, will occasionally prohibit US warplanes from flying over its airspace (environmental stress, E, high), but also why on almost all issues France and the United States agree (variance of interactions, V, low). Both countries understand that there is value to continuing a cooperative relationship, but that local exigencies may cause occasional defections. On a very basic level, this model captures two reasons why strategies such as ''generous tit-for-tat'' produce long-term benefits: most people are conditional reciprocators and relationships matter. These implications are similar to two-level games (Putnam 1988), but the NMT does not predict a return to a state of anarchy after each round of the game.

The NMT model also produces clear predictions for the role of stress, expected payoffs, and the history of interactions that can be tested using international data. For example, studies of deterrence and arms control are a fertile area of application of the NMT because payoffs are well established and reactions can be traced over the last 70 years. Such an analysis may provide new insights into the stability of deterrence during crises and identify methods to raise trust.

The model also shows that defectors will seek to demonstrate that their reciprocity function is positive, even if it is typically not. This is something that we have observed in 5% of participants playing the trust game in the laboratory; these individuals have deceptive personality traits, similar to psychopaths, and have an identifiable dysfunction in the OT system (Zak 2005, 2011). Unconditional nonreciprocators may seek to justify past defections by claiming that they had been in a high-stress environment and that the current environment will produce cooperation. Understanding these defectors neurologically may identify actions that institutionalize trust and deter aggression.

Can such claims be trusted? The NMT model shows that history matters, as does the current state of the decision maker. Which one dominates is an empirical question. These implications are consistent with the Russian proverb ''doveryai, no proveryai'' (trust but verify) that was used repeatedly by President Ronald Reagan when negotiating with the Soviet Union. The NMT may shed light on ongoing negotiations with Iran and North Korea regarding their nuclear ambitions in which trust is a key element needed for resolution.

Realist theorists contend that the central feature that distinguishes international from domestic politics is the state of anarchy. International actors are portrayed as players in a Hobbesian jungle that exists without a constraining rule of law. Interactions among these actors are modeled to reflect participation in one-shot Prisoner's Dilemma games where Nash equilibria are the prevailing outcomes (Waltz 1979; Mearsheimer 2001; Bueno de Mesquita and Lalman 1992). Participants do not evolve trust; rather, they discover a way to maintain gains under very restricted conditions, reverting to anarchy when these conditions are altered. Following the classic representation of the state of nature, realist theory portrays the interactions among states as an undersocialized, brutal struggle for self-preservation. In the absence of a central authority to punish malefactors, no individual actor can maximize his or her own welfare by building trust and mutual relationships with others.

Unlike the realist vision and collective security advocates, power transition and liberal theorists propose international politics is equivalent to laissez-faire economies where self-interest maintains autonomous order based on trust with unfettered exchanges. Rational actors holding information about the costs of war and the benefits of mutual cooperation have little incentive to initiate conflict if they can create links that ensure satisfaction and trust (Claude 1962; Organski 1968). To secure a trusting environment that enhances security, participants build bilateral and multilateral organizations that mirror the distribution of capabilities among the parties and seek to create congruent governance structures that can enhance stability (Keohane 1984). Serious conflict emerges among societies that are deeply dissatisfied with existing rules. The most serious wars—World War I and II—are waged when participants approach parity and anticipate that changing rules will result in a new, far more satisfactory order (Organski and Kugler 1980; Tammen et al. 2000).

Paradoxically, this prolonged academic tension exists even though realism and rationalism share the same fundamental assumption: nation-states narrowly maximize net gains. At the center of this debate is the concept of trust (or the lack thereof). Actors in anarchy pursue their self-interest without constraints and assume others do, too. Actors who base policies on self-interest and trust use reciprocating strategies to achieve larger gains. This discrepancy implies that similar situations can produce conflict and cooperation depending on the level of trust among participants. If we fully accept realist arguments, the United States should have used nuclear weapons at the onset of the Cold War or in Korea to assure deterrence credibility, encouraged further partition of the USSR in 1989 to reduce future challenges, or pre-emptively challenged China to assure long-term security. If, on the other hand, trust rather than anarchy prevails and defines the interactions among participants, then cooperation rather than fear is the basis for stable relations. Avoiding the first use of nuclear weapons assumes that nations trust that opponents are likely to reciprocate and also not engage in first strikes when arsenals are built. Similarly, nations appear to trust that partitions generate dissatisfaction and conflict rather than fear and stability and that pre-emptive challenges for potential opponents are less desirable than building trust for a time when preponderance wanes.

Implications and Conclusions

Is there a payoff to applying neuroscientific findings to questions in politics? We think there is for several reasons. First, neuroeconomics studies remove the ''middle man'' from modeling. That is, rather than guess about the mechanisms causing behavior that must be later verified, neuroscientific studies allow one to directly measure how decisions are being made. There is a caveat though—there is not always a one-to-one mapping from a neurologic mechanism to its behavioral component—the latter being what is put into a formal model. This is particularly endemic in brain imaging studies using functional magnetic resonance imaging (fMRI) or positron emission tomography (PET). In such studies, typically 10–15 or more brain regions are statistically more active in the treatment versus the control task, so papers inevitably focus on a few of these (often those most significant statistically), but these are only part of a much more complex network of interactions in the brain. Isolating parts of the network is nearly uninformative. Further, interpreting what such isolated differential brain activation means is fraught with post hoc judgments based on findings from previous studies that may have flaws, compounding misinterpretations. Finally, the statistical techniques typically used to analyze activity in 50,000 small chunks of brain issue every six seconds for an hour have been characterized as ''voodoo'' correlations (Vul, Harris, Winkielman, and Pashler 2009). On balance, one should be quite skeptical of findings from a single paper and using a single technique. Convergence is the watchword in neuroscience.

An additional concern is that a well-designed study recently produced data that questions whether fMRI signals correlate with brain activity at all (Sirota and Das 2009). The work linking oxytocin to trust avoids these post hoc judgments as it shows that being trusted is directly associated with OT release and manipulating OT causes participants to trust others in an active, rather than retrospective, task. This is direct and convergent evidence on mechanism. But the ability to do such studies in humans is limited for safety reasons and therefore unusual in human neuroscientific studies. So, political scientists should borrow from neuroscience, but borrow skeptically.

Second, neuroeconomics studies bring human beings back into formal and informal models. Social scientists often model ''agents'' making decisions. These mythical creatures do not inhabit the real world. By directly studying humans, one brings real decision making to bear when seeking to understand politics. This certainly can be done without measuring brain activity. Controlled laboratory studies and field studies are the place to start and are becoming more common in political science (Green and Gerber 2003). Even field observation is underused by most social scientists (Harrison and List 2004). It is interesting to note how few economists have visited in person the markets they seek to model and have given up the opportunity to speak to those whom are making decisions before picking up a pencil to describe these decisions. For such reasons, neuroeconomics is in an especially promising position to assist in the development of deterrence theory and related areas in IS.

Scholarship on IS also suffers from an ''office bias.'' For example, analyses of Russian policy after the collapse of the Soviet Union were often simplistic. The inclusion of findings from the neurologic model of trust into standard models in international politics could have added more nuance to these analyses. At the same time, many decision makers are unable to clearly articulate the reasons for some of the most interesting decisions they make. As scientists, we must devise ways to extract this information from them. Controlled experiments are the most straightforward way to do this. Combining these experiments with measurement of brain activity can directly inform models of political behavior (for example, Westen, Blagov, Harenski, Kilts, and Hamann 2006; Boudreau, McCubbins, and Coulson 2009). Models of foreign policy decision making would seem especially well-suited to injection of findings from neuroeconomics experiments.

Third, the process of building better models of political decisions is cumulative and iterative. The neurologically informed trust model took years of experiments before there was sufficient confidence that the assumptions behind the model were well supported with convergent evidence. Untethered by experiments, one could spin out many rational actor models and then hope the data would decide which was best. We now believe this approach is bad science, because the assumptions of a model matter. Increasing explained variation is not the best metric of a model. Assumptions determine mechanisms, and getting the mechanisms right increases the odds of making out-of-sample predictions that fit the data. This approach can and should be used in the field of IS.

We are not advocating that scholars of IS morph into neuroscientists—it takes an unusual skill set to run neuroscience experiments. But being an informed consumer of neuroeconomics and neuroscience is, we believe, the wave of the future.

Appendix A

Herein, we build a game-theoretic neurologic model of trust (NMT) based on the studies Zak's laboratory has done on the role of oxytocin in facilitating trust. The model is presented to show how findings from neuroeconomics studies can be included in an otherwise standard optimizing model. The model is a dyadic interaction that captures the essence of trust—that one party must make a decision first and the other party subsequently reacts to this. Our hope is that social scientists will use this model as a foundation to incorporate trust into models of political decisions particularly in the complex arena of deterrence where formal models affect policies that impact the safety of millions.

Let us begin with some notation. The players are identified as decision maker 1 (DM1) and decision maker 2 (DM2). These can be considered countries or individual political actors. Table A1 lists the variables in the model and their definitions.

The DMs in this model are self-interested but also value the ongoing relationship between the parties. Both parties have identical continuous, increasing, and strictly concave utility functions $U()$. Decisions are made with full information by both DMs, and we abstract from stochasticity in this version of the model. For simplicity and consistent with the parity conditions previously identified in power transition dynamics, assume both parties begin with equal resources ($M_1 = M_2 = M > 0$) and have a history of interacting with each other, $V(R) > 0$ and $V(R)$ finite. The results of the model do not change if these two assumptions are relaxed.

We know from Zak's studies of OT release discussed above that under conditions of low stress, when DM2 receives a transfer from DM1, OT is released and this induces a desire to reciprocate. The degree of reciprocity scales with the size of the transfer. We will call DM2′s reciprocity function $\alpha(S, E, V)$: $R^{+} \text{x}[0,1]\text{x}R^{+} \rightarrow [0,1]$ and assume that it is continuous and increasing in S reflecting status quo level in power dynamics and decreasing in E and V. The shared external environment, E, that both DMs experience affects the reciprocity that DM2 will have toward DM1 by affecting stress levels during the interaction. E is negatively affected by stress that can emanate from an international crisis, imminent elections, a shortage of time to make decisions, or other factors that impact decision making. As discussed above, high stress reduces OT release and therefore DM2 reciprocity.

Table A1. The Components of the NMT

Variable/parameter	*Definition*
M_i	Resources controlled by i
K_i	What party i keeps
S	What DM1 sends to DM2
R	Amount DM2 returns to DM1
$\eta > 1$	Investment multiplier
V	Variance of S
E	External environment
$\alpha(S, E, V)$	DM2′s reciprocity function
$U()$	Utility function

The variance, V, of what DM1 has sent to DM2, captures how trusting DM1 has been in previous interactions with DM2. This permits DM2 to ''right old wrongs'' by reducing returns R if DM1 has been inconsistent in showing trust. This term captures the notion that trust takes time to build but is easy to break. The effect of the variance on what is sent causes both DMs to indirectly place value on a continuing relationship. Since the game is positive sum, win–win solutions exist if $\alpha(S, E, V)$ is large enough.

The model is solved backwards. DM2's decision problem is

$\mathrm{Max}_{K2,\, R}\ U(K_2) + \alpha(S, E, V)\ U(R)$

s.t. $K_2 = M + \eta S - R$.

DM2 is self-interested because greater resources K_2 are valued, but at the same time, he/she receives a utility flow $U(R)$ from reciprocating with DM1. This positive utility occurs even in a one-shot interaction ($V = 0$) but is reinforced by a continuing relationship.

The necessary and sufficient condition for an optimum is

$U'(K_2) = \alpha(S, E, V)\ U'(R)$.

This determines DM2's optimal amount kept, K_2^*, and amount returned to DM1, R^*. It is straightforward to prove that R^* is increasing in α. For a low level of environmental stress E, the more resources DM2 receives the greater his/her reciprocity toward DM1. Nevertheless, for E sufficiently high, $\alpha(S, E, V) = 0$ and as a result DM2 uses the self-interested Nash strategy, $R^* = 0$. One can also show that R^* is decreasing in the variance, V.

DM1 is also self-interested, gaining utility from total resources he/she keeps K_1 and from what DM2 returns, R. DM1 understands (implicitly) that for a given environment E, that sending an amount S to DM2 will have a neurologic effect on him/her. That is, S will induce OT release that will motivate reciprocity by DM2. DM1 also understands the value of consistency, V, in the trust shown to DM2 and knows that inconsistency will reduce DM2's reciprocity. Laboratory experiments suggest therefore the process of building cooperative environments that can be extended and tested with international interactions.

DM1's decision is to solve

$\mathrm{Max}_{K1,\, S}\ U(K_1 + R)$

s.t. $K_1 + S = M$

$R = \eta S + M - K_2$.

$U'(K_2) = \alpha(S, E, V)\ U'(R)$

The optimum is found from the condition

$U'(K_1 + R)(\eta\text{-}1\text{-}\ \mathrm{d}K_2(S)/\mathrm{dS}) = 0$,

or

$\eta\text{-}1 = \mathrm{d}K_2(S)/\mathrm{dS}$.

This equation reveals that the amount that DM1 sends to DM2, S, depends on the anticipated return, η, as well as on how DM2 responds to being shown trust by DM1, $K_2(S)$. The function $K_2(S)$ is positive and decreasing in S (equivalently, $R(S)$ is increasing) so that DM1 expects a return from DM2 unless the environment has high stress (E high) or there is a fractured history of reciprocity (V high).

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