CROSSINGS

Acknowledgements

Honors Program Editorial Staff: Jim Tuedio (Honors Program Director) and Helena Janes (Co-Director). Special thanks to Helena Janes (Teacher Education) for providing substantial editorial feedback to students in HONS 4200, and to the following faculty who generously agreed to serve as **Research Mentors** for our **2009-10 Senior Capstone Research Projects:** *Koni Stone (Chemistry)*, *Dawn Strongin (Psychology), Stephen Routh (Political Science), Jane Howard (Psychology), Elmano Costa (Teacher Education), Edward Hernandez (Management), Susan Marshall (English), Chris Nagel (Philosophy), Shawna Young (Kinesiology), Tzu-Man Huang (Finance), Helena Janes (Teacher Education), Jim Tuedio (Philosophy), Margaret Winter (English), Darren Hutchinson (Philosophy), and Tim Held (Reference Librarian).* **Faculty teaching in the Honors Program this year included:** *Jim Tuedio (Philosophy), Arnold Webb (English), Ellen Bell (Anthropology), Janey Youngblom (Biology), Chris Nagel (Philosophy), Tom Carter (Cognitive Studies), Jason Winfree (Philosophy), As'ad AbuKhalil (Political Science), Michael Tumolo (Communication Studies), Darren Hutchinson (Philosophy), Helena Janes (Teacher Education), and Tim Held (Library).* Publication of this journal has been supported by a grant from the **Instructionally Related Activities (IRA) Fund,** with supplemental funding from the Department of Philosophy and Modern Languages.

Seniors in the Honors Program are encouraged to tackle complex problems using methods and knowledge drawn from relevant disciplines. Honors Program faculty and research mentors offer critical feedback and guidance along the way. The main objective is for students to explore, gather and analyze information effectively, and to reflect on the implications of what they have discovered. Group discussions help to promote thoughtful questioning. The goal is to communicate knowledge, judgments, and original perspective on the basis of careful inquiry, exploration and analysis. Our seniors give presentations on their research at our annual ***Senior Honors Conference*** *(our Spring 2010 conference met on May 17th in the John Rogers Faculty Development Center and featured presentations on the research topics introduced in this journal). We hope you can join us for our next conference, in* ***May 2011!***

A Publication of the CSU Stanislaus University Honors Program

California State University, Stanislaus
One University Ave.
Turlock, CA 95382

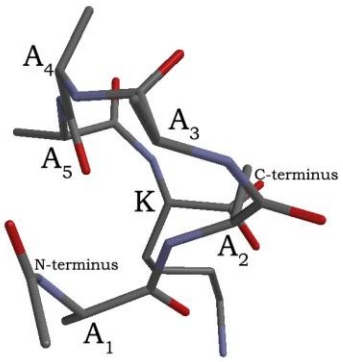
www.honors.csustan.edu
(209) 667-3180

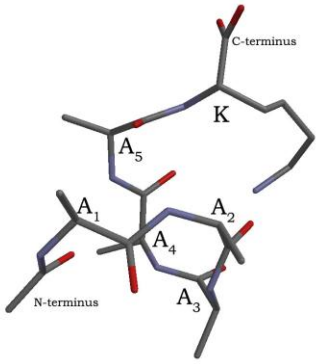
Photos & Journal Design:
Jim Tuedio

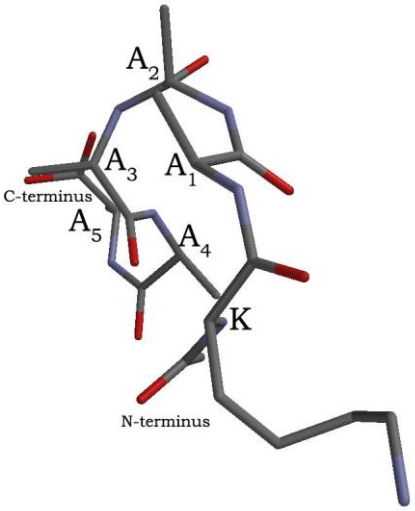
Front Cover: ***"Gaylor Sentries"***
Gaylor Wilderness/Tioga Pass
Yosemite National Park

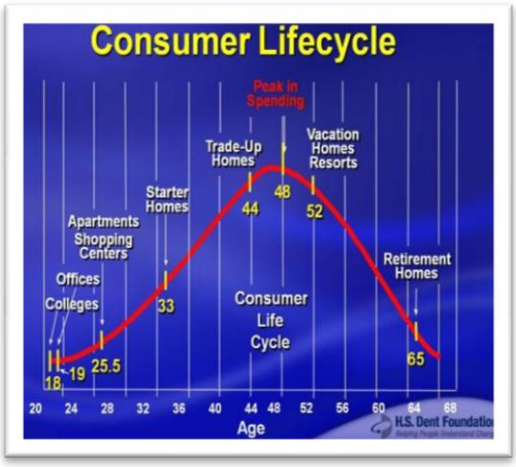
Back Cover: ***"Sandlit Spectrum"***
Painted Desert
Petrified Forest National Park

Table of Contents


A4
A3
A5
C-terminus
K
A2
N-terminus
A1

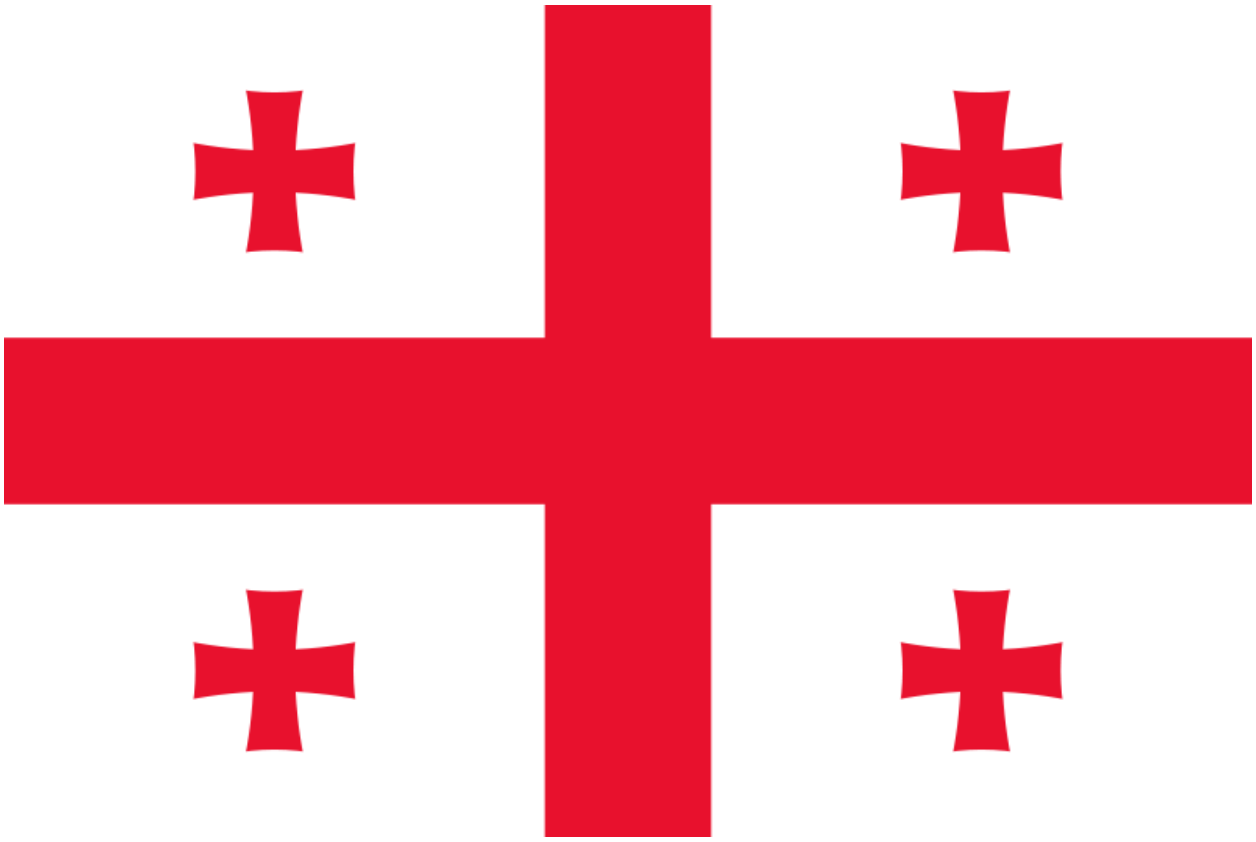

C-terminus
K
A5
A1
A2
A4
N-terminus
A3


A2
A3
A1
C-terminus
A5
A4
K
N-terminus


Consumer Lifecycle
Peak in Spending
Trade-Up Homes
Vacation Homes Resorts
Starter Homes
Apartments
Shopping Centers
Offices
Colleges
Retirement Homes
Consumer Life Cycle
18
19
25.5
33
44
48
52
65
20
24
28
32
36
40
44
48
52
56
60
64
68
Age

"The Russians responded to the Georgian offensive with a massive mobilization of troops and equipment, including this column, which moved on Tskhinvali."
http://www.time.com/time/photogallery/0,29307,1831536_1748328,00.html

"A Georgian man cries near the body of his relative after the bombardment in Gori."
http://www.time.com/time/photogallery/0,29307,1831536_1748340,00.html



Crossing Georgia: An Analysis of the Russia-Georgia War of 2008

Isaac William Farhadian

On August 7, 2008, war broke out between Georgia and Russia in response to the secession of the breakaway regions of Abkhazia and South Ossetia. The conflict, which is now often called the *Five Day War*, cost the lives of over eight hundred and fifty people, resulted in a massive exodus of innocent civilians, and made once-thriving villages and towns into unrecognizable battlegrounds for the two warring nations. The Russian war machine marched its infantry into the separatist regions in what Moscow claimed was an act of duty to protect the Russian citizens who were persecuted by the Georgian military expedition. The Russians claim they were only protecting the freedoms and rights of the over 35,000 Russian citizens in Ossetia. At the same time, Georgia claims that it was simply protecting its territorial districts in a time of a national crisis. Georgia is seeking to unify its nation despite strong resistance from the separatist regions while Russia seeks to reestablish itself as the regional hegemon in the Caucasus. In order to understand the context of this conflict it is imperative to examine the following areas: international responses to the war; Georgian and Russian politics since the

collapse of the Soviet Union; and the direct consequences of the war. Information, which sheds light on the realities of this inter-regional conflict, has been gathered for analysis from a range of European, Georgian, Russian, and American (U.S.) sources. Data examined include reports of official investigations, interviews, newspaper and journal articles, and declassified files. The primary source of information is the Independent International Fact-Finding Mission on the Conflict in Georgia (IIFFMCG), which was established by the Council of the European Union.

International Responses

On August 7, 2008, Russia challenged the West by acknowledging the independence of two separatist regions in the nation of Georgia. Angela Merkel, chancellor of Germany, referred to the Russian invasion as "absolutely unacceptable" (EuroNews, 2008). The European Union (EU) declared that Russian aggression was "contrary to the principles of Georgia's sovereignty and territorial integrity" (Osborn, 2008). President George W. Bush pressured Russia to "reconsider this irresponsible decision" (Osborn, 2008). According to Vivienne Walt, of the Wall Street Journal, Bush dispatched Secretary of State, Condoleezza Rice, to the Georgian capital for peace talks (Walt, 2008). Her arrival was significant because it reassured Georgia that the United States would continue to support the American educated Georgian President Mikheil Saakashvili in delivering aerial and naval shipments of humanitarian supplies. Former Ambassador to the United Nations Richard C. Holbrooke has proclaimed Russia's actions in the Caucasus as having two goals: firstly to annex the separatist regions of South Ossetia and Abkhazia and secondly to overthrow the pro-American president in Georgia (Scwirtz & Barnard, 2008). In response to the offensive, President Saakashvili, in an interview with *Newsweek* has reiterated the fact that "They already have decreed annexation by [giving them] so-called independence. It is certainly not independence – from my point of view, it is annexation. If they get away with this effort, they will go after Crimea" (Weymouth, 2008). Russian President Dmitry Medvedev responded by stating, **"**The Georgian head of state is not just a man we won't do business with. He's an unpredictable pathological and mentally unstable drug abuser. Western journalists know it! A two-hour-long interview on the high – that's over the edge for a head of state. Does NATO need such a leader?" (Russia Today, 2009).

The United Nations issued an immediate referendum calling both sides to renounce all use of force and to establish a ceasefire agreement between the two nations. The North Atlantic Treaty Organization (NATO), which Georgia was planning to join, has been outspoken towards the Kremlin by demanding that Russia withdraw its troops immediately. NATO's demands have been given little to no attention on the grounds that NATO has not stated the repercussions Russia would face if the Kremlin remains defiant despite international pressure (Trofimov, 2008). China, in deference to the opening of the 2008 Olympics, has mutually requested that both sides accept a ceasefire agreement (Scwirtz & Barnard, 2008). Walt makes reference to both President Elect Barack Obama, and Senator John McCain, regarding their opinions on the matter. He claims that both senators called on Saakashvili to express support in the midst of the turmoil. McCain has gone as far as saying that Russia should be evicted from the *Group of Eight* club from leading industrial nations (Holland, 2008).

Georgia was a powerful Washington ally in the region; Georgia's two thousand troops in Iraq at the time made up the third largest coalition there. Bush called Georgia, under Saakashvili, "a beacon of democracy" in a

hostile region (Lowe & Dobbie, 2007). For the United States, it was imperative to show staunch support for Georgia because it was considered a strategic goldmine in transporting troops to Iraq to combat sectarian violence and terrorism. The U.S. was exercising what political theorists call "offensive realism." Offensive realist principles proclaim that security in the international system is not plentiful and that security for a great power is best obtained through regional hegemony. In its war with Islamic fundamentalism in the nation of Iraq, the U.S. has strategically placed its troops and military bases in Georgia for quick deployment and has geopolitical reasons to strengthen its position in the Republic of Iraq.

Champion and Osborn stress that Georgia is also an important ally in the global economy. Geopolitically speaking, Georgia is economically significant in that it is a primary transit route for oil heading west of the Caspian Sea. According to Michael Shwirtz and Anne Barnard, the Caucasus region is an extremely important conduit for the transfer of oil from the great Caspian Sea to hungry world markets (Obama, 2008).

After the conflict was over, the international community came to a consensus to investigate the origins of the clash. After months of deliberation and planning, the Council of the European Union established an Independent International Fact-Finding Mission on the Conflict in Georgia (IIFFMCG) on December 2, 2008. This resolution was significant because this intercontinental decision marked the first time in the history of the European Union that it collaborated to arbitrate and investigate the causes of an inter-regional armed conflict. Swiss diplomat and peacekeeper Heidi Tagliavini was appointed as the head of the IIFFMCG from December 2, 2008 until July 31, 2009. The EU allocated 1.6 million Euros (2,400,000.00 USD) to be used for the IIFFMCG between December and July (XE, 2009). The official stated goal of the Mission was "to investigate the origins and the course of the conflict in Georgia, including with regard to international law, humanitarian law and human rights, and the accusations made in that context" (The Council of the European Union, 2009, p. 3).

Although the IIFFMCG was the most extensive and comprehensive investigation on the conflict in Georgia, the fact-finding mission has stated, "In spite of all the work involved, this Report cannot claim veracity or completeness in an absolute sense. It incorporates what has been available to the Mission at the time of writing. It may well be that additional information will become available at a later date, This has been done with the utmost care, and although there can never be total assurance that there are no mistakes or omissions, all efforts were made to keep their number down" (The Council of the European Union, 2009, pp. 8-9). A number of respected international organizations took part in the investigations with the IIFFMCG. Some of the main contributors to the cause include the Council of Europe (COE), the British House of Lords, the US Congress, the Parliaments of Georgia and of Ukraine, the United Nations High Commissioner for Refugees (UNHCR), the International Committee of the Red Cross (ICRC), Human Rights Watch (HRW), International Crisis Group (ICG), and Amnesty International. To date (Fall 2009), the IIFFMCG is the most in-depth, exhaustive, comprehensive analysis and account of the conflict that took place in the summer of 2008 in Georgia.

Two international legal issues related to the conflict were the self-determination of the Abkhazians and South Ossetians as well as their right to unilateral secession from the Republic of Georgia. The South Ossetians and the Abkhazians envisaged their right to self-determination as the legal foundation for their pursuit of sovereignty and self-governance of

the two regions. International law does not recognize the right to form new states or declare independence for reasons of self-determination or desired emancipation - outside of the colonial context in developing nations as a response to apartheid. No instance of attempted secession other than unprecedented circumstances such as genocide had ever found acceptance in the international community. The IIFFMCG confirmed the following points:

> In the case of the conflict in August 2008 and the ensuing recognition of South Ossetia and Abkhazia, the Mission has found that genocide did not take place. This applies also to a process of dismemberment of a state, as might be discussed with regard to Georgia after the dissolution of the Soviet Union. According to the overwhelmingly accepted *uti possidetis* principle, only former constituent republics such as Georgia but not territorial sub-units such as South Ossetia or Abkhazia are granted independence in case of dismemberment of a larger entity such as the former Soviet Union. Hence, South Ossetia did not have a right to secede from Georgia, and the same holds true for Abkhazia for much of the same reasons. Recognition of breakaway entities such as Abkhazia and South Ossetia by a third country is consequently contrary to international law in terms of an unlawful interference in the sovereignty and territorial integrity of the affected country, which is Georgia. It runs against Principle I of the Helsinki Final Act which states "the participating States will respect each other's sovereign equality and individuality as well as all the rights inherent in and encompassed by its sovereignty, including in particular the right of every State to juridical equality, to territorial integrity and to freedom and political independence (The Council of the European Union, 2009, p. 17).

Uti possidetis (Latin for *"as you possess"*) is a principle in international law (originating in ancient Roman statutes) which decrees that territory and other property remain with their possessor at the end of a conflict, unless otherwise provided for by a treaty (*uti possidetis*, 1980). After the conflict was over, international law dictated under the universal doctrine of *uti possidetis* that South Ossetia and Abkhazia, fighting on Georgian territory, could not declare independence from Georgia. A vast majority of the international community rebuffed attempts by the separatist regions to gain autonomous rule from Georgia.

Georgian and Russian Politics Since the Collapse of the Soviet Union

Russia has recognized the West's Achilles heel in the energy sector. In the infant stages of the Georgian conflict, the Russian military machine realized that the Western reaction would be passive because it would not risk war with neighboring Russia over a minor disruption in Georgia. Indeed, Western reaction in terms of theoretical politics took a "defensive realist" stance in its response to the Russian Federation. "Defensive realism" stresses that warlike behavior is counterproductive because risking conflict would undermine a nation's national security in a system that is deemed anarchical. Conflictual conduct during a time of interregional crisis is detrimental because it triggers counterbalancing coalitions. States act on the basis of self-help and they must take the steps necessary to ensure their own survival in times of disorder in a international anarchical system. The Russians were right to a certain extent; the only international reaction they have received is a list of insignificant rebukes. Alan Cullison and Andrew Osborn of *The Wall Street Journal*, argues that Russia has been invigorated by its economic industrial surge in the energy sector and has strategically taken geopolitical action in a time when the United States has been overstretched in terms of military and economic resources. Walt suggests that European leaders do not want to alienate Russia because it provides Europe over a third

of its energy supplies. The Russians have recognized this energy-dependency well before the conflict arose and they have taken every measure to use their advantage to the fullest.

The European Union took on a "liberal internationalist" approach in the sense that it engaged in free trade with Russia. Liberal internationalists emphasize the promotion of free trade as a positive outcome for all who partake in it because free trade leads to greater economic interdependence resulting in a diminishing tendency of military hostility. If Europe continues free trade with Russia, then that eliminates the chance of conflict between the two blocs because their economies will be interdependent with each another. The Russians receive abundant funds and the Europeans receive needed energy supplies to run their governments efficiently. If the Europeans had decided to halt diplomatic trade relations with Russia over Georgia than that would have harmed their energy supply sector because they would have had no other regional suppliers to turn to. In addition, relations between the two would have been damaged and further conflict might have arisen erupting in an all out war that would have cost ample resources and lives.

Walt makes an interesting connection between Kosovo and Ossetia. She states that Kremlin officials believe that "Washington ignores Russian interests." A recent example of this was when the Bush Administration and the European Union internationally humiliated Moscow by recognizing the independence of Kosovo from the Russian ally Serbia. Former Caucasus director Magdalena Frichova was prophetic in stating that "Russia warned there would be repercussions for Kosovo" (Walt, 2008). Don Editor from *The New Republic* declared that Georgia was playing straight into the hands of Vladimir Putin when it decided to engage militarily. Editor claims that Putin had Kosovo in mind (which Russia refers to as a historical humiliation) when he invaded South Ossetia (Editor, 2008). He suggests that the Russian bear had come out of hibernation and was seeking to avenge its global humiliation over the independence of Kosovo.

To add yet further tensions, NATO leaders in early 2008 agreed to consider the entrance of Ukraine and Georgia as its latest members, and in 2009, it was agreed that they would eventually become members. Entrance into NATO entails an extensive process, culminating in a nation's full cooperation and involvement in a Membership Action Plan (MAP). According to NATO Handbook, "MAP was launched in April 1999 to assist those countries which wish to join the Alliance in their preparations by providing advice, assistance and practical support on all aspects of NATO membership" (NATO-Publications, 2002). From the beginning, Russia has been strongly opposed to Ukraine and Georgia receiving MAPs from NATO. A U.S. response to advancing the entrance of Georgia and Ukraine came from tenured U.S. Senator Barack Obama in March 2008. Obama declared that the United States should "oppose any efforts by the Russian government to intimidate its neighbors or control their foreign policies," and stated repeatedly "that Georgia and Ukraine should receive accelerated MAPs for entry into NATO" (Obama, 2008). In March 2009, Secretary of State, Hilary Clinton stated during her European excursion "that Russia will not gain veto power over NATO membership" (McNamara, 2009).

If Georgia and Ukraine were allowed to join, this would mean that if Russia or any other country invaded these NATO member states then in theory it has declared war on all of NATO. In the course of any conflict, NATO, whose fundamental purpose is to safeguard the freedom and security of its member countries by political and military means, would combine militarily with all its members to handle the situation. Russia is

strongly opposed to Georgia becoming a member of NATO for a number of reasons. First and foremost it feels threatened that the U.S. is trying to spread, if not surround, its sphere of influence around Eurasia. The U.S. has taken an "offensive realist" approach since WWII. Once the U.S. achieved regional hegemony in the Western Hemisphere, its main goal was to prevent the emergence of other regional hegemons. Regional hegemons do not like peer competitors. The U.S. has utilized an offshore balancing grand strategy to prevent other regional hegemons from forming, and in this particular case, it has undermined Russian ambitions by allying itself with the Caucasus. Secondly, if Russia engaged in any military conflict with one of its neighbors, according to the rules of NATO alignment stated above, it would be as if it is engaging in war with a whole bloc of nations.

Champion and Osborn assert that Georgia's ambition in entering NATO has angered Moscow because it views this as a precarious move that challenges Russia's sphere of influence in the region (Champion & Osborn, 2008). Georgia has taken a "defensive realist" approach in its intention to join NATO. Defensive realist thought argues that states are fundamentally security maximizers. Preserving and amplifying a nation's security is the idiosyncratic objective of defensive realist thought. In other words, a state seeks only an appropriate amount of power to ensure its survival and to protect and expand its national sovereignty. Saakashvili, who is a "defensive postionalist," understands that it is in the best interests of his country to unite with NATO because it will strengthen his nation's position in an unstable region filled with hostile neighbors seeking to augment their power. In an interview with *Newsweek* in August 2008, President Saakashvili was asked whether he thought if he forgot about joining NATO, would Russia leave Georgia alone? He responded by stating that it is not about NATO, "it is about two conflicting systems, two conflicting ideas, and two conflicting ways of life" (Weymouth, 2008). According to Saakashvili, Russia simply cannot accept that two of its former satellite states (Ukraine & Georgia) are pro-western democracies that champion free markets and free societies. Medvedev referred to Saakashvili by stating that, "You know, lunatics' difference from other people is that when they smell blood it is very difficult to stop them. So you have to use surgery" (Reuters, 2008). Medvedev further remarked that Saakashvili is a pathological liar who uses the global media to distort truth into fiction.

Direct Consequences of the War

The war with Russia has left Georgia's military exhausted and the countryside littered with bombs and evidence of tank fire (Walt, 2008). The war officially ended on August 12, 2008, when Moscow and Tbilisi agreed to a mutual cease-fire. The authorization of the preliminary ceasefire agreement took place on the eve of August 12, signed by Russian President Dmitry Medvedev, Georgian President Mikheil Saakashvili, and French President Nicolas Sarkozy, who was acting on behalf of the European Union. Sarkozy, who is Chair of the European Council, shuttled between Moscow and Tbilisi to stop continued military hostilities between the warring nations. Despite the proposal of the six-point ceasefire plan, Russian and South Ossetian forces continued their military advances for many more days after the Georgians had agreed to halt all of their military action. After Georgia had officially recognized the ceasefire plan and stopped all advances, a coalition of Russians and South Ossetians continued to occupy additional territories, including the Akhalgori district. A partial withdrawal of Russian troops did not occur until August 22, while some troops did not withdraw until after an implementation agreement was reached on September 8, and

the remaining forces did not leave until the month of October.

After signing the preliminary ceasefire agreement, the Georgian side reported losses of 170 service members, 14 police officers and 228 civilians, with 1,747 persons seriously wounded. The Russian side reported losses of 67 service members killed, and 283 seriously wounded, while the South Ossetians reported 365 deaths. In total, 850 persons lost their lives, including individuals who went missing. Over 135,000 civilians fled their homes, most of them from the South Ossetian region, and approximately 35,000 Georgian residents evacuated their homes and are currently (September, 2009) unable to return due to the continued insecurity of the situation and the destruction of their properties (The Council of the European Union, 2009, p. 27). The result of the war has left 850 dead, with tens of thousands of ethnic Georgians and Russians homeless (Walt, 2008). While the international community is scrambling for a solution, war-torn Georgia is painfully recuperating from the aftermath. The United States in response to the Five Day War has collaterally pledged to provide a one billion dollar relief package for reconstruction, resettlement, and humanitarian needs (Anonymous, Q&A: Conflict in Georgia, 2008). The International Monetary Fund (IMF) has agreed to loan Georgia seven hundred and fifty million dollars to repair all damages caused during the Russo/Georgia War (Anonymous, IMF and Georgia Discuss $750 Million Loan Package, 2008).

The greatest effect of the Russian invasion has been economic for both sides. In late August 2008, the Russian Trading System has finished its economic session at 1579.12, the lowest point since 2006. The value of the Russian Ruble has also dropped in its overall value, down 1.5 percent in comparison to the U.S./Euro in terms of worth (Cullison & Osborn, 2008).

A shift in Russian politics was solidified the day Moscow sent military envoys to Tskhinvali, to crush all Georgian resistance in the heavily populated Russian region. President Medvedev made his intentions clear in stating that he seeks to maintain privileged interests in the Russian sphere of influence, including all bordering nations that were once a part of the Soviet Union (Anonymous, Q&A: Conflict in Georgia, 2008). Robert Kagan, of *the Wall Street Journal*, in reference to Hans Morgenthau, summed up the international response and background to the conflict in stating that Vladimir Putin "launched a small but decisive war on a weaker neighbor while a surprised and dumbfounded world looked on helplessly. Here was a man and a nation pursuing 'interest defined as power' acting in obedience to the objective law of international power politics." (Kagan, 2008).However, the deeper analysis of the IIFFMCG into this complex issue reveals otherwise: Georgia was also found culpable.

The IIFFMCG, which has provided the most comprehensive documented analysis of the conflict, has stated that the war was started by a Georgian attack that was an infraction under international law. The IIFFMCG declares that the shelling of Tskhinvali during the night of August 7/8, 2008, was unjustifiable under global law. The IIFFMCG states that although the South Ossetian defensive actions conformed to international laws, "any operations of South Ossetian forces outside of the purpose of repelling the Georgian armed attack, in particular acts perpetrated against ethnic Georgians inside and outside South Ossetia, must be considered as having violated International Humanitarian Law and in many cases also Human Rights Law" (The Council of the European Union, 2009, p. 23). In addition, all external military actions specifically directed against the Georgian armed forces after the signing of the ceasefire

agreement on August 12, 2008 were deemed illegal (The Council of the European Union, 2009). Georgian action or use of force against Russian peacekeeping members on Georgian territory also ran contrary to international law (The Council of the European Union, 2009).

The IIFFMCG has conducted extensive research on the legality of Russian armed forces attacking the Georgians. The report divides the examination into two phases: the first concerns the immediate response from the Kremlin to defend Russian peacekeepers, and second, the full invasion of Georgia by the Russian military stretching far past the South Ossetian boundaries to the Georgian capital. The first phase was defended by appeal to international law because Russian peacekeepers were attacked and Russia had "the right to defend them using military means proportionate to the attack" (The Council of the European Union, 2009). Thus according to the tribunal, the Russian use of military force proportionate to protect innocent peacekeepers during the conflict was legal. The second issue analyzed by the IIFFMCG concerned whether the deep penetration of the Russian military campaign was necessary and proportionate in regard to defensive measures undertaken against the initial Georgian attack. Evidence of extended military action includes bombing the Kodori Valley, setting up military positions in major Georgian metropolitan areas, controlling principal highways, and releasing large deployments of navy units to the Black Sea. All these actions indicate that Russian military action went far beyond the reasonable limits of defense (The Council of the European Union, 2009). Another example of disproportionate use of force was the continuing presence of advancing Russian military forces in Georgian territory after the signing of the ceasefire peace agreement. This use of excessive force was in clear violation of international statutes. The IIFFMCG declared that Russian military action outside the boundaries of South Ossetia and Abkhazia was conducted in violation of international law (The Council of the European Union, 2009).

In summary, the IIFFMCG has confirmed that both nations violated international law and human rights; that despite being warned and advised against shelling Tskhinvali, Georgia went ahead and lit the match that started the conflict; and that the Russian and South Ossetian persistent military advances deep into Georgian territory, and their excessive use of disproportionate force, was in violation of international law. In conclusion, according to the investigative tribunal (IIFFMCG), Georgia triggered an unnecessary war by shelling Tskhinvali and shooting at Russian peacekeepers, and Russia responded with a disproportionate, unjustified measure of military force in clear violation of international law (BBC, 2 009).1

Georgian soldiers race past an apartment block in Gori after Russian warplanes dropped bombs on the city. GLEB GARANICH / REUTERS

1 I would like to take this opportunity to thank Dr. Stephen Routh (Politics & Public Administration) and Dr. Helena Janes (Honors Program/Teacher Education) for their comments, suggestions and critical feedback on earlier drafts. Their assistance has been much appreciated.

References

Amnesty International USA. (2009). Retrieved November 12, 2009, from Georgia Human Rights: http://www.amnestyusa.org/all-countries/georgia/page.do?id=1011157

Anonymous. (2008, September 3). *IMF and Georgia Discuss $750 Million Loan Package.* Retrieved November 16, 2009, from International Monetary Fund: http://www.imf.org/external/pubs/ft/survey/so/2008/new090308a.htm

Anonymous. (2008, August 26). *Merkel condemns Russia over Georgia regions.* Retrieved November 1, 2009, from EuroNews - English Version: http://www.lexisnexis.com/us/lnacademic/delivery/printdoc.do?fro

Anonymous. (2008, September 4). *Q&A: Conflict in Georgia.* Retrieved September 8, 2008, from BBC News: http://news.bbc.co.uk/2/hi/europe/7549736.stm

Article 62. (n.d.). Retrieved November 21, 2009, from The Constitution of the Russian Federation: http://www.departments.bucknell.edu/russian/const/ch2.html

BBC. (2009, September 30). Retrieved October 17, 2009, from Georgia 'started unjustified war' : http://news.bbc.co.uk/2/hi/8281990.stm

Champion, M., & Osborn, A. (2008, August 9). *Russia, Georgia Clash over Breakaway Province; Nations on Brink of War; U.S. Calls for Ceasefire.* Retrieved October 2, 2008, from The Wall Street Journal: http://proquest.umi.com/pqdweb?index=2&did=1528027541&SrchMode=2&sid=2&Fmt=4&VInst=PROD&VType=PQD&RQT=309&VName=PQD&TS=1225674543&clientId=17873

Chivers, C. (2008, September 16). *Georiga Offers Fresh Evidence on War's Start.* Retrieved October 2, 2009, from The New York Times (Late Edition (East Coast)): http://proquest.umi.com/pqdweb?index=0&did=1555346061&SrchMode=2&sid=1&Fmt=3&VInst=PROD&VType=PQD&RQT=309&VName=PQD&TS=1226183763&clientId=17873

Cullison, A., & Osborn, A. (2008, August 27). *Moscow, Defying West, Recognizes Independence of Georgian Regions.* Retrieved October 2, 2008, from The Wall Street Journal: http://proquest.umi.com/pqdweb?index=0&did=1541501361&SrchMode=2&sid=3&Fmt=4&VInst=PROD&VType=PQD&RQT=309&VName=PQD&TS=1226869072&clientId=17873

Editor, D. (2008, September 10). *Dark Tzar.* Retrieved September 19, 2008, from The New Republic: http://web.ebscohost.com/ehost/detail?vid=1&hid=103&sid=e6347d50-496e-42e8-9c394233823fa55b%40sessionmgr108&bdata=JnNpdGU9ZWhvc3QtbGl2ZQ%3d%3d#db=mth&AN=34002809

Holland, S. (2008, October 15). *McCain would exclude Russia from G8 nations.* Retrieved November 2, 2008, from Reuters: http://www.reuters.com/article/politicsNews/id USN1536962020071015?feedType=RSS&feedName=politicsNews&rpc=22&sp=true

Kagan, R. (2008, August 30). *Weekend Journal; Essay: Power Play.* Retrieved October 7, 2008, from The Wall Stree Journal: http://proquest.umi.com.ezproxy.lib.csustan.edu:2048/pqdweb?index=4&did=1544564921&SrchMode=2&sid=1&Fmt=3&VInst=PROD&VType=PQD&RQT=309&VName=PQD&TS=1226458033&clientId=17873

Lowe, C., & Dobbie, e. b. (2007, November 7). *Georgia's Saakashvili divides country.* Retrieved November 15, 2009, from Reuters: http://www.reuters.com/article/worldNews/idUSL0235425420071107

McNamara, S. (2009, March 25). *NATO 60th Anniversary Summit: An Agenda for American Leadership*. Retrieved February 10, 2010, from The Heritage Foundation: http://www.heritage.org/Research/Europe/bg2254.cfm#_ftnref25

NATO-Publications. (2002, October 2). *Chapter 3: The Opening Up of the Alliance: The Process of NATO Enlargement: The Membership Action Plan*. Retrieved February 10, 2010, from NATO Handbool: http://www.nato.int/docu/handbook/2001/hb030103.htm

Obama, B. (2008). *Obama Statement on NATO Summit in Romania.* Washington D.C.: Office of U.S. Senator Barack Obama

Osborn, A. (2008, August 27). *Moscow, Defying West, Recognizes Independence of Georgian Regions.* Retrieved September 27, 2008, from The Wall Street Journal: http://proquest.umi.com/pqdweb?index=2&did=1541501361&SrchMode=2&sid=2&Fmt=4&VInst=PROD&VType=PQD&RQT=309&VName=PQD&TS=1225574125&clientId=17873

Reuters. (2008, August 12). Retrieved October 30, 2009, from Russia's Medvedev slams Saakashvili over conflict: http://www.reuters.com/article/gc07/idUSLC52643920080812

Riannovosti. (2009, October 9). Retrieved October 16, 2009, from World Venezuela recognizes S. Ossetia, Abkhazia as independent: http://en.rian.ru/world/20090910/156083204.html; http://en.rian.ru/world/20080904/116538071.html

Russia Today. (2009, September 11). Retrieved October 25, 2009, from We did everything right, and I'm proud of it – Medvedev: http://russiatoday.com/Top_News/2008-09-13/we_did_ everything_ right_and_im_proud_of_it_-_medvedev.html

Scwirtz, M., & Barnard, A. (2008, August 9). *Russia and Georgia Clash Over Breakaway Region.* Retrieved October 7, 2008, from The New York Times (Late Edition (East Coast)): http://proquest.umi.com/pqdweb?index=4&did=1527955471&SrchMode=2&sid=3&Fmt=3&VInst=PROD&VType=PQD&RQT=309&VName=PQD&TS=1226271969&clientId=17873

The Council of the European Union. (2009). *Independent International Fact-Finding Mission on the Conflict in GeorgiaVolume: Volume I.* September: Council of the European union.

Trofimov, Y. (2008, August 20). *Russia Tightens Its Grip; Gains in Ossetia Look Permanent; NATO Call for Withdrawal.* Retrieved October 2, 2008, from The Wall Stree Journal (Eastern edition): http://proquest.umi.com.ezproxy.lib.csustan.edu:2048/pqdweb?index=5&did=1535350821&SrchMode=2&sid=2&Fmt=4&VInst=PROD&VType=PQD&RQT=309&VName=PQD&TS=1226453135&clientId=17873

uti possidetis. (1980). Retrieved October 13, 2009, from Oxford English Dictionary: http://dictionary.oed.com/cgi/entry/50274056?single=1&query_type=word&queryword=uti+possidetis+&first=1&max_to_show=10

Walt, V. (2008, August 25). The Bear is Back on the Prowl. *Time* , 28-29.

Weymouth, A. (2008, August 10). *At the Helm in the World's Hot Spots: Georgia.* Retrieved October 7, 2008, from Newsweek: http://vnweb.hwwilsonweb.com/hww/results/results_ single_fulltext.jhtml;hwwilsonid=ORCUSTMC5RR43QA3DILSFGOADUNGIIV0

XE. (2009, October 25). Retrieved October 25, 2009, from XE: The World's Favorite Currency Site, Universal Currency Converter Results: http://www.xe.com/ucc/convert.cgi?Amount=1%2C600%2C000&From=EUR&To=USD&x=36&y=18

Effects of Iconicity on American Sign Language Acquisition and Retention: Supplementing Treatment of Communication Deficits in Children with Autism

Natalie M. Hammond

Seek first to understand, then to be understood. –Stephen Covey

The ability to communicate is a vital skill, for communication provides opportunities for individuals to make connections with others and to learn more about themselves and the world around them. Each interaction provides numerous opportunities for growth and development of ideas and individuals alike. Because of this, language is an important ingredient that forms much of the foundation of the human experience. Without a way to effectively and accurately communicate with others, an individual will experience much difficulty in trying to get his or her needs and wants across to others along with difficulties in understanding the messages and feelings of others, which, in turn, limits the individual's ability to respond appropriately and minimizes what the individual can gain from the interaction. It is easy to see how this type of situation would quickly degrade and lead to misunderstanding, being misunderstood, feelings of frustration, and even isolation.

Because of this, many people realize the importance of improving communication skills and make many attempts to do so. Unfortunately, acquisition of communication skills does not always occur at the rate that each communicator needs or wishes it to. Of course, this can occur in different situations with differing levels of significance. For individuals with communicative disorders this impact is typically much higher. These individuals have deficits in their ability to exchange information with each other, such as speech production problems (lisps, stuttering, or difficulty producing certain sounds), dysnomia (the difficulty or inability to retrieve the correct word from memory when needed, as seen in people who have experienced brain trauma or with particular learning disabilities), and difficulties understanding language or the emotional, social, and pragmatic aspects of language (such as autism spectrum disorders).

The American Psychiatric Association states in the *Diagnostic and Statistical Manual of Mental Disorders-IV-Text Revision* (DSM-IV-TR) that impairments in communication are a key factor in determining if an individual is on the autism spectrum, along with impairments in social interaction and restricted, repetitive, and stereotyped patterns of behavior, interest, and activities, along with other factors (2000). These impairments in communication as defined by the DSM-IV-TR may be delayed (or total lack of) spoken language which is not accompanied by an attempt to compensate through alternative modes of communication (such as gesture); marked impairment in the ability to initiate or sustain a conversation with others; stereotyped and repetitive use of language or idiosyncratic language; and lack of varied, spontaneous make-believe play or social imitative play appropriate to developmental level.

As soon as a child receives a diagnosis of autism, it is recommended that he or she be placed in an individualized therapy program to assist the child in improving the skill sets that are underdeveloped as well as maintaining each positive behavior the child already displays. Specialists believe it is important also to extinguish all maladaptive behaviors. In light of the social and communication deficits exhibited by those diagnosed to have autism spectrum disorders, it is crucial for these interventions to include attending and

language programs. The prognosis appears to be considerably more favorable for children with effective language skills at age five than for children who have failed to develop language by that time (Eisenberg, 1956). This suggests a crucial role for early intervention. In addition to communicative and attending programs, clinicians also include practice in imitation skills, play skills, gross and fine motor skills, and self-help skills. As a result of such intensive therapy, it is hoped that the child can enter into mainstream education with the skills needed to participate interactively and fully with his or her peers.

Even well-implemented teaching programs may still fall short by not producing the language component the family and clinicians desire. Current estimates suggest 30% to 40% of people with autism remain mute throughout their lifetime (Tager-Flusberg, Paul, & Lord 2005). Though it is not clear why this is the case, various strategies with an increased focus on communication practices utilizing "unspoken" language skills have become more prominent as clinical approaches to nonverbal children with autism. These strategies include "signing, gesturing, picture cards, or any other system meaningful to a child," and have become increasingly prevalent since their initial successes in the late 1970s (Schopler & Mesibov, 1985, p. 7). Critics have cautioned that the use of these approaches may inhibit the development of verbal communication by reinforcing a behavior that is other than speech, but there are studies which suggest the contrary (to be discussed later).

If someone does not have a socially acceptable way to communicate, he or she will repeat behaviors that have been reinforced in the past (i.e. the child will partake in activities that typically bring about the desired outcome) even if these behaviors are physically or emotionally hazardous; this could include self-injurious behaviors (SIB), which typically become more severe as time progresses. Nor are severe behaviors the only maladaptive behaviors to be concerned with. Behaviors like screaming, crying, laughing, grabbing, pulling and pushing, if they take place at inappropriate times or to achieve inappropriate goals, would also be considered maladaptive.

One of the largest growing topics of interest for those providing language therapy to children with autism is the use of American Sign Language or a form thereof (other sign systems that are not languages themselves such as Signing Exact English (SEE)—Appendix will include discussions of differences between the two), not only as a possible alternative communication system but also for promoting verbal language skills. It has been suggested that simultaneous communication training together with separate vocal training may be the best method for children with autism who are completely nonverbal, while simultaneous communication training may be enough for those who naturally possess good verbal imitation skills to further develop those skills (Carr, 1979). Another study, involving a four-and-a-half year old boy with autism who did not have spoken language skills, investigated three training strategies (total communication sign training, "sign alone" training, and "oral alone" training) and determined that the total communication model was "substantially superior to both the oral and sign-alone training models" (Barrera, Lobato-Barrera, and Sulzer-Azaroff 1980). In addition to research involving autistic children, other studies have examined the positive effects of learning a sign language on cognitive development in typically developing children (Caprici, Cattani, Rossini, & Volterra 1998).

ASL is the primary mode of communication for the majority of deaf and hard-of-hearing individuals in the United States and Canada, though estimates of such statistics are in need of updating (Mitchell, Young, Bachleda, & Karchmer 2006). ASL is a natural and complete language that has changed over the course of time and continues

to adapt to new demands and situations (such as the development of signs for the internet and President Obama). It has its own semantic and phonological structure along with its own syntax, pragmatics, and morphology that is produced through facial expressions, gestures, use of various hand shapes and different placements of those shapes in relation to the body, body placement, and the use of the space surrounding an individual to convey meaning. ASL can be used to express anything from simple and concrete ideas to those that are complex and abstract.

As there are words in spoken languages that combine to represent concepts, there are signs in ASL (this is not imply there is a one-to-one correlation from each spoken word to each sign, as each sign language is an independent language). Each sign can be described according to a number of features, including handshape(s) (some include more than one throughout the production of the sign), expression, movement (such as from the corner of the mouth to near the earlobe), placement (in relation to the body, such as near the forehead, chin, or shoulder), and orientation. Through utilizing the space around the person, head movement, and eye gaze, the signer can indicate and discuss a person or item that is not present, make comparisons between people or objects, indicate temporal occurrence, direction, perspective, and more. Though a person with severe communication disorders may not achieve elaborate or complete control over such devices, introducing a system with the foundation for such communication to occur is more desirable than one that does not foster further language and cognitive development.

There are other aspects of signs that are beyond the physical description of each sign. Each of these aspects may have an impact on the acquisition of each sign. Such aspects include the level of difficulty to produce, level of enjoyment, familiarity, similarity to other signs, and iconicity. *Iconicity* is the measure of how much an item naturally resembles the item it signifies. Klima and Bellugi separated signs into three categories: transparent, translucent, and opaque. Some signs are highly iconic to the point that those who do not have knowledge about the structure of the language can deduce their meanings. These are called transparent signs. There are signs that people who are not proficient in ASL can understand the connection once they are given their meaning referred to as translucent signs. Most signs, however, are opaque signs, that are not often guessed by those who are not fluent in the language and are required to communicate clearly with other ASL users.

In this study, the researcher wishes to determine if iconicity has an impact on the acquisition (learning of signs) and retention (remembering learned signs over the course of time) of signs. The researcher expects that signs that are more iconic will be learned more quickly and retained more easily over time than those that are less or non-iconic. If this is the case, further studies should be done to find if similar differences exist in populations of individuals with communicative difficulties such as autism. There has been some suggestion that difficulty in understanding the correlation between words, objects, and concepts may lead to some of the difficulties for some individuals with autism in the acquisition of language (Grandin, p. 1285). Perhaps if an individual with such difficulties could more easily understand the connection between signs that are highly iconic and what they represent, it could provide the realization that is necessary to further develop language.

METHODS

Participants

The participants in this study will be several classes of elementary students at a few different schools in California's Central Valley. They will be in the first and second

grades, most likely in private school or summer camp settings. The children will be typically developing, with no experience with American Sign Language. The students who take part in the preparation stages will not be used in the experimental group.

Setting

All instruction will take place in the respective classroom of each group of students or in a common purpose room if the students are in a summer camp setting.

Materials

Preparation of Sign Lists: The researcher will create a video of several groups of related signs and present them to multiple groups of people: three classes of hearing second grade students (will be issued verbally), as many members of the Deaf community as possible, and at least three classes of college students (including an intermediate, college-level American Sign Language class). This video will show four presentations of the same sign. First each sign will be shown with the survey requesting the rater to guess the meaning of the sign. After the series is completed, there will be a repeated presentation of the first sign with the meaning of the word in written English (where the survey will ask the participant to rate the level of iconicity of the sign), another presentation of the same sign (asking the rater to state how difficult they consider the production of the sign while producing the sign themselves), the word in written English again, followed by the presentation of the sign for the final time (asking the rater to judge the level of enjoyment during the production of the sign). The information will not be directly linked to any individual, but demographic information will also be taken to compare any differences between the different groups that could have an impact on their ratings (age, whether hearing or Deaf, experience level with ASL). Drafts of each script and survey are in the appendix. Following the collection of the surveys, two lists of signs will be compiled of equal standing in difficulty and level of enjoyment of the signs, with the independent variable being iconicity (highly iconic versus low or non-iconic). Any sign that is consistently correctly labeled as its meaning will be placed in the highly iconicity group. Any sign that is consistently mislabeled with something other than its meaning and/or consistently rated as lowly iconic will be placed in the low iconicity group. The data on each of the areas rated for each sign will be presented in a consolidated manner in the appendix.

Sign Language Lesson: The researcher will introduce herself and American Sign Language to the children according the script provided in the appendix. Each class of second graders will be randomly assigned a group of signs to be taught to each of the students (if possible to have both high and low iconic signs for a same group—ex. Animals LOW and HIGH, things you do during the day LOW and HIGH, etc.). For each sign, the researcher will present the sign, voice its meaning, and ask the class to sign along with her. Each child will produce the sign. Two research assistants, who have been trained by the researcher, will assist in monitoring the students and prompting those who are having trouble imitating from the model presented to the entire class. After each of the signs on the first half of the list (highly iconic) have been taught (as many as possible in five minutes, probably three signs), the students will be lead in a game for five minutes that is unrelated to the teaching of signs. Any requests for information about the signs or what the sign is for different members of the group (i.e. wanting to practice the signs or learn the signs for other members of the same group such as other animal signs) will be redirected. If this occurs, the students will be informed that after I come back the following week to see what they remember I will be able to tell them what the signs are for other things. Following the

five minute break, the students will be taught the signs on the other half of the list. After this period of time, the class will review the signs with the researcher. Following this, the researcher and her assistants will assess which signs each of the children has learned by having the child produce the sign from memory or identify the meaning of the sign from a model presented by the evaluator. Each child's assessment will be randomly assigned as to which signs are being assessed from understanding versus producing the sign from memory. (A sample data sheet reflecting acquisition scores is included in the appendix.)

One week later, the researcher and her assistants will return to the school to assess the students' retention of the signs. The same type of data sheets will be used. The same aspects that the child was tested in before will be reassessed. That is, if Child 1 was tested in Comprehension of signs A, B, and Y and Production of C, X, and Z, the same test will be administered again and the data scored. This data will represent the students' retention scores.

SCRIPT ONE: DEVELOPING SIGN LISTS

For adults:

Today I will be showing you a video of various signs from American Sign Language. Each sign will be shown four times. The first time the sign is shown, write what you think that sign might represent. Please do not feel that you need to come up with the correct answer, just write what comes to mind. Many signs do not look anything like what they represent. The second time you see the sign, it will be presented with its meaning in written English. At that time, please rate the sign in the area of iconicity, that is, how much that particular sign looks like what it represents. The third time, produce the sign yourself along with the video and rate how difficult the sign is to produce. The fourth time, rate the sign in how fun it is to produce that sign. Do you have any questions before we get started? [*following administration of the survey:*] Thank you for your time in assisting me with my research project today. All answers are valuable and your time is greatly appreciated.

SCRIPT TWO: DEVELOPING SIGN LISTS

For children:

Today I would like to show you a video of different signs from American Sign Language. Each sign will be shown four times. The first time, I just want you to write what you guess the sign might mean. Don't feel like you have to get it right because some signs don't look anything like what they mean. The second time you see the sign, the video will tell you in English what the sign means. When you see that, tell me how much you think that sign looks like what it means by circling the number of how much it does or does not look like what it means on your paper. The third time, sign along with the video and then tell me how hard it is to make the sign. The fourth time, tell me how fun it is to make that sign. Do you have any questions before we begin? [*following administration of the survey:*] Thank you for helping me with my project. You guys have helped a lot!

SURVEY (ADULT VERSION)

Demographic Information

Age: _____ Gender: _____

Circle one: I am Deaf/H of H/hearing.

I have had _____ years of experience with American Sign Language.

Please rate each sign in the aspects listed in the order given. (Remember: Iconic means how much the sign looks like what it represents.)

SIGN 1

What do you think this sign means? _____

How iconic is this sign?

1	2	3	4	5
Not Iconic				Very Iconic

How difficult is this sign to produce?

1	2	3	4	5
Not Difficult				Very Difficult

How fun is this sign to produce?

1	2	3	4	5
Not Fun				Very Fun

SURVEY (CHILD VERSION)

Background Information

Age: _____ Circle one: Boy / Girl

Circle one: I am Deaf / Hard of Hearing / hearing.

Which one fits you best? Please underline it.

I do not know sign language at all.

I know a couple of words in sign language.

I know some sign language (five to ten words).

I know a lot of signs (over twenty).

I practice sign language very often (Deaf family member that you sign with often).

Tell me what you think about each sign on this video.

SIGN 1

What do you think this sign means? _____

Does this sign look like what it means?

1	2	3	4	5
Not At All	Very little	Kind Of	Yes, after I saw what it means	Yes

How hard is it to make this sign?

1	2	3	4	5
It's really easy	Pretty Easy	Not Easy or Hard	A Little Hard	Very Hard

How fun is it to make this sign?

1	2	3	4	5
Boring	A Little Boring	Not Boring or Fun	A Little Fun	Very Fun

SCRIPT THREE: INSTRUCTION OF THE SIGNS

Hi, my name is Natalie and I'm working on a project for school. I have a couple of helpers with me that are going to help me teach you today. Their names are _____ and _____. I want to teach you a little bit about sign language. Some people don't hear and those people have a different language that uses their bodies instead of using their voices to talk so I will teach you guys some signs that the Deaf use to communicate. Today we'll be learning _____ (animal signs, job signs, daily activities, etc.).

The first sign we're going to learn is _____. Everyone do this. ("Good job!" "You got it!") What does this sign mean again? That's right _____.

The next sign we're going to learn is _____. Everyone copy me. ("Excellent!" You got it!")

This means _____. Right!

Now we're going to learn _____. What does this sign mean? _____.

Right!

[Take a Break]

Next three signs in the fashion described above.

Let's go over all of the signs we learned today. (comprehension of all signs, followed by production of all signs, in random order)

Okay! Now we're going to see how much you guys have learned from our little lesson today. [Separate out students and evaluate] You are awesome! Thank you so much for helping me with my project today! I'll come back next week and visit you guys again. I'll teach you guys a game and any other signs you'd like to learn that we didn't get to today. Thanks again for your help!

DATA SHEET

Bobbie Brown

BB Sign	Comprehends Y/N		Produces Y/N		Given Tiger, Cat and Turtle are the HI and Bear, Dog, and Rabbit are the LO
Tiger		X			Explaining the Data: The black rectangles indicate what kind of knowing was tested for the sign. (i.e. Child 1 was tested in Comprehension of Tiger, Cat, and Dog PLUS Production of Turtle, Bear, and Rabbit) The marks (X) are made in the column of either Yes or No meaning the child could or could not do what was tested. (i.e. Child 1 did NOT comprehend Tiger or Dog, but DID comprehend Cat. Child 1 could NOT produce Bear but COULD produce Turtle and Rabbit.)
Cat	X				
Turtle			X		
Bear				X	
Dog		X			
Rabbit			X		

Alex Jacobs

AJ Sign	Comprehends Y/N		Produces Y/N		Given Tiger, Cat, and Turtle are the HI and Bear, Dog, and Rabbit are the LO
Turtle		X			Explaining the Data: The black rectangles indicate what kind of knowing was tested for the sign. (i.e. Child 2 was tested in Comprehension of Turtle, Tiger, and Rabbit PLUS Production of Cat, Bear, and Dog) The marks (X) are made in the column of either Yes or No meaning the child could or could not do what was tested. (i.e. Child 2 did NOT comprehend Turtle or Rabbit, but DID comprehend Tiger. Child 2 could NOT produce Bear but COULD produce Cat and Dog.)
Tiger	X				
Cat			X		
Bear				X	
Rabbit		X			
Dog			X		

Works Cited

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders* (4th ed., text revision). Washington D.C.: American Psychiatric Publishing.

Barrera, Ricardo D. Lobato-Barrera, Debra, & Sulzer-Azaroff, Beth. (1980). A simultaneous treatment comparison of three expressive language training programs with a mute autistic child. *Journal of Autism and Developmental Disorders, Vol. 10(1),* 21-37.

Capirci, Olga, Cattani, A., Rossini, P., & Volterra, V. (1998). Teaching sign language to hearing children as a possible factor in cognitive enhancement. *Journal of Deaf Studies and Deaf Education, Vol. 3(2),* 135-142.

Carr, Edward G. (1979). Teaching autistic children to use sign language: Some research issues. *Journal of Autism and Developmental Disorders, Vol. 9(4),* December 1979, 345-359.

Grandin, Temple. A personal perspective of autiusm. In F.R. Volkmar, R. Paul, A. Klin, & D. Cohen (Eds.) *Handbook of Autism and Pervasive Developmental Disorders. Vol. 2: Assessment, Interventions, and Policy.* (pp. 1276-1286). Hoboken, NJ: Wiley.

Klima, Edward, & Bellugi, Ursula. (1979). *The signs of language.* Cambridge, Massachusetts: Harvard University Press.

Mitchell, Ross E., Young, Travas A., Bachleda, Bellamie, & Karchmer, Michael A. (2006). How many people use ASL in the United States? Why estimates need updating. *Sign Language Studies, 6,* 306-335.

Tager-Flusberg, Paul, & Lord. (2005). Language and communication in autism. In F.R. Volkmar, R. Paul, A. Klin, & D. Cohen (Eds.) *Handbook of Autism and Pervasive Developmental Disorders. Vol. 1: Diagnosis, development, neurobiology, and behavior* (pp. 335-364). Hoboken, NJ: Wiley.

Evaluating the Use of Spartan in Studying the Effects of Charged Lysine Residues

Mark Lazari

Abstract

Spartan by Wavefunction, Inc. is a powerful computational modeling tool that is used in both the research and academic realms.[1] This study reviews Spartan's ability to run conformational searches on alanine and lysine containing peptides, and compares Spartan's calculated values to those of Gaussian, another computational modeling program. The goal is to begin steps in understanding the effects of protonation of a lysine residue in a string of alanine residues, where lysine will reside either as the amino acid on the N-terminus or the C-terminus of the peptide. The study found that the protonation of a lysine residue placed at the C-terminus stabilized the α-helical structure of the peptide, and destabilization of the α-helix occurred when the protonated lysine residue was placed at the N-terminus. Spartan allows for a more user-friendly approach to conformational searches than Gaussian, and it gives a more graphical view of the conformations. This allows for better viewing of the structures and conformations while simultaneously calculating their thermodynamic data.

Background

Introduction to Computational Chemistry

Computational Chemistry has revolutionized our way of viewing molecules at the quantum mechanical scale by allowing us to simulate various chemical scenarios that are not possible to study in a lab. In Organic Chemistry, the transition states of molecules represent the theoretical structure molecules go through during a reaction. In lab, these transition states cannot be isolated. With Computational Chemistry, the transition states can be modeled, and their thermodynamic properties can be studied in various conditions (e.g. solvents, gas-phase, etc.) and at various temperatures. For Biochemistry, proteins can be better understood in terms of their behavior with other molecules (e.g. an enzyme binding to its substrate), and the structures and conformations of peptides and nucleic acid sequences can be more readily seen and understood via computational simulations. This *in silico* work draws its basis from what we have learned thus far from Physics and Physical Chemistry by bringing in wavefunction theory and various statistical mechanics methods based on quantum mechanics. The details of these theories and resulting mathematical methodologies will not be covered in this paper. For clarity, any mention of "methods" refers to the particular mathematical approach taken to run a calculation. Examples of these methods include but are not limited to semi-empirical AM1, molecular mechanics or MMFF, and density functional B3LYP/6-31G*).

As one might assume, something based solely on simulations from statistics and probability has its advantages and disadvantages. Many of the advantages are listed above, however, the disadvantage is clearly a lack of tangible, reproducible experimental lab results. Many *in silico* studies are done in tandem with experimental data, and many computational programs contain built-in protocols to help researchers better compare experimental data with the calculated theoretical results. By comparing reproducible computational data with reproducible lab data, one can better fine-tune the programming to continually gain more reliable results.

Spartan Review

One program that is used for computational analysis and molecular modeling is Spartan by Wavefunction, Inc. Spartan boasts a more user-friendly interface in terms of modeling and programming, which lowers the learning curve in both the academic and commercial realms of research. The modeling aspect is simple, straightforward, and allows for a wide range of molecules to be built quickly and efficiently. Spartan separates modeling "pieces" in terms of their relative uses, as seen in Figure 1 to the right, which is taken from Spartan '08. One tab in Spartan's build menu is set up specifically to deal with most organic molecule pieces, such as tetrahedral carbon atoms, trigonal pyramidal nitrogen atoms, as well as groups such as benzene rings and carbonyl groups. Another tab allows for more customizability, which is used most often for Inorganic Chemistry. This tab gives the user the ability to choose the atom, its geometry, and its bond type (i.e. single, double, triple, etc.). Spartan's builder also allows for amino acids and nucleic acids to be added individually or in sequence. For peptides, the user has the option to give the amino acid sequence an α-helix or β-sheet conformation as well as choose how to terminate the peptide at both the N-terminus and C-terminus. Using the peptide builder in concert with the other builder tabs, the user can easily adjust the peptide to fit his or her own personal needs.

Once the molecule is built, depending on the version of Spartan one has (e.g. '02, '06, '08), the user can view the molecule in various forms (e.g. ball and stick, tube, etc.), as well as reveal any hydrogen bonding, ribbons for proteins, labels, chiral centers, etc. Using some keyboard shortcuts and keyboard-mouse combinations, the user can also rotate the molecule at a chosen bond, adjust the bond length, and adjust the chirality of given chiral centers. For further customization, the user can lock certain bond lengths, angles, and dihedral angles, and use those constraints as starting points as well as limitations when optimizing the molecule's geometry. One example of this is forcing an ammonia (NH_3) molecule to remain in its trigonal planar geometry, which represents the transition state of ammonia during inversion. This can be seen in Figure 2 below. With these tools, the user can effectively build a molecule, view and adjust its restrictions and conditions, and label the molecule and its constituents for complete customizability all while having an easy to understand visual representation of these changes.

Figure 1: Build Tabs

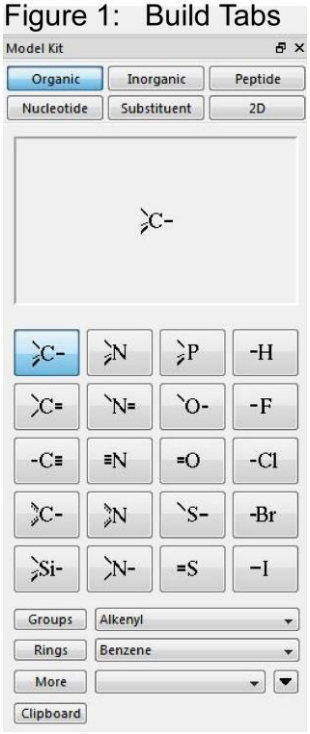
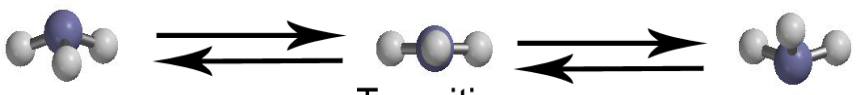


Figure 2: Inversion of NH_3



Transition State

Spartan Calculations

After a molecule has been built, a series of calculations can be done on it that will optimize it in terms of energy. Essentially, the calculations serve to find the lowest energy conformation, or the arrangement of the atoms of a molecule in three-dimensional space. How Spartan does this is dependent on the type of calculation desired, which are explain below. Spartan will also calculate a variety of chemical and physical properties that are common for all molecular modeling programs. The advantage Spartan has over many other modeling programs, however, is the fact that it can calculate and output a molecule's conformations at various energies. This is helpful in analyzing, understanding, and determining the physical representations of organic and biological molecules in both the energetically favorable (high energy) and unfavorable (low energy) conformations.

The calculations used in this study are conformer distribution, equilibrium geometry, and energy (or single point energy). Spartan offers other calculations for transition state analysis, other conformational search protocols, etc. that can be found in the program's handbook. These calculations are used to quickly, efficiently, and accurately determine the most energetically favorable conformations of each polypeptide. The methods are explained in the following sections, but the follow are brief summaries of what each calculation does.

Conformer distribution uses the Monte Carlo method of searching through possible conformations of molecules. The Monte Carlo method is described below. Spartan allows the user to customize the amount of conformations that will be searched through (e.g. a simple two residue peptide has on the order of 200,000 possible conformations) as well as tell Spartan to retain the structures of a given number of those conformations. What Spartan keeps is determined by the amount the user had defined to keep as well as the energy interval designated for the samples. By default, this interval is set to 40 kJ/mol, and only versions of Spartan '06 and above have the ability to adjust the default energy interval value. Spartan will search through and calculate the energies of all the conformations allowed by the user (e.g. 5000 of the 200,000) using the defined method (e.g. semi-empirical AM1) and generate in a separate file the number of conformations defined by the user, assuming it was able to find that many conformations within the defined energy interval. If 100 conformations are kept, Spartan will generate 100 conformations that are within an interval of energies that range from most energetically favorable to 40 kJ/mol higher than the favorable energy (assuming the default energy interval was used). Due to Spartan's graphical nature, these conformations can be easily viewed and judged both in terms of structure and energy. The amount of conformations the computer can search through and store are greatly limited by the computer's RAM capacity and available hard drive space. The speed, aside from the computer's processor quality, is determined by the method for energy calculations set for each conformation (e.g. semi-empirical, molecular mechanics, etc.).

Equilibrium geometry is one of the more straightforward calculations to run using Spartan, and its goal is to simply optimize the geometry of the molecule in terms of energy. What makes Spartan a powerful program is its ability to optimize a series of molecules stored within a given file. For example, if the 100 conformations retained from the conformer distribution calculation were determined using molecular mechanics calculations, and the user wanted to optimize each molecules' geometry in terms of AM1 calculations, the user could simply run each calculation the same as one would for a single

molecule. Spartan would calculate each molecule in the list one at a time until all molecules were optimized. This is called Global Calculations and can be seen in the calculations setup window. Spartan will also continue on to the next molecule if for any reason a molecule fails to be optimized, rather than cancel the entire run due to a single fault. An error would show up once the calculations are complete, and Spartan '08 will show these failed molecules in red in the spreadsheet. Otherwise, for older Spartan versions, the energy values would remain "pending" since the calculations were not completed for the failed molecules.

Energy or single point energy calculations are also straightforward to run in Spartan. They are often used for determining accurate thermodynamic data for each molecule. Often the more powerful methods of calculations are used for this (e.g. density functional B3LYP/6-31G*). Similar to the equilibrium geometry calculation, energy calculations can also be done for a series of molecules. This allows a user to build a peptide, gather 100 conformations within an interval of 40 kJ/mol out of 10,000 conformations searched randomly, optimize their geometries, and gather detailed energy values for each of 100 molecules with minimal setup. The time it would take to do this would only be limited by the computer handling the calculations and the method used rather than the user spending large amounts of time setting up the calculations.

Spartan also has the same breadth of methods and calculations that many other modeling programs have. These range from simple molecular mechanics calculations to a variety of semi-empirical and ab initio methods. The later versions of Spartan add more "point and click" option changes on the calculations screen, however, any custom changes can be programmed in using the Options bar. Here, options like wanting the output data to contain the three-dimensional (3-D) coordinates of the atoms of the molecule, adjusting the conformer distribution energy interval, adjusting temperature values and limitations, adding solvent conditions, etc. can be added or adjusted. Spartan files can hold many molecules, and often it is advantageous to append molecules to a single Spartan file in order to plot energy diagrams, build animations, as well as study and calculate values for multiple molecules more efficiently. Together with its graphical nature, Spartan offers high quality modeling that is intuitive, straightforward, and only limited in certain customization options found in other modeling programs.

Goal

This study aims to analyze the conformations of small polyalanine and single lysine containing peptides as the single lysine residue is protonated. We are studying the effects of the protonation of the lysine on the α-helical nature of peptides when the lysine is placed either on the N-terminus or the C-terminus of the peptide. It is believed that that an α-helical peptide forms a permanent dipole due to the arrangement of the amide formed in peptide bonding, where the N-terminus holds the partial positive charge and C-terminus holds the partial negative charge.[2] This study will test whether the position of the charged lysine residue will have any effect on the α-helical nature of the peptide.

Results from the calculations done with Spartan will also be compared to the results generated from calculations done with Gaussian, which is a comparable modeling program that allows for more custom calculation options but is considered less user-friendly (i.e. has a greater learning curve). Initial usage has shown that because of its graphical nature and greater automation, setting up calculations with Spartan appears to be more straightforward and take less time than the equivalent calculations done with Gaussian.

Materials and General Methods

Three versions of Spartan, by Wavefunction, Inc., were utilized for this study, because of the slight variations in their options and their availability in lab. They were Spartan '02, Spartan '06, and Spartan '08. Spartan '06 was used for the majority of the calculations because of its greater availability. The only differences that exist between the versions of Spartan are the amount of features available for the user and the accessibility of those features.

The computers used for the majority of the calculations were Dell Precision 690 workstations running Microsoft® Windows® XP 64-bit, an Intel® Xeon® 5140 processor @ 2.33GHz, and two PC2-5300 2GB RAM sticks @ 333MHz. Note also that all the calculations done in this study were for molecules in the gas-phase, which is a theoretical consideration. The use of gas-phase calculations eliminates the variability that arises when other molecules are near the peptide being studied. It is important to note that peptides do not naturally exist in the gas-phase.

Peptide Construction and Labels

Multiple residue peptides were tested in this study. The peptides were constructed using the Peptide tab under Spartan's build menu. Here, single amino acids are available as pre-built models to be added separately or to existing models. Also, a sequence of amino acids could be created and organized as α-helix, β-sheet, or some custom formation. For this study, all molecules were constructed with initial α-helical conformations to calculate the energies of conformational changes caused by the protonation of the lysine residue. The sequence begins with the N-terminus and ends with the C-terminus, and each terminus can be protonated or deprotonated by using the terminate command in the build screen. Once the peptide sequence is built and added to the workspace, the N-terminus was N-acetylated ($-C=OCH_3$) and the C-terminus had an OH group added to make it a carboxylic acid. The reason for these additions is to limit the ability of the peptide to be protonated at another site other than at the lysine residue. All peptides, unless otherwise stated, have the N-terminus acetylated and the C-terminus as a carboxylic acid, and the order in naming and organizing the peptides will be N-terminus to C-terminus (e.g. AK is a two residue peptide with alanine at the N-terminus that is acetylated and a lysine at the C-terminus as a carboxylic acid). Since the study aims to see the conformational changes resulting from the protonation of the lysine residue, both the protonated and deprotonated forms of the peptides were built. To distinguish between the two, an H was added at the end of the label (e.g. for the AK peptide, AKH would be the protonated version). These labels will be used throughout this report, though this form of labeling is not conventional.

Results, Discussion and Detailed Methods

Conformer Distribution

Once a peptide was properly built (see Peptide Construction and Labels), the peptide was put through the conformer distribution calculation. The calculation methods used were both molecular mechanics (MMFF) and semi-empirical (AM1) methods. The test was to see what would be the most efficient method of testing through the Monte Carlo method, which is described below.

For the MMFF method, the calculations take far less time, and thus more conformers can be searched through in a given time interval. The molecule of choice for the testing was the four residue peptide A3KH (i.e. A3 corresponds to three consecutive alanine residues). The conditions of the calculation were these:

CONFSEXAMINED = 10000 CONFSKEPT = 50 MAXENERGY = 5 PRINTCOORDS

with CONFSEXAMINED and CONFSKEPT as options available on the calculation screen for Spartan '06 and above, representing the amount of conformations to search through, and how many to keep, respectively. MAXENERGY refers to the energy interval to search through (see Spartan Calculations in the Background section, and note that Spartan '02 does not have this option), and the PRINTCOORDS simply displays each atom's 3-D coordinates in the output. The peptide was subject to symmetry in order to begin conformation variation from the initial α-helix built (see Peptide Construction and Labels above), and the thermodynamic data was printed as well.

For the AM1 method, the above conditions were identical except the method was set to semi-empirical AM1 rather than molecular mechanics MMFF. On the computers used in this study, the MMFF calculation took between 3-5 hours to complete, while the AM1 calculations took almost a week. Due to the nature of the calculation methods, the energy values were not able to be directly compared, therefore, the MMFF conformations displayed were also run with AM1 equilibrium geometry in order to run the extra AM1 calculations the AM1 conformer distribution underwent. To remain consistent, the AM1 calculation also had an AM1 equilibrium geometry calculated on it, though it had little to no effect, which was expected.

The reason the AM1 calculation took much longer lies within the fact that each of the 10,000 conformations that were searched through had their geometries optimized with AM1, whereas for the MMFF method, only the 50 conformations that were kept had to be optimized with AM1 in order to be comparable to those initially run with AM1. Initially running MMFF proved to be the most efficient method, and the results of the most energetically favorable conformations from each test were within five significant figures in kcal/mol (Table 1 below shows a different molecule as an example). However, the conformations that resulted from each method were different, which is in the nature of the Monte Carlo method. Analysis of conformation vs. energy is discussed below in the Helical Nature vs. Energy section.

To better study the differences in methods, a systematic approach is necessary that is considered reproducible. This is in contrast to the Monte Carlo method, which is not reproducible when using a large data set. The Monte Carlo method allows a random sample to be tested, thus giving the user a greater chance of avoiding being caught in local energy wells, which is a common issue with the systematic approach. The systematic approach allows for a predetermined sequence of calculations to be run in order for a reproducible result to be obtained from any consistent starting point (see Spartan Handbook). The systematic approach was not tested at this stage, though Spartan does have the ability to run such a protocol.

MaxEnergy

Extensive tests that did not use the MAXENERGY option for the conformer distribution calculation revealed that the program does indeed give the user an interval of conformation energies equal to 40 kJ/mol. When the MAXENERGY option was used to limit the value to 5, the program seemed to have adjusted the range to 5 kcal/mol instead. The reason behind has not yet been found, but it could have something to do with the program deciding what units would be best for the given molecule. It also could have been a coincidence, and other tests have shown that Spartan seemingly ignored the maxenergy command (see Helical Nature vs. Energy below and compare energy ranges). More tests need to be run with Spartan ’06 or above, which have the MAXENERGY option.

Comparison to Gaussian

The reliability of Spartan was tested against another modeling program, Gaussian, which was used and verified by Dr. Jianhua Ren's research team at the University of the Pacific in California. Gaussian '03 was compared to Spartan '06 in regards to energy calculations of the conformations that were determined from Spartan '06. The peptides tested were AK and AKH, both of which had 20 conformations kept from a pool of 3,000 conformers searched using the conformer distribution calculation with the AM1 method. The 20 conformers' geometries were optimized using AM1, and the energies were calculated using the density functional B3LYP/6-31+G* method. The optimization and energy calculation aspects were done separately using each of the programs to determine an energy value for each conformer in Hartrees, where one Hartree is equal to 627.509 kcal/mol. Below is a list of these energies for comparison:

Table 1: Energy Comparison of Gaussian '03 and Spartan '06

	Gaussian '03		Energy in Hartrees	Spartan '06	
Molecule	AK	AKH		AK	AKH
1	-897.035	-897.430		-897.036	-897.430
2	-897.024	-897.416		-897.024	-897.425
3	-897.015	-897.420		-897.015	-897.416
4	-897.021	-897.420		-897.021	-897.420
5	-897.018	-897.418		-897.018	-897.426
6	-897.028	-897.418		-897.028	-897.423
7	-897.029	-897.426		-897.029	-897.425
8	-897.024	-897.421		-897.024	-897.413
9	-897.017	-897.420		-897.017	-897.413
10	-897.027	-897.411		-897.027	-897.418
11	-897.020	-897.419		-897.021	-897.418
12	-897.033	-897.427		-897.033	-897.441
13	-897.019	-897.409		-897.019	-897.420
14	-897.027	-897.438		-897.027	-897.435
15	-897.028	-897.432		-897.028	-897.432
16	-897.030	-897.426		-897.030	-897.432
17	-897.041	-897.428		-897.041	-897.431
18	-897.025	-897.430		-897.025	-897.428
19	-897.037	-897.430		-897.037	-897.430
20	-897.030	-897.425		-897.031	-897.428

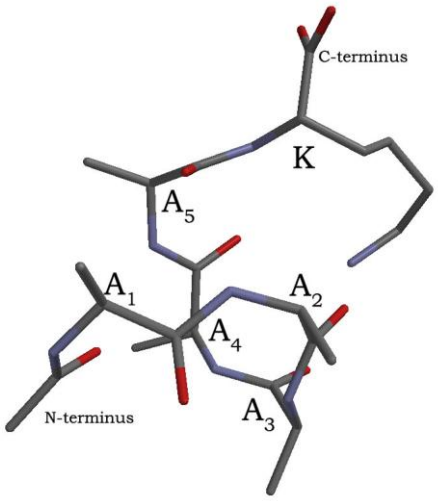
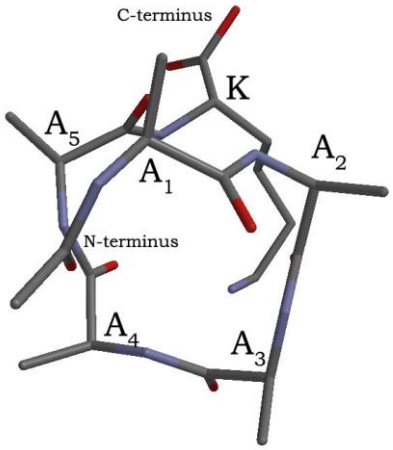
Table 1. Energy was calculated using B3LYP/6-31+G* after optimization with AM1 from each of the respective programs. The initial 20 molecules came directly from a conformer distribution calculation using AM1 from Spartan '06 of both a protonated and deprotonated lysine of an alanine and lysine containing peptide that was acetylated on the N-terminus and had a carboxylic acid as the C-terminus.

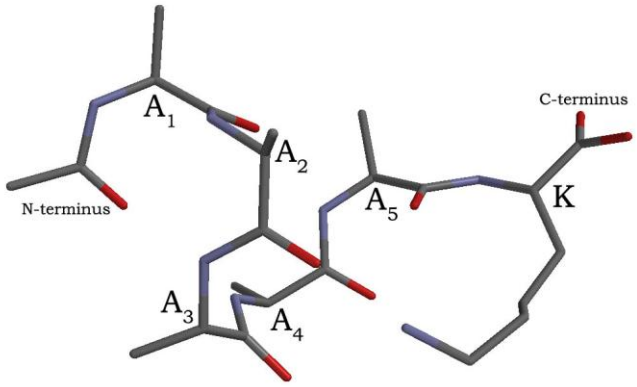
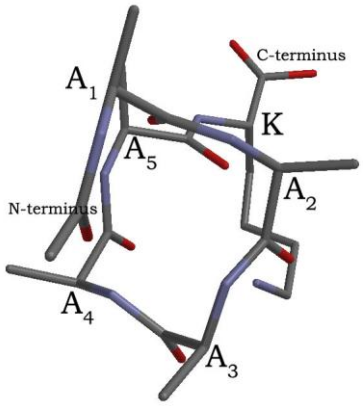
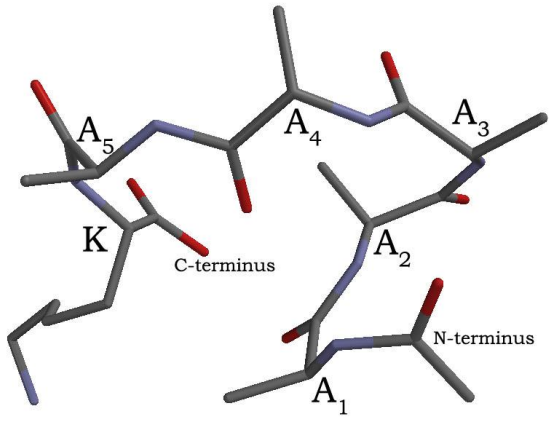
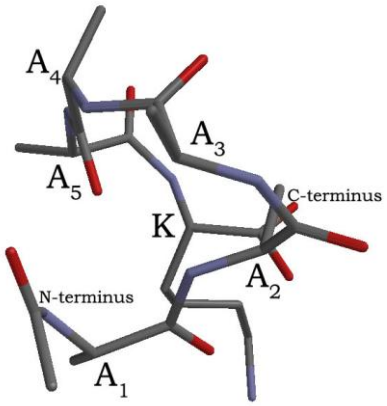
From the above table, the differences in energies between the values obtained from Gaussian and Spartan occur at the fifth or sixth significant digit. The reason for these changes must be in the subtleties within the calculation process and programming rather than the actual equations used in the methods. This allows these programs to be used in tandem with each other based on the needs and preferences of the user. For example, Spartan can be used to run the conformational search while Gaussian can be used to optimize them, or Spartan can optimize and Gaussian can do further analysis with custom calculations not available in Spartan.

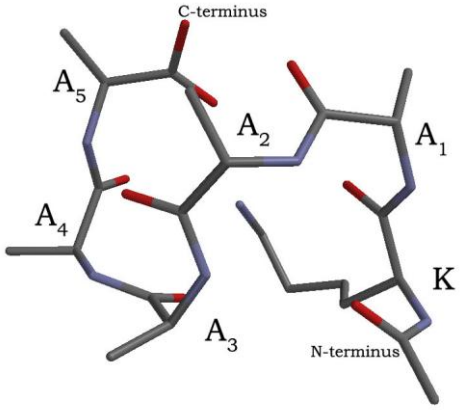
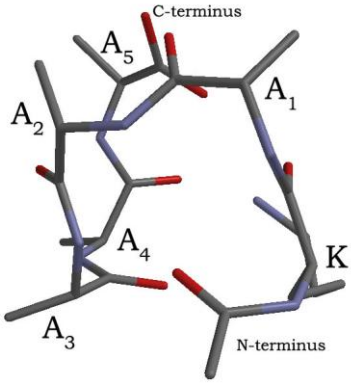
Helical Nature vs. Energy

Through various conformational searches, it seemed somewhat evident that the lower (i.e. more negative) energy does correlate to a helical structure of a peptide. Since all these studies are in the gas-phase, the conformation, orientation, intra-molecular forces, etc. of the peptides determine its relative energy, rather than interactions with solvent molecules or other intermolecular forces. Though peptides occur in α-helical and β-sheet conformations in protein folding, in the gas phase, it is not necessarily certain that the lowest energy conformation must be α-helical, let alone β-sheet. Below are six conformations. Three come from A5KH and three from KA5H (see Peptide Construction and Labels for naming rules). The three conformations consist of the two most energetically favorable and the least energetically favorable when 10,000 conformers were searched through using conformer distribution using MMFF. Spartan kept 200 conformations, which were then optimized using AM1 equilibrium geometry. The MAXENERGY command was also set to 100, though it seemed not to have any affect.

Table 2: Helical Nature vs. Energy Comparison

Molecule	Energy (kcal/mol)	Side View	Through the Center View
Most energetically favorable	-256.702		

Next energetically favorable	-256.339		
Most energetically unfavorable	-194.603		

Most energetically favorable	-250.250		

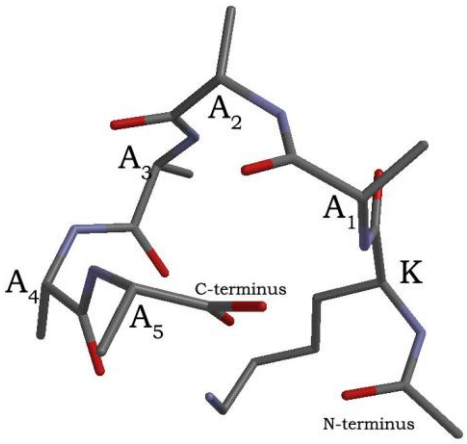
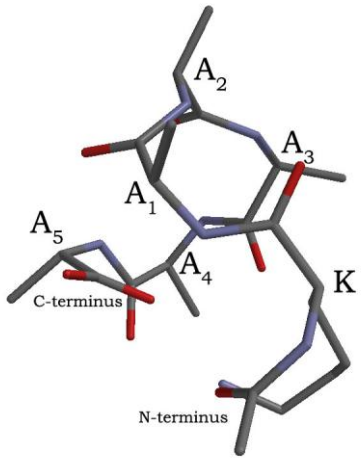
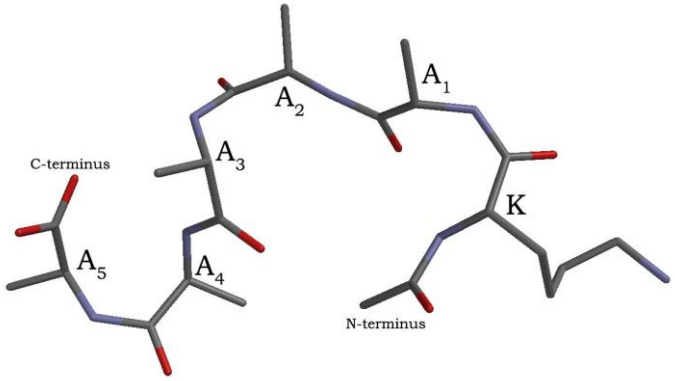
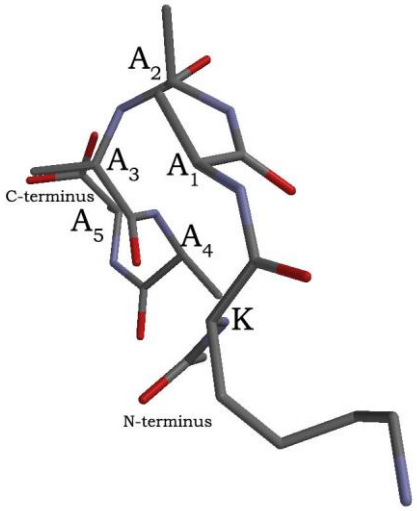
Next energetically favorable	-249.979		
Most energetically unfavorable	-191.793		

Table 2. *The hydrogen atoms have been removed and the style of model is tube in order to show the structure with the least amount of clutter while still maintaining a clear view of the molecule. Two different views are offered for each peptide as well as labels to help identify the location of the amino acids as well as the N-terminus and C-terminus. Purple is nitrogen, red oxygen, grey carbon, and double bonds and possible hydrogen bonding are not shown.*

From this sample, it is clear to see that the A5KH, which has the charged lysine residue placed at the negatively charged end of a possible permanent dipole, maintains somewhat of a helical shape when viewing the most energetically favorable conformations. The most energetically unfavorable of the A5KH conformations searched through does not form a helix.

KA5H seems to lose its helical shape regardless of energy. KA5H does show that the two energetically favorable conformations are quite different in shape, though similar in energy. The most energetically unfavorable KA5H conformation shows a more unraveled peptide, which results in a loss of any form of helical nature.

The results here are not conclusive by any means, but serve more as a stepping stone for further research on these peptides. There appears to be evidence that placing a positively charged species near the negative end of the permanent dipole seems to stabilize the helical nature of a peptide, whereas placing the same charged species near the positive end on the permanent dipole seems to disrupt the peptide's helical nature. Also, from the KA5H, there seems to be evidence pointing towards a discrepancy in assuming that energetically similar conformations would also be similar in shape. This seems true for A5KH, which appears to be most stable in the helical nature, thus the most energetically favorable conformations would be suited best in the helical form. This is not true for KA5H, which seems disrupted by the position of the charged lysine residue.

Issues and Errors

RAM

RAM stands for random access memory, and it is used to store information that will be sent to the central processing unit (CPU) for calculation. Spartan requires more RAM as more conformations are needed to be searched through. Preliminary tests were run with only 1GB of RAM in each of the computers, and this proved to be quite difficult when larger peptides needed to be calculated. Spartan shows the error of having insufficient memory to continue the calculations. To remedy this, the computers were upgraded to 4GB of RAM each, and this allowed for more conformations to be run for larger peptides.

Spartan Crashes

Occasionally when running calculations on sets of peptides (e.g. after a conformational search), Spartan will finish the calculation and yet show an error message upon completion. What this often means is that Spartan was not able to finish the calculations on all of the molecules, but it was still able to complete others in the set. If no particular issue was found for the failed peptides, sometimes rerunning the calculation solved the problem. Some things to check are charges and multiplicities, as well as any constraints that may not be applicable to all of the molecules in the set. This study was not able to determine all the reasons for the errors.

Monte Carlo Method

The Monte Carlo method is a powerful tool used to run the conformer distribution calculation. This method uses a statistical mechanics approach to randomly sort through potential energies. For conformational searches, the Monte Carlo method allows the user to search a population of conformations at random, in order to gain a more uniform look at the sample as a whole. With systematic methods, predefined patterns are used to move a molecule through potentials, so as to create a reproducible approach to searching through conformations. The Monte Carlo method uses the previous conformation's potential as it searches, to determine whether or not to keep the value or reject it. In terms of the conformational search, it seems as though the method takes the potential of the previous conformation, puts it into an equation if the potential is higher than the previous, and compares the output to a randomly chosen number, and in this way the program randomly keeps potentials that are not always moving towards a lower energy, in order to avoid getting caught in local minima energy wells. According to Atkins and De Paula, $0 < e^{-\Delta V/kT} < 1$, where ΔV is the change in potential energy (which is positive if the next potential in the series is higher than the previous), k is Boltzmann's constant, and T is the temperature.[3] The method must then generate a random number between 0 and 1, and compare the value obtained with the random number. Due to this randomization, local energy wells can be avoided, but the results are not reproducible or necessarily reliable to

be the lowest energy. Therefore, it is recommended that the Monte Carlo method be repeated to in order to obtain a accurately expressive set of conformations.

Conclusion

Spartan is a powerful computational program that allows for a variety of calculations to be done, including the valuable conformational search. The energy calculation values match with those of Gaussian, another computational program that can offer more detailed calculations and protocols, but Gaussian is not as user-friendly as Spartan.

If the alanine and lysine helical peptides do form a permanent dipole where the N-terminus holds the positive end and the C-terminus hold the negative end, then putting a protonated (i.e. positively charged) lysine residue at the C-terminus seems to stabilize the helix whereas placing the charged lysine at the N-terminus seems to disrupt the helix. More calculations and examples need to be performed to test this hypothesis, but this study has shown that helical stability can be seen and calculated using Spartan.

The next step would be to study the proton affinity of the lysine residue as well as test more conformations to see how the charged species affect the helical stability of these peptides.

Acknowledgements

Special thanks to the Chemistry Departments at both the University of the Pacific and California State University, Stanislaus for providing the computers and software necessary to perform this study, and to Dr. Jianhua Ren under whose auspices this study was possible, and to Dr. Scott Russell for providing for the RAM.

References

(1) Spartan. *Wavefunction, Inc.* 2008. http://www.wavefun.com/index.html

(2) Oommachen, S., Ren, J., and Michael McCallum, C. Stabilizing Helical Polyalanine Peptides with Negative Polarity or Charge: Capping with Cysteine. *J. Phys. Chem*. 2008. *112*, 5702-5709.

(3) Atkins, P., DePaula, J. *Physical Chemistry*. 8th Edition. W.H. Freeman and Company, 2006. Page 607.

Conformational Preference of 2,2'-Dinitrodiphenyl as Determined by Proton NMR Spectroscopy

Grant Langlois

General Theory

Valence Shell Electron-Pair Repulsion (VSEPR) theory has been regarded for decades as a highly successful, albeit non-quantitative model used to predict molecular geometries.[1] The VSEPR model bases its conjectures on the simple modeling of repulsive forces between electron pairs surrounding a central atom. As two charges of the same sign—positive or negative—are brought closer together, each charge feels a greater and greater repulsive force due to the electric field produced by the other charge. Under simple electrostatic treatment[2]:

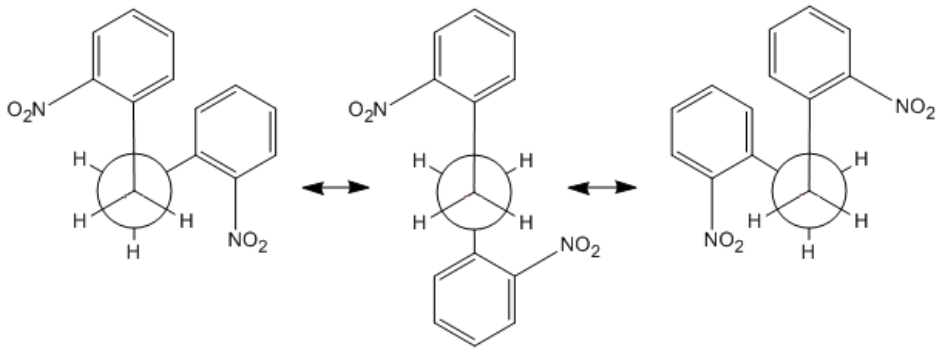
$$\vec{F}_{12} = q_1\vec{E}_2$$

This general idea can be likened to electron pairs, atoms, or substituents in a molecule: these differing electron "clouds" tend to orient themselves in a way so that the least amount of repulsion between their respective charges occurs.[3] By combining the predicted models of multiple central atoms, one can obtain a reasonable picture of conformation: how a more complex molecule will be oriented in space.

However, as with many theories, serious exceptions to the guidelines put forth by VSEPR theory exist. For example, the possible conformations of 1,2-Difluoroethane, depicted through Newman projections, are as such:

The VSEPR model in this case would predict the middle *anti* conformation as the most stable and most energetically favorable. However, experimental data has shown that the most stable conformer of this compound at room temperature is that of the possible *gauche* conformations[4] shown at the left and right, in direct conflict with this model. This concept is called the "gauche effect," in that the compound adopts a conformation with the most *gauche* interactions between substituents.[5] Numerous reasons could account for why this effect occurs. When analyzing the conformation of any compound, the task lies in explaining why this effect or any other perceived oddity happens. Within this framework, laboratory procedures is primarily geared toward determination of conformation, while actual "book research" is geared toward explaining the reasons for conformation.

The compound in question is 2,2'-Dinitrodiphenyl, with possible conformations:



1a **2** **1b**

The VSEPR model would predict the conformation resembling that of **2**, but it is possible that perhaps the most stable conformation is that of the **1a** or **1b** conformers, those exhibiting a gauche effect. There are many possible reasons for the occurrence of a more stable conformation of 2,2'-Dinitrodiphenyl with its substituent groups oriented *gauche* to each other.

First and foremost is the possibility of stabilization through hyperconjugation. This phenomenon occurs due to an interaction of the bonding and anti-bonding orbitals of two vicinal substituents of the ethane system.[6] In the compound of interest, each phenyl ring is greater stabilized through the donation of electron density into its ring, meaning it strongly attracts electrons being shared with electron-donating substituents, such as those from the alkyl group in this case, and so its anti-bonding acceptor orbital will interact with any coplanar carbon-hydrogen bonding donor orbital in the ethane molecule. In addition to this, the nitro group on each phenyl ring is strongly withdrawing, increasing the substituents' pull of possible donor electrons due to the depletion of electron density from the aromatic ring. Confirmation of the presence of a gauche effect within the molecule, a preferred conformer similar to **1a** or **1b**, could be explained by the presence of the two coplanar bonding-anti-bonding interactions, as opposed to the absence of this effect altogether in conformer **2**.

However, if the more stable conformer is more similar to that of **2**, a different explanation would be needed, and the VSEPR model would come back into play. In this case the important factor at work would simply be coulombic repulsion. Again, sites of high negative charge density exist in the phenyl rings. The repulsion of these two like charges would yield the preferential conformations as noted previously, with the least number of *gauche* interactions between substituents.

Another explanation of a more stable *anti* conformer would be because of steric hindrance. The nitrophenyl substituents are free to rotate around their bonds with the ethane backbone, but they are bulky, and would require more energy in order to rotate if they are situated *gauche* to each other, rather than *anti* due to the electron clouds experiencing a strong repulsion.[7] The *anti* conformation could subsequently relieve this steric congestion and yield an overall

decrease in energy, making it the preferred conformer.

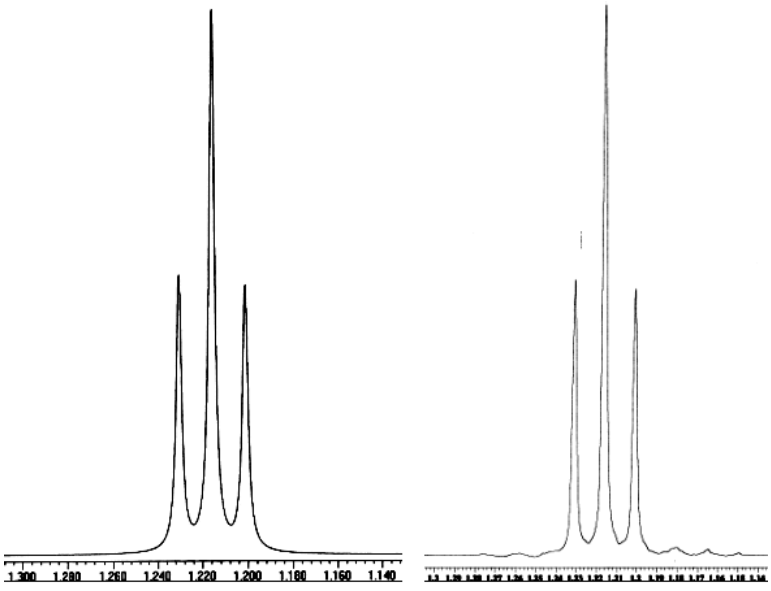
Finally, the importance of the solvent used to obtain NMR spectra is one other conformation-influencing factor that needs to be addressed. Initial laboratory work suggests that 2,2'-Dinitrodiphenyl dissolves in relatively non-polar solvents and aprotic polar solvents despite the large dipole moment associated with a nitro substituent on each phenyl ring. This is evidence already of possible conformational preference; this preference may still change due to interaction with the solvent.

In summation, there are many different and important effects to look for within analysis of the conformational preference of 2,2'-Dinitrodiphenyl, and confirmation of one preference would allow for subsequent further analysis of the effect of the placement of the nitro groups on the conformation of the molecule.

Procedure

2,2'-Dinitrodiphenyl, a solid in powder form, was purchased from TCI America with a purity of at least 98.0% measured by Gas Chromatography. Samples prepared for analysis by the JEOL 500 MHz NMR Spectrometer were approximately 0.2 M in concentration, requiring at least 41 milligrams of compound in 0.75 milliliters of solvent. If greater resolution in the NMR spectrum or better dissolution into the solvent was required, the concentration was reduced to approximately 0.1 M. ^{1}H spectra were taken at 25 °C in the deuterated solvents $CDCl_3$, Acetone-*d6*, DMSO-*d6*, and Acetonitrile-*d3*, each with TMS serving as a reference at 0.00 ppm. Each spectra acquired was comprised of thirty-two scans of approximately 8,000 data points, and the line broadening and zero-fill spectrum parameters were set to 0.0 Hz and 4, respectively. These latter two specifications were modified slightly to increase or decrease resolution of the spectrum if necessary.

All spectra obtained were then duplicated using an NMR spectra modeling software known as gNMR, which, when completely duplicated, yielded the vicinal and geminal *J*-values for the splitting patterns in question. For example, the duplicated spectrum of one peak of the compound 1-Ethyl-2-nitrobenzene is on the left, with the real spectrum on the right:



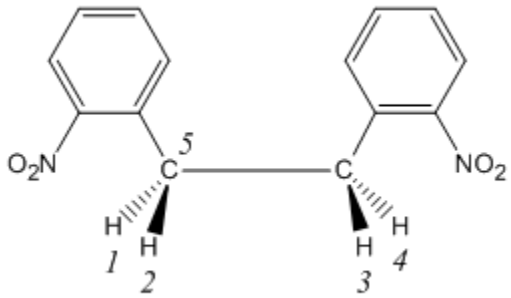
In this case, the splitting patterns of the carbon satellite peaks present in this compound were analyzed, resulting from the 1% probability of one of the carbons in the ethane backbone being a ^{13}C isotope. Their interactions with hydrogen atoms in the compound yield a splitting pattern with a frequency of ~150 Hz.

Lambda values used in the Altona Equation[8] are then left to be calculated for each of the substituents involved. Since the only substituent of the compound in question is the nitrophenyl group mentioned previously, ^{1}H NMR spectra of 99.0% 1-Ethyl-2-nitrobenzene, a liquid, was obtained and analyzed in each solvent analyzed previously using the same concentrations.

From all calculated *J*-values and Lambda values for 2,2'-Dinitrodiphenyl in each solvent, the Altona equation would be used to calculate the statistical weights of the possible conformations of the molecule. The Altona equation used in this part of the experimental data acquisition period is in the form of a programmed Mathematica worksheet.

Results

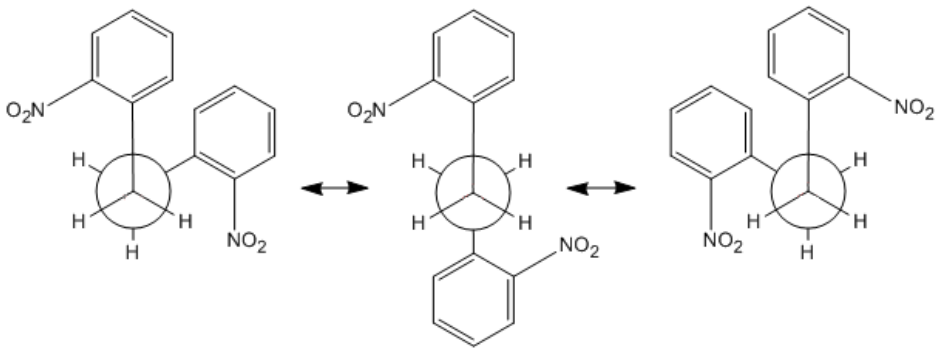
Conformational preferences of the compound in question, 2,2'-Dinitrodibenzyl, along with the *J*-values at 25 °C determined from the analysis in gNMR were found to be as follows, in order of increasing polarity of solvent:



Deuterated Solvent	***μ (D)*[9]**	***J_{13}, J_{24} (Hz)***	***J_{14}, J_{23} (Hz)***	***λ***	***Total % Gauche***
Chloroform	1.8963	10.47 ± 0.22	5.32 ± 0.25	0.82	29 ± 5
Acetone	2.88	10.22 ± 0.22	5.58 ± 0.24	0.48	36 ± 2
Acetonitrile	3.92519	9.28 ± 0.11	6.30 ± 0.11	0.48	48 ± 3
DMSO	3.96	9.10 ± 0.14	6.42 ± 0.12	0.48	50 ± 3

Discussion

Results for the *J*-values of the different coupling interactions present in 2,2'-Dinitrodibenzyl suggested initially that the conformation was more or less independent of the solvent; however, the differing lambda values coupled with this information yielded a large statistical difference in the percent *gauche* for each solvent. The data shows an increase in the overall conformation's *gauche* character as the polarity of the solvent increases, and by a rather significant amount. However, the total conformation still has a much larger *anti* character overall:



~15-25% **~50-60%** **~15-25%**

This preference is clearly explainable under the VSEPR model, although using this model may not yield all of the information possible. This finding may also substantiate the effect of steric hindrance — the bulky nitrophenyl groups make complete bond rotation in the molecule difficult. The results, in general, are nothing unexpected, but the dependence upon solvent polarity is something important to look into. It is perhaps possible that if the solvent is polar enough, and assuming the solvent can effectively dissolve the compound, the *gauche* conformer of 2,2'-Dinitrodibenzyl an become statistically favorable.

Conclusion

2,2'-Dinitrodibenzyl is significant in the realm of conformational studies in that the *J*-values determined between the different atoms on the ethane backbone deviate significantly enough from the expected value of ~7 Hz to expect a conformation either strongly *anti* or strongly *gauche*, as calculated through the use of the Altona equation. Hence, a specific conformational preference was to be expected for this compound, and it was exhibited: 2,2'-Dinitrodibenzyl is preferably *anti* in its conformation. However, the *gauche* character appears to increase with increasing solvent polarity, and this aspect warrants further investigation.

References

[1] Box, V.G.S. *J. Mol. Model.* 1997, *3*, pp 124 – 141.
[2] Griffiths, D.J. *Introduction to Electrodynamics*, Upper Saddle River: Pearson Prentice Hall; 1999.
[3] McMurry, J.; Fay, R. *Chemistry***,** Englewood Cliffs: Pearson Prentice Hall; 2003.
[4] Craig, N.C.; Chen, A.; Suh, K.H.; Klee, S.; Mellau, G.C.; Winnewisser, B.P.; Winnewisser, M. *J. Am. Chem. Soc.* 1997, *119*, pp. 4789–90.
[5] Wolfe, S. *Acc. Chem. Res*. 1972, *5*, pp 102 – 111.
[6] Dale, J. Stereochemistry and Conformational Analysis, 1978; p. 69.
[7] Wade, L.G. *Organic Chemistry*, Upper Saddle River: Pearson Prentice Hall; 2006.
[8] Haasnoot, C.A.G.; de Leeuw, F.A.A.M.; Altona, C. *Tetrahedron*. 1980, *36* (19), pp. 2783-92.
[9] *CRC Handbook of Chemistry and Physics*. Various eds**.** Boca Raton: CRC.

Is Porcine Pancreatic Elastase a Suitable Model for Human Leukocyte Elastase?

Erik Todd, Mark Lazari, and Koni Stone

Human Leukocyte Elastase (HLE) has recently been implicated as a poor prognostic marker in certain breast cancers and as a key component involved in Chronic Obstructive Pulmonary Diseases. Because HLE is so expensive, Porcine Pancreatic Elastase (PPE) has been used to model elastase activity and inhibition. This paper elucidates the differences and similarities between HLE and PPE through enzyme activity assays, protein sequence alignment, and specificity comparison. In addition, PPE is a nonglycosylated protein which is secreted as a zymogen, where HLE is glycosylated at two positions and is released as a series of isoenzymes. The enzyme activity assays help to prove that HNE and PPE have different substrate specificities. HLE prefers valine while PPE prefers alanine. The two proteins, when aligned using uniprot, show only a 47% similarity.

Enzymatic activity is essential for the activity of most, if not all, biological systems. Enzymes allow for the most specific and efficient use of nutrients and energy required for living systems to maintain their peak activity while other stresses in the environment threaten them.[1] The enzyme this study focuses on is elastase in human leukocytes. Elastase, which gets its name from its specificity to break down elastin, is a proteolytic enzyme that is naturally inhibited by the binding of alpha-1 Protease Inhibitor (α-1PI). When α-1PI is oxidized it no longer binds elastase which causes elastase to become activated. During tissue remodeling (wound healing) H_2O_2 is produced and it provides the mechanism for α-1PI oxidation.1 Elastin is a key component in keeping parts of the body flexible, such as the elasticity in the skin and in the lungs.

The loss of this elasticity can have substantial effects on the body. In the lungs, elastin maintains the ability of the connective tissues connecting the air sacs to expand and contract. If the α-1PI is oxidized outside of normal remodeling, the lungs could lose their ability to perform their function of breathing; this results in a family of diseases called Chronic Obstructive Pulmonary Diseases (COPDs). Cigarette smoke and other environmental pollutants oxidize α-1PI and thus activate elastase, which causes undamaged elastin to be broken down faster than it is resynthesized.

Neutrophil elastase has also been found in high concentrations in human breast cancer cells. One such breast cancer is the MDA-MB-231 strain.2 In this context, elastase plays a different role. Elastase cleaves 50-kDa cyclin E into a more active 35-kDa cyclin E. The presence of 35-kDa cyclin E has been associated with a poor prognosis in patients with the MDA-MB-231 breast cancer3

Cyclin E is a cell cycle protein which is required to send the cell into the S-phase of division. The lower molecular weight cyclin E (LMW) is more active than the higher molecular weight cyclin E (HMW). As a result, cells with a predominance of LMW will progress through the cell cycle more rapidly inducing a tumerous cell. Based on the cleavage locations of the LMW it was

[1] Lazari et al. (2009

1 Lazari et al.

2 Nguyen et al.

3 Nguyen et al.

determined that the enzyme responsible is a protease of the elastase family. To confirm this, wild type Cyclin E was partially digested using porcine pancreatic elastase. The digested cyclin E was analyzed using Western blot and compared to the in vivo cyclin E from tumor cells. The band patterns for the two digests were similar and showed nearly the same LMW products.4

Indole-3-Carbinol is a natural product found in cruciferous vegetables. Studies performed by Firestone et al. have indicated that I3C arrests G_1 cell-cycle progression in estrogen-responsive and unresponsive human breast cancer. I3C acts by fostering the accumulation of HMW as opposed to LMW. Western blot analysis indicates that MDA-MB-231 cancer cells treated with I3C show a significant decrease in the concentration of LMW. With the knowledge that elastase cleaves cyclin E, Western blot and chromogenic assays were performed to determine if I3C inhibits elastase and, if so, how it inhibits. Both assays reveal that the I3C arrests G_1 cell-cycle progression by binding elastase in a noncompetitive fashion.5

Studying Indole-3-Carbinol, and its binding to elastase was the important next step. Crystallographic studies appeared to be the best suited to analyze the inhibitory binding site of elastase to I3C. Approximately 20ug of HLE from Sigma Aldrich costs $112, and since milligram amounts of protein are needed to grow a proper crystal the use of human leukocyte elastase (HLE) is too expensive. Due to the cost associated with using HLE, porcine pancreatic elastase (PPE) was considered for use in crystallography binding studies because of its cheaper price, 10mg of PPE from Elastin Products Company costs $57.

Before the PPE could be used, it had to be verified that PPE models HLE. An assay was created using PPE to study the inhibition of PPE with I3C. The assay was adapted from Gestin et al.6 The substrate used for the PPE was n-succinyl-ala-ala-ala-p-nitroanilide (SANA), a chromogenic substrate which releases a yellow color when cleaved by the elastase. Thus the kinetics, or rate of reaction, can be measured and the mode of inhibition can be determined.

Methods

PPE and SANA were found to be moderately soluble in water so Trizma-base buffer was used in the assay. The trizma buffer was titrated to a final pH of 8.0 using concentrated hydrochloric acid. The PPE was kept at a concentration of 0.508 units/mL and the concentration of the SANA varied and was comprised of four values which varied between 0.1 and 0.5 µmol/mL. The inhibitors were used at concentrations of 0 and three others ranging between 0.1 and 0.5 µmol/mL. Using a 1 mL quartz cuvette and a Varian Cary 100 Bio UV-Vis Spectrometer, the kinetics of the cleavage of SANA with PPE was monitored at 380nm. The graph of absorbance versus time was displayed. Absorbance is proportional to the concentration of the cleaved SANA. As the absorbance increases, the concentration increases and as the change in absorbance increases the rate of the cleavage of SANA increases. The slope of the initial straight portion of the graph is the value of the initial rate. Each concentration of substrate gave a different rate, and these were plotted as a Lineweaver-Burk graph, inverse of the initial rate versus the inverse of the concentration of the SANA. This is the common method for testing the mode of inhibitors for a specific enzyme.

Results

This experiment was performed on 28 separate occasions using a series of slight modifications, including concentration and temperature adjustments. Each time the experiement was performed, the results were erratic but followed a similar pattern (Figures

4 Porter et al.

5 Nguyen et al.

6 Gestin et al.

1 and 2). There was no trend distinguishable in the difference of the different trials, nor was there a trend found on the Lineweaver-Burk plot. Of the 28 experiments performed none showed any inhibition of the PPE with the I3C. After a great deal of experimentation no advancements were made on the project.

Through a search of literature a potential answer was found. In 1987 a paper was published in the Proceedings of the National Academy of Sciences (PNAS) which posed the potential answer. The PPE is secreted as a zymogen, it cleaves N-side alanine residues, it is sensitive to increased ionic strength, and synthesized as a nonglycosylated protein. HLE is a lysosomal enzyme which is electrostatically bound to an insoluble polysaccharaide matrix, it cleaves at bulkier side chains such as valine, and it degrades elastin more slowly than PPE. In addition to this, the HLE shows increased activity at higher ionic strength, is synthesized as a series of isoenzymes, and it is inactivated by fatty acids and activated by fatty alcohols.7

This indicates that it may not be possible to use PPE as a model for HLE; therefore, an experiment was designed to test this comparison. Using a method for HLE assays which was adapted from Firestone et al.[3], PPE was compared to HLE. Rather than using the SANA, a different substrate, n-methoxy succinyl-ala-ala-pro-val-p-nitroanilide, was used because it is the standard substrate for HLE activity assays. The final concentration of cleaved substrate was monitored and compared.

New Method

For both human and porcine elastases, the concentration within the well was 5 x 10^{-5} units. The substrate concentrations were 0.5, 3.0 and 5.0mM. Three concentrations of the inhibitor were also used at values of 0, 25, and 50 µM. The substrate and the inhibitor were dissolved in dimethyl sulfoxide (DMSO) for solubility purposes. 100mM Trizma-HCL buffer system was used with 250 mM sodium chloride (NaCl) at a pH of 7.5, pH adjustments made using concentrated hydrochloric acid.

New Results

After allowing the solutions to incubate for 10 minutes at 37°C, they were allowed to return to room temperature and the absorbance at 410 was measured. The HLE shows an interesting trend which may be attributed to the progression of the elastase cleaving the substrate(Figure 3). When the PPE was analyzed, there was no cleavage detectedThus PPE does not cleave at the valine sites that HLE does.

The amino acid sequences of HLE and PPE were compared to one another using EMBOSS (Figure 5). The results of this analysis indicate that there is only a 47.1% similarity in amino acid sequence between the two proteins. There are identical matches of only 99 of the 295 amino acids (33.6%). These two proteins do, however, share the same active site amino acids but the surrounding amino acids differ enough to cause their substrate specificities to be different.

Using a similar method to how the HLE results were analyzed, previous data for PPE cleavage of SANA with and without I3C was revisited (Figure 4). Using the time 0.50 minutes after the start of the reaction, the absorbance values for the different substrate concentrations were plotted against inhibitor concentration. This graph should show a negative slope as inhibitor concentration increases indicating that the inhibitor does in fact bind to and inhibit elastase activity. However, the data does not show this, it shows little to no change in absorbance based on addition of inhibitor. This is the same result as seen for HLE, no I3C inhibition. The results for the HLE might be attributed to previously mentioned time lapse between first sample analyzed and last sample analyzed., however the PPE did not have a time lapse.

7 Sinha et al.

Conclusion

Based on this experimentation, it can be safely concluded that these two proteins are different. They differ in substrate specificity, size, amino acid sequence, rate of reaction, and how they are synthesized. Based on these differences it is likely that the proteins bind to inhibitors differently. For this reason, strong caution should be taken when using porcine pancreatic elastase to model human neutrophil elastase. Further studies should be conducted in order to compare relative amounts of a substrate cleaved by both HLE and PPE in order to compare reaction rate. Kinetics of inhibition of both HLE and PPE to similar substrates should also be considered for comparison.

Figures

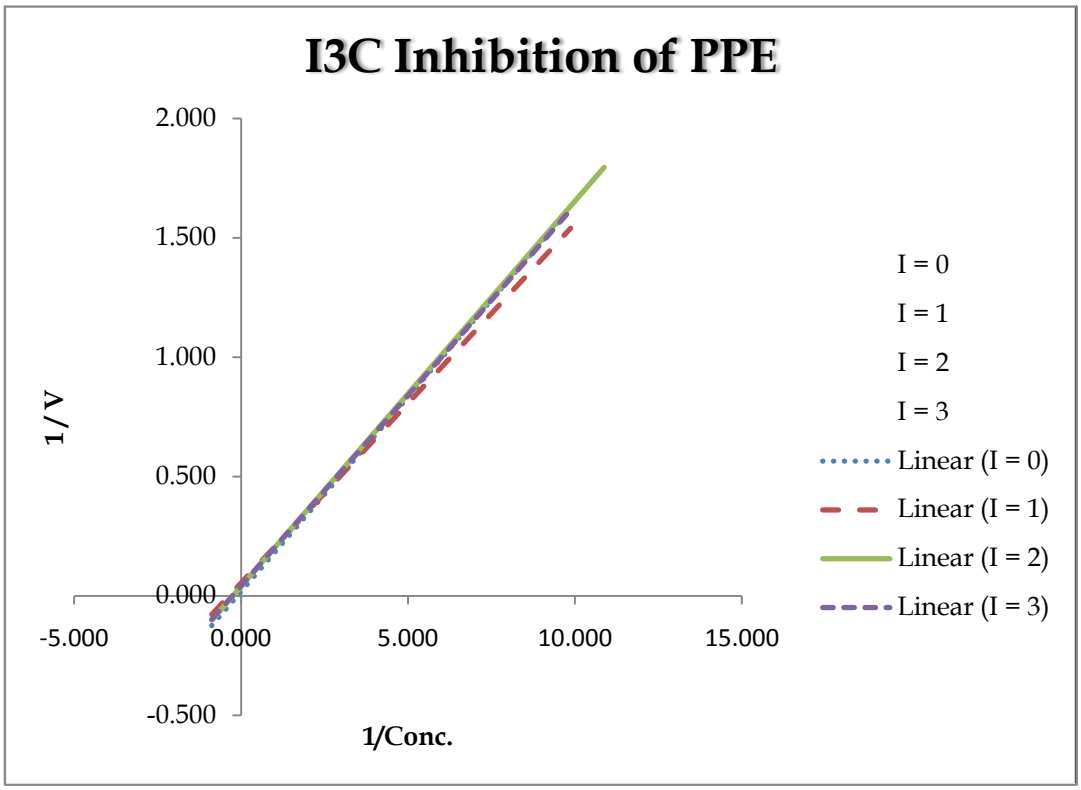


Figure 1: The graph is the Lineweaver-Burk plot which was made from the data of PPE with SANA as the substrate being inhibited by I3C. The trendlines do not behave as expected. There should be one of three graphs formed either the lines should all be parallel or they should intersect at one point. The values of I; 0, 1.2.3; refer to the increasing concentrations of the inhibitors not the actual value of the concentrations.

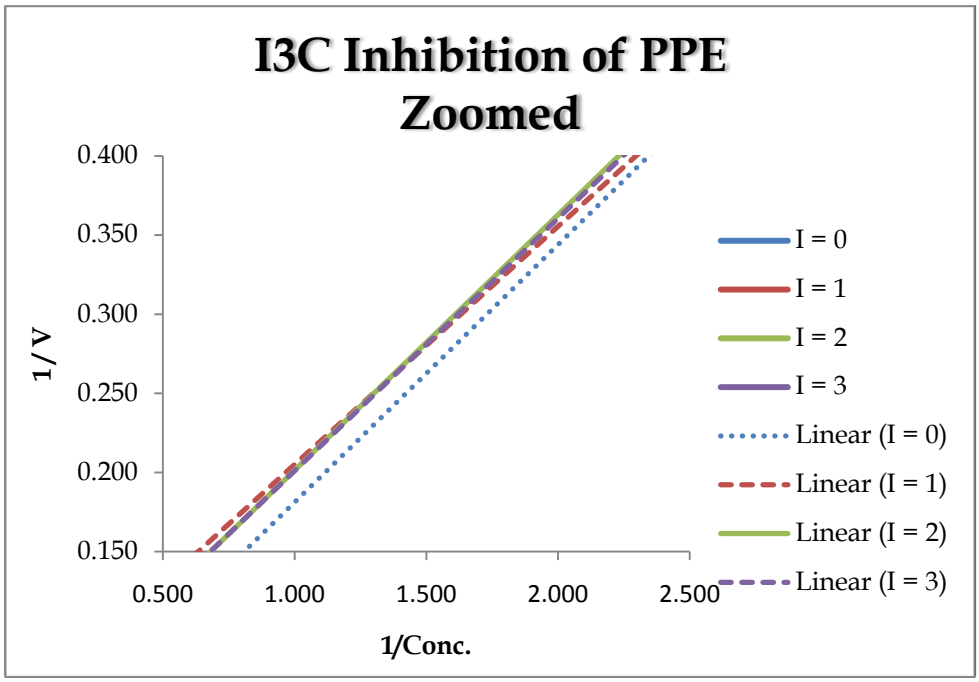


Figure 2: This is a zoomed in version of the Lineweaver-Burk from figure 1 which shows the lack of convergence.

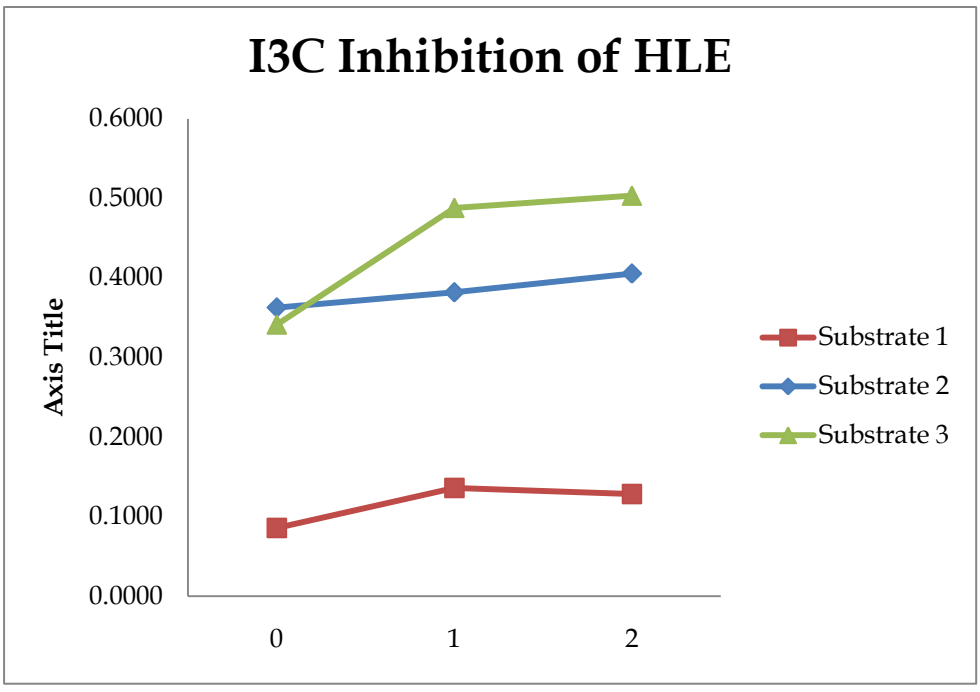


Figure 3: A plot of absorbance verses inhibitor concentration at three concentrations of substrate with HLE as the enzyme. The expected trend is a decrease in absorbance as inhibitor concentration increases. However, this is not seen. This may be attributed to the time delay between analysis at the lowest inhibitor concentration and at the highest inhibitor concentration. Data acquisition required this time lapse. Values of substrates refer to the increasing concentrations, not the actual value of the concentrations.

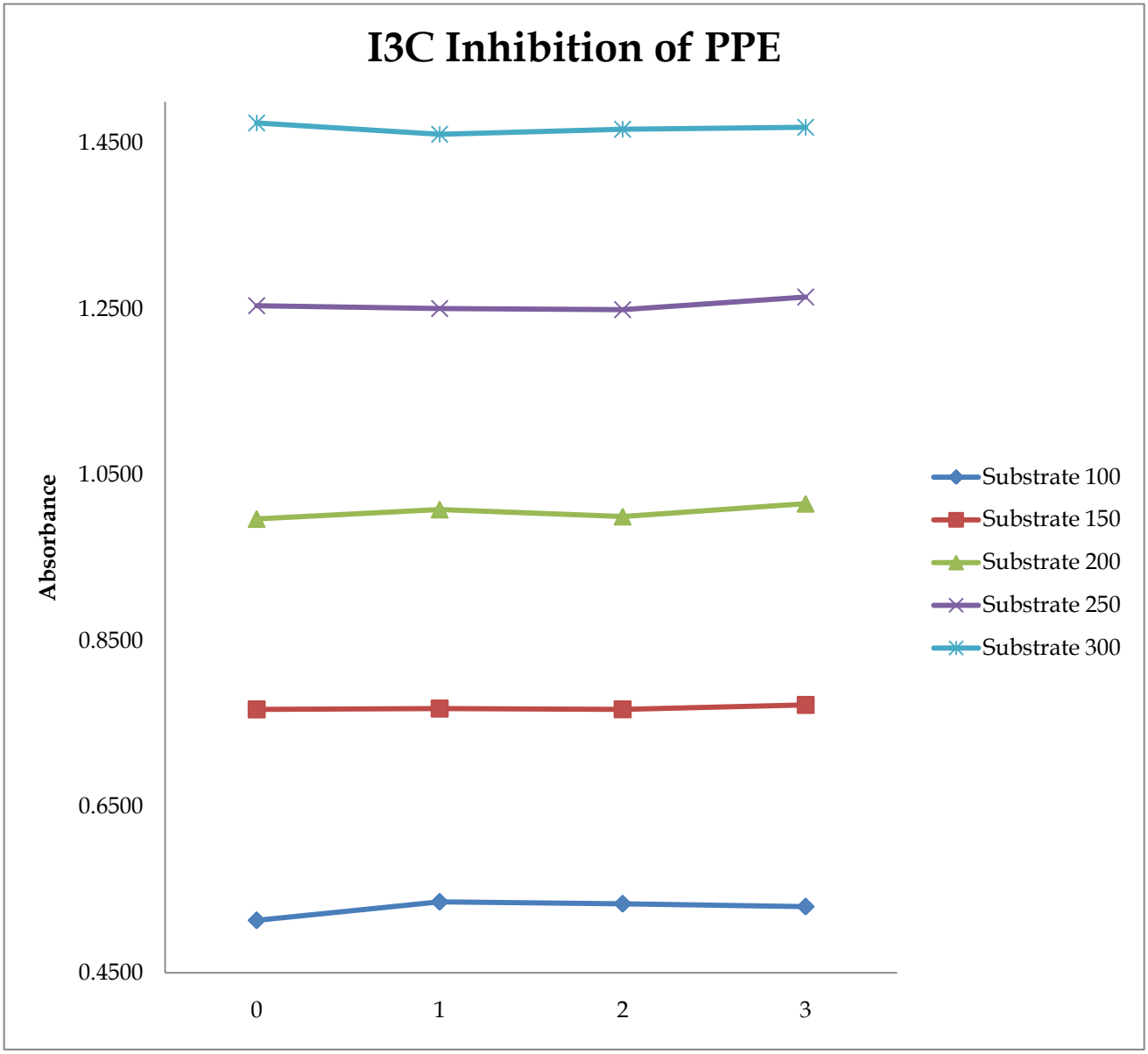


Figure 4: The data from PPE analysis in figures 1 and 2 was analyzed in a similar fashion to the HLE from figure 3. This data shows a nearly flat line for each substrate concentration which may indicate no inhibition.

```
#=======================================
#
# Aligned_sequences: 2
# 1: ELNE_HUMAN
# 2: CELA1_PIG
# Matrix: EBLOSUM62
# Gap_penalty: 10.0
# Extend_penalty: 0.5
#
# Length: 295
# Identity:      99/295 (33.6%)
# Similarity:   139/295 (47.1%)
# Gaps:          57/295 (19.3%)
# Score: 383.0
#
#
#=======================================

ELNE_HUMAN          1 MTLGRRLACLFLACVLPALLLGG-TA-L--A-SEIVGGRRARPHAWPFMV
45
                        .|.|..|...:|.|. |. .  . :.:|||..|:.::||..:
CELA1_PIG           1 --------MLRLLVVASLVLYGHSTQDFPETNARVVGGTEAQRNSWPSQI
42

ELNE_HUMAN         46 SLQLR-GG---HFCGATLIAPNFVMSAAHCVANVNVRAVRVVLGAHNLSR
91
                      |||.| |.   |.||.|||..|:||:|||| : .....|||:|.|||::
CELA1_PIG          43 SLQYRSGSSWAHTCGGTLIRQNWVMTAAHCV-D-RELTFRVVVGEHNLNQ
90

ELNE_HUMAN         92 REPTRQVFAVQRIFENGY---DPVNLLNDIVILQLNGSATINANVQVAQL
138
                      .:.|.|...||:|..:.|   |.|....||.:|:|..|.|:|:.||:..|
CELA1_PIG          91 NDGTEQYVGVQKIVVHPYWNTDDVAAGYDIALLRLAQSVTLNSYVQLGVL
140

ELNE_HUMAN        139 PAQGRRLGNGVQCLAMGWGLLGRNRGIASVLQE-----LNVTVVTSLC--
181
                      |..|..|.|...|...||||...|..:|..||:     ::..:.:|..
CELA1_PIG         141 PRAGTILANNSPCYITGWGLTRTNGQLAQTLQQAYLPTVDYAICSSSSYW
190

ELNE_HUMAN        182 ----RRSNVCTLVRGRQAGVCFGDSGSPLVC--NG--LIHGIASFV-RGG
222
                          :.|.||....|.::| |.||||.||.|  ||  .:||:.||| |.|
CELA1_PIG         191 GSTVKNSMVCAGGDGVRSG-CQGDSGGPLHCLVNGQYAVHGVTSFVSRLG
239

ELNE_HUMAN        223 CASGLYPDAFAPVAQFVNWIDSIIQRSEDNPCPHPRDPDPASRTH    267
                      |.....|..|..|:.:::||:::|..:
CELA1_PIG         240 CNVTRKPTVFTRVSAYISWINNVIASN----------------    266


#---------------------------------------
#---------------------------------------
```

Figure 5: Needle output of the alignment of HNE and PPE. ELNE_HUMAN is the Human Neutrophil Elastase, whereas the CELA1_PIG is porcine pancreatic elastase. The program analyzed the similarity between the two amino acid sequences by matching key pieces of the PPE to the HNE sequence. Identity is the exact amino acid to amino acid matching between the two elastases. The similarity is the percentage of matches between the two sequences. Vertical lines between the two sequences show identical matches.

References

Lazari, M.; Todd, E.; *Stirrings*. A publication of the CSU Stanislaus University Honors Program. 2009, 23-26.

Lazari, M.; Todd, E.; Firestone, G.; Stone, K.; *FASEB J.* 23, 853.6

Nguyen, Hanh H.; Aronchik, Ida; Brar, Gloria A.; Nguyen, David H. H.; Bjeldanes, Leonard F.; Firestone, Gary L.; *PNAS*. 2008, 105, 1975-19755

Porter, D.C.; Zhang, N.; Danes, C.; McGahren, M.J.; Harwell, R.M.; Faruki, S.; Keyomarsi, K.; *Mol Cell Biol*. 2001, 21, 6254-6269

Gestin, M.; Desbois, C.; Le Huërou-Luron, I.; Romé, V.; Le Dréan, G.; Lengagne, T.; Roger, L.; Mendy, F.; Guilloteau, P.; *Lait*. 1997, 77, 399-409

Sinha, S.; Watorek, W.; Karr, S.; Giles, J.; Bode, W.; Travis, J.; *Proc. Natl. Acad. Sci. USA*. 1987, 84, 2228-2232

E-Commerce: A Statistical Market Analysis and Forecast of Emerging Trends

Grady Maguire

Introduction

On August 11, 1994, Daniel Kohn and one of his Swarthmore College classmates stood on the cusp of history. Little did they know, but these college graduates and founders of NetMarket were about to initiate a trend that would revolutionize the culture for decades to come. With the purchase of the Sting CD, "Ten Summoner's Tales," these college grads completed the first ever secure retail transaction on the World Wide Web. Although Randy Adams and the Internet Shopping Network argue that they completed the first online transaction a month prior, one fact is clear – the year 1994 represents groundbreaking achievements in the internet realm (Gilbert 2004). Fast-forward just 14 years later to read the following statement regarding the industry these pioneers unlocked: "Relatively strong growth was seen in the global Internet and E-Commerce sector in 2007-2008, despite the global economic crisis...The Internet is about saving time (and therefore saving money), and the potential of the Internet has barely been tapped (*E-Commerce*)." If what Plunkett Research states about electronic commerce is even remotely correct, the world is likely to experience a Power Wave - a revolution in business practices that truly exploits the advantages of new technologies ("Dent Method").

Analyzing the past and present growth of online retail sales in the United States, a trend will be identified and given a projected duration time. In order to identify when online retail sales will reach market maturity, a forecast will be created to identify the depth and impact of the e-commerce trend in quantifiable terms. Overall, the impact of e-commerce on consumer purchasing will be thoroughly reviewed. The analysis and forecast will cover U.S. online retail sales independently and as a percentage of total retail sales through 2020. Comparing the results under two models, S-Curve analysis and the Dent Method, forecast consistencies and discrepancies will be noted and analyzed. Only time will tell the degree to which the internet will make its imprint upon consumer society.

Short and Long-Term Research

The research is framed by the work of economists such as Harry S. Dent and research organizations such as Forrester Research, Jupiter Research, and Plunkett Research. At the short-term end of the research spectrum, Forrester Research, Jupiter Research, and Plunkett Research gather and analyze data concerning trends that are happening now. They often find correlations and make predictions based on current statistics. Similar methods will be used in this research project to analyze e-commerce sales data and compare it to total commerce data.

At the long-term end of the research spectrum, Harry Dent is an economic forecaster who uses a common sense approach. Essentially, he states that economics are tied to demographics. In turn, commerce is the logical result of people making predictable spending decisions as they move through life ("Dent Method"). Analyzing these predictable trends generates accurate long-term forecasts which can be utilized by both businesses and consumers. The Bureau of Labor Statistics supports Harry Dent's methods by emphasizing the importance of demographics. Demographics provide a direct link to the condition of the labor force and purchasing patterns. The government institution recognizes that population trends affect employment

opportunities by influencing the demand for goods and services. Population changes produce related changes in the demographic composition and size of the labor force. The Bureau of Labor Statistics also states that "Population is the single most important factor in determining the size and composition of the labor force…" ("Tomorrow's Jobs"). Since such a high degree of importance is placed on the composition and size of American society, much attention will be placed on analyzing demographic trends and their relation to consumption. Using aforementioned techniques, the research will consist of finding and analyzing the e-commerce trend as it emerges. The better data can be used in accordance to accepted methodologies such as the Dent Method, the more accurate and useful the predictions will be.

Research Methods

In order to accurately analyze and forecast the online shopping trend, adherence to industry-approved methods is tantamount. The primary methodologies used will be the Dent Method (mentioned above), SPSS analysis, and S-Curve Economics. Following industry standards for social science research will provide a solid foundation for the generation of reliable forecasts.

First of all, Statistical Package for Social Sciences (SPSS) is a widely used analysis tool for the social sciences. Recently rebranded as Predictive Analytics SoftWare (PASW) in 2009, the statistical analysis tool can be implemented to interpret data in a number of ways. The software can be used to find differences, relationships, or descriptions of data. However, no analysis is meaningful unless the data is reliable and valid. Data is reliable if it can "consistently measure the topic under study at different times and across different populations" (Hinton 356). On the other hand, validity refers to the strength of the conclusion. Simply put, are they right? Keeping both reliability and validity in mind, SPSS becomes a powerful tool. SPSS creates a mathematical way in which to make fact-based predictions using current data. Furthermore, finding correlations in the data will help generate predictive models for analysis and conclusion. While SPSS facilitates the detailed analysis of e-commerce data, it is the methodology of S-Curve economics which enables trends to be forecasted.

S-Curve economics illustrates the introduction, growth, and maturation of innovations as well as the technological cycles that most industries experience. Essentially, an S-Curve can be broken down into four phases: innovation, growth, maturity, and decline. Innovation refers to the introduction of a new product or technology to the market place. The majority of products and technologies never make it past the first phase due to the high costs and low revenues associated with new ideas. Specifically, the innovation phase represents the period of time when 0%-10% of the market adopts the new technology or product. As a product moves through the innovation phase, market adoption grows very slowly if it is adopted at all. However, once a concept, such as e-commerce, reaches 10% market penetration, it is said to be a concept whose 'time has come.' Entering the growth phase, which represents 10%-90% market penetration, the concept starts to grow in an exponential fashion. Unlike the slow growth during innovation, once about one out of every ten people readily uses the technology, it begins to grow like wildfire. To put it into perspective, it takes roughly the same period of time to grow from 10%-90% as it did to grow from 0-10% market penetration. Virtually nothing can stop its rapid growth once it enters into the growth phase. As adoption nears nine out of every ten people, growth slows as it enters maturity. Although almost no technology is universally adopted and reaches 100% market penetration, maturity refers to slow growth

that occurs between 90% and 100%. Once a market matures, growth often tapers off and declines. The decline phase only occurs when a new technology or product is created which makes the old obsolete. Once the new begins to be readily adopted by the masses, the old starts its decline. The S-Curve is essential to understanding how markets move. Combined with the Dent Method, it further improves the accuracy of forecasts related to e-commerce.

Initial Projections

Based on current data, it is projected that e-commerce will experience the growth phase of its S-Curve over the next decade. I expect the rapid growth to result in the maturation (roughly 90% penetration of the potential market) of online shopping by 2020. Despite the current economic downturn, e-commerce continues to grow while other industries move backward ("E-Commerce"). Since online shopping is based on saving time and money for the consumer, as well as the business owner, hard economic times will only deepen the e-commerce trend. While sales may not increase as rapidly as in strong financial conditions, individuals will look to spend their limited finances in as efficient a fashion as possible. The internet, coupled with the ability to do comparison shopping, research, analyze customer reviews, and order from a single location, provides the demanded shopping efficiency.

S-Curve economics presents a case for the rapid growth of online shopping. Due to the nature of market development, exponential growth occurs once a new technology reaches roughly 10% market penetration and continues until it reaches roughly 90% market penetration. Data compiled by Forrester Research shows that e-commerce has entered its growth phase in the United States. Their definition of e-commerce retail sales includes all online sales except auto, travel, and prescription drug sales. Since the expected market cap of US online sales is 50% of total U.S. sales, the growth phase begins once online sales equal 5% of all sales. In 2007, the feat was achieved according to Forrester Research when online retail sales reached 5% of all retail sales in America ("U.S. E-Commerce"). Historical evidence strongly suggests that a period of exponential growth will follow, accelerated by the speed of the information age. As stated earlier, new products and technology generally take the same time to complete the introduction phase as they do to complete the growth phase. E-commerce appears to have its humble beginnings during the latter months of 1994. Since it took 13 years (from 1994-2007) for e-commerce to reach 10% market penetration, it is expected to take approximately 13 years from 2007 for US online sales to reach 45% of total US sales, which is 90% penetration of the projected market. According to my initial projections, e-commerce would complete its growth phase during the year 2020. The results may be historically significant as the American culture is transformed by internet shopping.

Cultural Impact

The fact that American society is in the midst of a culture-changing trend makes it a significant area of investigation for Americans in general, for research, and for the business field. On the individual level, e-commerce tends to save Americans both time and money. Online shopping allows consumers to compare costs and read product reviews from the comfort of one's own home. This saves time that would otherwise be spent in traffic or waiting in line. The nature of e-commerce forces businesses to respect the consumer. The internet makes it easier than ever to compare and contrast products, do research, and read reviews. Businesses must offer customers competitive pricing and a satisfying online experience or risk losing the sale. With the click of a button, customers can leave one virtual store and enter another. According to a Forrester Research report, retailers must make their websites more

conducive to browsing. They can elicit favor with shoppers by focusing additional energy on accurate product information, improved imagery, flexibility in payments and returns, and by reducing the hurdles of shipping costs (Rosencrance 2008). Essentially, e-commerce empowers the consumer. The concept of consumer empowerment is demonstrated by the fact that people's actions on the internet dictate the response of businesses. The supply of specific information, products, and services is tailored to the individual based on past purchases or search results. The level of consumer empowerment created online cannot be duplicated in the traditional store.

On the research level, e-commerce is important because it is altering the face of the consumer. As convergence of the telecommunication industry and internet occurs, individuals change the way they buy products and services, communicate, bank, pay bills, and research information.

According to one of the world's leading authorities on technology and trends shaping the world of wireless mobility, Mr. Andrew M. Seybold, this connection allows for greater access to voice, audio, data, and video services than ever before (Seybold 11). New research is now necessary to understand how the new consumer makes decisions. As information is constantly changing, a rapid response from researchers is required to stay up-to-date. Online shopping is creating major changes in not only the way consumers think, but the way in which businesses market to their customers. The growth of e-commerce and converging technologies recreate the need for trust. Analyzing the need for trust is central to market research. Piotr Cofta, Chief Researcher in British Telecom's Mobility Research Group, shows that without a trust in businesses or the medium through which the transaction takes place (the internet), no commercial transaction will occur no matter how convenient or developed the technology is (Cofta 1).

Despite the recent scare of entering credit card and personal information online, security measures and higher encryption standards allow consumers to trust the safety of online shopping. In the 21st century, it has become more a risk to hand one's credit card to a clerk in a store than to enter the information on a mainstream website. Although risks do exist on lesser known websites with lower levels of data encryption, the majority of competitive internet companies offer high levels of security for customers. More and more online firms offer all-encompassing return policies. Such policies guarantee that the customers receive the exact product they are looking for in excellent condition. If they are not satisfied, they can send it back to the company for replacement or refund. As return policies are improved, customers will be more confident in making purchases over the internet. E-commerce will continue to flourish and grow if trust continues to grow in the minds of consumers. On both sides of the equation, e-commerce is laying the groundwork for major changes in society – changes which pave the way for future research.

On the retail level, internet shopping is extremely significant to the business field. Currently, many businesses are changing their focus from traditional retailing to driving online sales. According to Ken Allard, a chief executive strategist, a wide range of organizations are making large investments in internet commerce. He understands the new investment cycle to be the result of four main trends, consisting of internet commerce becoming a reliable engine for growth, new web technologies enabling additional capabilities, both consumers and businesses demanding new features and services, and marketing budgets shifting to the internet (Allard). As current trends propel online shopping to not simply become the way of the

future but the way of the present, companies must quickly adapt their business practices to meet the growing demand. Similar to researchers, businesses must learn to understand the changing face of the consumer. They must learn to supply customers with what they want and how they want it, while competing with more and more competitors online. If actions are not taken to utilize the marketplace of the future, online market share is lost daily. Companies simply will not survive if they do not have a viable internet option for customers to access.

Preliminary Findings

I initially projected that e-commerce retail sales will become a mature market by 2020 based on Forrester Research's e-commerce sales data. According to Forrester's measure of online retail sales (which excludes auto, travel, and prescription drug sales), e-commerce entered its growth phase (10% market penetration) in 2007. However, for the purpose of this report, I will be utilizing the U.S. Census Bureau's measure of online retail sales. Their measure includes all online retail transactions except online travel services, financial brokers and dealers, and ticket sales agencies. Since they record e-commerce data differently than Forrester Research, online retail sales were only 3.17% of total retail sales (6.34% market penetration) in 2007 ("Measuring the Electronic Economy"). Thus, e-commerce as recorded by the U.S. Census Bureau has not yet entered its growth phase. Using this scale means that U.S. online retail sales are not expected to reach 90% market penetration until after 2020.

Since I have not yet had access to SPSS software, my forecast under the S-Curve model is based on an exponential regression (LOGEST function) in Microsoft Excel. Although a logistic regression would be more accurate in forecasting a complete S-Curve, Excel does not currently have such a function. Until I have access to a logistic analysis tool, the exponential regression will do a good job of forecasting the exponential growth portion of the S-Curve (which is the portion I am analyzing). Using both online and offline retail sales data from 1999-2008, I forecasted the growth rate of retail e-commerce sales, the volume of retail e-commerce sales, the retail e-commerce growth rate as a percentage of total retail sales, and the final e-commerce percentage of total retail sales for each year from 2009-2020. According to my forecasts, online retail sales will not enter the growth phase until 2011 when they represent 5.8% of total retail sales (11.6% market penetration) in the US. At this level, online retail sales will total over $257 billion in 2011. My short-term forecasts line up closely to that of Forrester research, which predicts that e-commerce sales will reach $334.7 billion in 2012 (Rosencrance 2008). My forecasts place the 2012 online retail sales forecast at $318.57 billion. The variation may exist due to differences in the definition of an online retail sale. Different forecasting methods might also be a reason for the discrepancy. Nonetheless, my short-term estimates are strongly correlated with a well-established forecasting company.

In the long-run, I predict that online retail sales will surpass $1 trillion by 2018 according to the model. Online sales are expected to exceed $1.6 trillion in e-commerce sales in 2020. At this point in time, e-commerce should capture approximately 27% of total retail sales (54% market penetration) in the United States. If this comes to pass, the e-commerce trend will continue for at least another decade until it captures 45% of total retail sales (90% market penetration) and becomes a mature market. Besides considering the factors of S-Curve Economics, the Dent Method should be considered in the analysis as well.

The Dent Method allows economists to logically forecast future consumption in the U.S. The forecast is ultimately determined by the size and composition of the population.

Personal consumption represents roughly 70% of the Gross Domestic Product in America. At an average age of 47.5, consumers reach their predictable peak in spending ("Dent Method"). The consumer influences the overall economy greatly in the U.S. It is important to analyze the size of those groups in their peak spending years during the e-commerce trend from 2000-2020. This will provide better a better understanding of the growth rates estimated in the regression analysis.

Based on the most recent U.S. Census of 2000, 60.1 million people were between the ages of 40 and 54 years of age in 2000 ("QT-P1. Age Groups and Sex: 2000"). This age bracket represents groups in their peak spending years according to the Dent Method. From 2000 to 2010, the number of people between 40 and 54 years old grew over 9.2% to 65.7 million (the growth level assumes the same number of individuals who were 30-44 years old in 2000 are now 40-54 years old in 2010). However, from 2010 to 2020, the number of people between 40 and 54 years old is expected to fall roughly 10.4% to 58.9 million. The contraction in the population represents a larger generation (the Baby-Boomers) preceding a smaller generation (Generation X). This may impact the e-commerce trend in a number of ways. Since there is an expected reduction of those who will be in the peak spending years from 2010 to 2020, I expect personal consumption to grow slowly or even fall during the decade. Due to the anticipated slow-down in spending, I expect my estimates for 2020 to be too high. How high is difficult to determine until future analyses can be made. However, I still expect e-commerce to be within 5% of the 27% of total sales anticipated in 2020. I also expect online retail sales to exceed $1 trillion by 2020, despite reduced consumption levels.

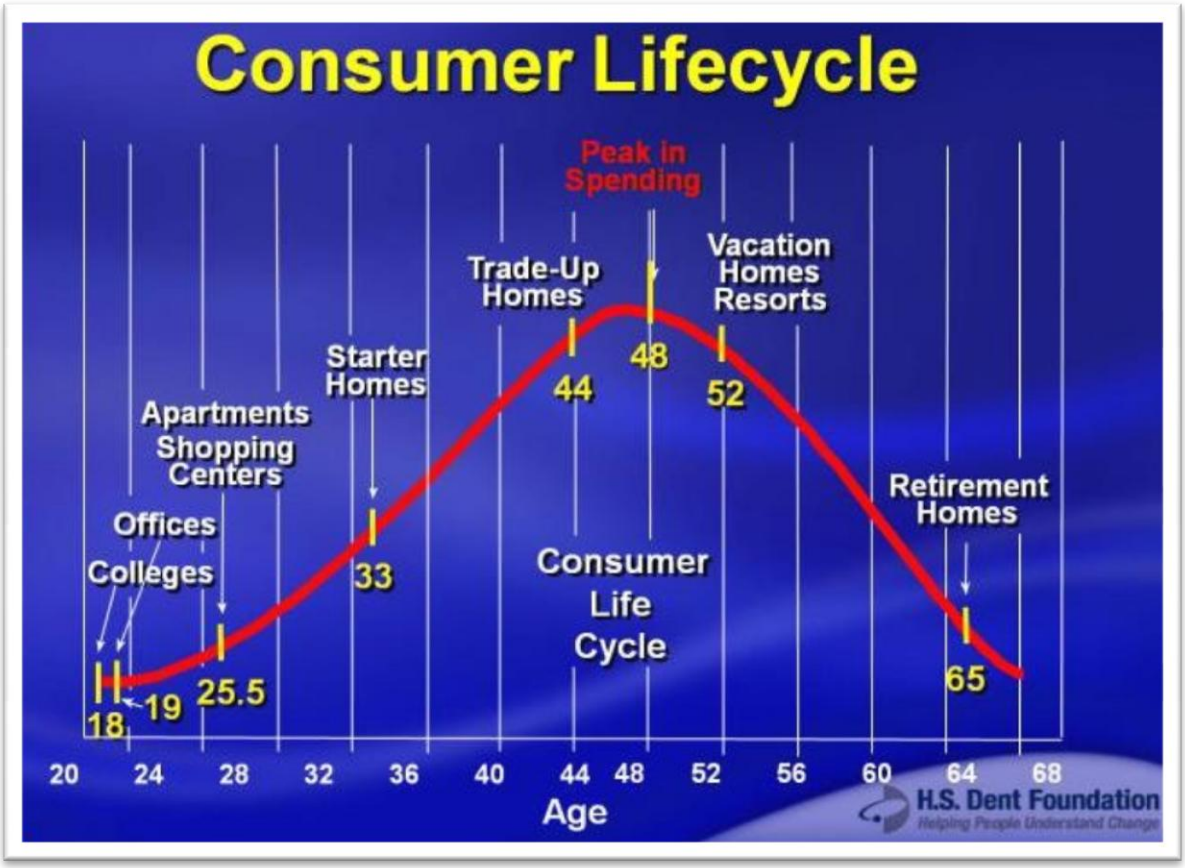
Conclusion

America is likely to experience a dramatic restructuring of its consumer culture over the next two decades. The growth of the internet coupled with the rapid nature of the information age will produce changes expected to occur faster than ever. E-commerce is the driving force behind the significant changes in store for research, for the business field, and for Americans in general. After analyzing the past and present growth of online retail sales in the United States, it is clear that a trend is emerging. Comparing the data from the S-Curve analysis perspective and the Dent Method perspective proved useful. While the S-Curve model allowed me to forecast both e-commerce sales ($1661.357 billion) and its percentage of total sales (27.297%) in 2020, the Dent Method highlighted the limitations of the growth rate under current demographic conditions. Even though the changes in internet use over the past fifteen years have been significant, the potential of online shopping has barely been tapped. The greatest period of growth has yet to be experienced, but it has already altered many aspects of America's consumer society either directly or indirectly. It is only a matter of time before e-commerce completely integrates itself into American society. Once it does, e-commerce will have completed its journey from its first sale involving a Sting CD, to provoking rapid cultural change, to maturing and becoming synonymous with American culture.

Current Economic Data: 1999-2008										
Year	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Retail E-Commerce Sales (billions)	15.004	28.824	34.263	44.706	55.731	76.344	93.28	107.014	126.697	132.257
Total Retail Sales (billions)	2866.898	3060.748	3156.754	3141.468	3275.407	3474.34	3693.43	3869.536	3994.823	3959.957
% of Total Retail Sales	0.523%	0.942%	1.085%	1.423%	1.701%	2.197%	2.526%	2.766%	3.172%	3.340%
Actual Growth Rate (E-Commerce Sales)	92.109%	18.870%	30.479%	24.661%	36.987%	22.184%	14.723%	18.393%	4.388%	26.026%
Actual Growth Rate (% of Total Retail Sales)	79.942%	15.255%	31.114%	19.563%	29.143%	14.936%	9.502%	14.680%	5.308%	21.280%

Forecasted Economic Data: 2009-2020												
Year	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Forecasted Growth Rate (e-commerce sales)	26.026%	24.740%	24.004%	23.561%	23.284%	23.104%	22.984%	22.901%	22.843%	22.802%	22.772%	22.749%
Forecasted Retail E-Commerce Sales (billions)	166.6784	207.9149	257.8231	318.5701	392.746	483.4861	594.6091	730.7817	897.7167	1102.414	1353.453	1661.357
Forecasted Growth Rate (% of Total Retail Sales)	21.280%	20.197%	19.577%	19.204%	18.970%	18.818%	18.717%	18.647%	18.598%	18.563%	18.538%	18.519%
% of Total Retail Sales	4.051%	4.869%	5.822%	6.940%	8.256%	9.810%	11.646%	13.818%	16.388%	19.430%	23.032%	27.297%

Consumers' Peak Spending Years				
	2000	**2010**	**2015**	**2020**
40 to 44 years	22,441,863	20,510,388	19,381,336	18,964,001
45 to 49 years	20,092,404	22,706,664	20,510,388	19,381,336
50 to 54 years	17,585,548	22,441,863	22,706,664	20,510,388
Peak Spending Population Total (40-54years)	60,119,815	65,658,915	62,598,388	58,855,725
Population Growth (2000-2010)	9.213%			
Population Growth (2010-2015)	-4.661%			
Population Growth (2015-2020)	-5.979%			
Population Growth (2010-2020)	-10.361%			
Population Growth (2000-2020)	-2.103%			



Bibliography

Allard, Ken. "The New Investment Cycle in Internet Commerce: Web 2.0 Goes Mainstream," Information Today 25 Apr 2008. 4 Apr 2009. <http://www.allbusiness.com/technology/software-services-applications-electronic/8956791-1.html>.

Cofta, Piotr. "Convergence and Trust in eCommerce." BT Technology Journal Vol 24 (2 Apr 2006). 4 Apr 2009 <http://portal.acm.org/citation.cfm?id=1145507>.

"Dent Method: Economic Forecasting Based on Changes in Demographic Trends." HS Dent: Helping People Understand Economic Change. 2009. HS Dent. 20 May 2009 <http://www.hsdent.com/the-dent-method/>.

"E-Commerce & Internet Trends." Industry Statistics, Trends and In-depth Analysis of Top Companies. 2008. Plunkett Research, Ltd. 21 May 2009 <http://www.plunkettresearch.com/Industries/ECommerceInternet/ECommerceInternetTrends/tabid/168/Default.aspx>.

Gilbert, Alorie. "E-Commerce Turns 10." *CNET News.* 11 Aug 2004. 24 Nov 2009. <http://news.cnet.com/E-commerce-turns-10/2100-1023_3-5304683.html>.

Hinton, Perry, Charlotte Brownlow, Isabella McMurray, and Bob Cozens. SPSS Explained. New York, NY: Routledge Inc, 2004.

"Measuring the Electronic Economy." *E-Stats Report*. 2007. U.S. Census Bureau, 2009. <http://www.census.gov/econ/estats/>.

"QT-P1. Age Groups and Sex: 2000. Census Summary File 1 (SF 1) 100 Percent Data. United States." *American FactFinder*. 2000. Bureau of the Census. 15 Dec 2009.

Rosencrance, Linda. "E-Commerce Sales to Boom for Next 5 Years." *ComputerWorld*. 5 Feb 2008. 13 Dec 2009. <http://www.computerworld.com/s/article/9061108/E_commerce_sales_to_boom_for_next_5_years_>.

Seybold, Andrew. "The Convergence of Wireless, Mobility, and the Internet and its Relevance to Enterprises." Information Knowledge Systems Management 23 Nov 2008. 13 Mar 2009 <http://portal.acm.org/citation.cfm?id=1402707>.

"Tomorrow's Jobs." Bureau of Labor Statistics, U.S. Department of Labor, Occupational Outlook Handbook, 2008-2009 Edition. 3 March 2009 <http://www.bls.gov/oco/oco2003.htm>.

"U.S. E-Commerce Gaining Market Share as Growth Slows." *Seeking Alpha*. 5 Feb 2009. Forrester Research. 13 Dec 2009. <http://seekingalpha.com/article/118785-u-s-e-commerce-gaining-market-share-as-growth-slows>.

New Math: How U.S. Schools Can Realize Singapore's Success in Mathematics Achievement

Dana Whetstone

Since 1995, Singapore students have consistently ranked among the top nations on the Trends in International Mathematics and Science Study (TIMSS), while the United States has ranked lower than many industrial countries. In fact, Singapore ranked first in 1995, 1999, and 2003, and in the top three in 2007. The U.S., however, placed 12th and 15th out of 46 participating countries in 2003 (Mullis, Martin, Gonzalez, and Chrostowsky 34-35) and 11th and 9th in 2007, for fourth and eighth grades respectively (Martin, Mullis, and Foy 34-35).

In 2005, the American Institutes for Research, funded by the U.S. Department of Education, conducted a study that compared mathematics teaching in elementary schools in the U.S. and Singapore. They found that Singapore's system for teaching mathematics is superior to that of the U.S., stating, "Singapore's textbooks and assessment examinations are more demanding and their teachers more skilled mathematically." The U.S. does not have a comparable mathematics framework (Ginsburg, Leinwand, Anstrom, and Pollock ix).

What is Singapore's educational system, and how do their methods for teaching mathematics consistently earn them top honors? Are reforms feasible in the U.S.? In an effort to answer these questions, this research paper will analyze the major differences between the U.S. and Singapore educational systems, as well as their mathematics curriculum, textbooks, assessment, and teacher training. It will mainly address mathematics education in the primary grades, a time when students need to build strong mathematics skills.

Literature Review

In 2005, Ginsburg et al., of American Institutes for Research, wrote a comprehensive study, *What the United States Can Learn from Singapore's World-Class Mathematics System,* detailing the major differences between education in Singapore and the U.S., initiated in consequence of the 2003 TIMSS results. Particularly, they focus on mathematics frameworks, textbooks, assessments, and teacher preparation. In addition, they made recommendations for implementing Singapore's methods in the United States.

Using this as a basis for my research, I further explored other sources of statistical data. The *TIMSS 2003 International Mathematics Report* and *TIMSS 2007 International Mathematics Report* ranks participating countries based on student achievement in mathematics. It also reports on international benchmarks for fourth and eighth grades. *The Nation's Report Card* discusses achievement of U.S. 4th and 8th grade students on the National Assessment of Educational Progress (NAEP) for various subjects including mathematics. The NAEP is the source of data regarding U.S. mathematics achievement in the TIMSS reports.

To investigate comprehensively the educational systems, standards and curriculum, assessments, and teacher training in Singapore and the United States, I also consulted a variety of additional sources. These include the websites of the Singapore Ministry of Education, the U.S. Department of Education, and seven representative state departments of education.

In addition, "The Model Method: Singapore Children's Tool for Representing and Solving Algebraic Word Problems" from the National Council of Teachers of Mathematics (NCTM) journal, *Journal for Research in Mathematics Education*, is a study describing the model method that is used for teaching mathematics in Singapore. A second article, Menon's "Should the United States Emulate Singapore's Educational System to Achieve Singapore's Success in the TIMSS?" from the NCTM journal, *Mathematics Teaching in the Middle School*, discusses the factors resulting in Singapore's success and the viability of adopting their methods. Menon addresses topics such as adopting a centralized curriculum and early tracking. His main suggestions include a shift in values and improved teacher preparation.

From this research basis, it is my hypothesis that Singapore has developed a superior mathematics framework. Focused textbooks covering topics in-depth using application-based development, challenging assessments with constructed-response questions, and teachers with exceptional mathematics skills, support this framework. I propose that it is possible to employ parts of Singapore's methodology to improve the quality of mathematics education in the U.S.

Methods

Despite calls for reform over the past two decades, including framework recommendations by the NCTM and legislature in the form of the No Child Left Behind Act, U.S. schools continue to perform below expectations in mathematics on national assessments. Worse yet, the U.S. consistently ranks far below other industrialized countries on international assessments. Researchers frequently look to Asia—Singapore, in particular—in addressing the poor mathematics performance of U.S. schools.

This research paper will compare the major differences between the U.S. and Singapore public educational systems, as well as the methods of teaching mathematics. It will be limited to the study of public schools receiving government funding. This analysis will synthesize government-funded studies, government publications and websites, and journal articles. The focus will be on educational systems, standards and curriculum, textbooks, assessments, and teacher training. Because of the unfamiliar, centralized, and highly tracked nature of Singapore schools, an analysis of its educational system from preschool to primary school is first presented.

The website of Singapore's Ministry of Education will serve as the primary source of information regarding its educational system. Because the U.S. educational system is not centralized, as is Singapore, certain components of the U.S. system will be studied using typical examples from selected U.S. states. These states, as chosen by Ginsburg et al. in their study and representing about one-third of all students in the U.S., will include California, Florida, Maryland, New Jersey, North Carolina, Ohio, and Texas.

Findings

Analysis of Educational System

The educational system in Singapore is under the purview of the Ministry of Education (MOE). The MOE controls the administration of schools receiving government funds and plays an advisory role over private schools. The MOE determines national goals and coordinates curriculum for the entire country. School principals have authority to plan and coordinate their school's program under the guidelines established by the MOE. Thus, within national guidelines, local schools maintain flexibility to meet the needs of their students.

Whereas Singapore has a centralized educational system, the U.S. has no national standards. Under the U.S. Constitution, education is under the jurisdiction of the states. Each individual state defines its own curriculum and assessment standards, approves textbooks, and establishes teacher-credentialing requirements. Most states base their standards on the NCTM recommended framework for curriculum, with widely varied results.

Kindergarten in Singapore

Kindergartens provide three years of preschool for children four-years old to six-years old. Kindergartens are privately run by community, business, and religious groups. Kindergarten is not compulsory, although the majority of children attend. According to Tan Ching Ting of the MOE, "Instead of mandating pre-school education for all, the government aims to target its efforts in areas which would give the greatest leverage on raising the quality of pre-school education, especially for children from less advantaged homes, and in getting the small number who do not attend pre-school to do so" (36).

Primary School in Singapore

Primary school education begins the year the child turns age seven. This period is divided into two stages, foundation stage (Primary 1 to 4) and orientation stage (Primary 5 to 6). The foundation stage consists of a common curriculum that provides a solid foundation of English, their Mother Tongue (based on their heritage), and Mathematics. During the orientation stage, students are taught each subject at a level based on their abilities (MOE, *Education in Singapore* 4). Other subjects, taught through Primary 6, include civics, moral education, arts and crafts, music, health, social studies, and physical education (see Exhibit 1).

At the end of Primary 4, students take a school-based exam that determines the subjects the student will take during the orientation stage (Primary 5 and 6). During the orientation stage, English, Mother Tongue, and Mathematics are taught by subject-based banding, or differentiated instruction. Banding provides students with the opportunity to mix instruction levels based on their interests and abilities. Using the exam, the school makes recommendations to the students and their parents, and then parents indicate their preferred subject-level choices for their child. There are two tracks to choose from, foundation—for those students struggling with a particular subject—and standard—for those doing well in a subject (MOE, *Nurturing Every Child* 4).

At the end of their six years in primary school, all students take the Primary School Leaving Examination (PSLE) to test their readiness to enter secondary school. Subjects tested in the PSLE include English, Mother Tongue, Mathematics, and Science. Placement in a particular secondary school is determined by the student's performance on the PSLE.

Placement in a secondary school occurs through a process of two "exercises." In the Post-PSLE Option Exercise, following the release of the results, parents indicate their preferences for which secondary school they wish their child to attend. During the Direct School Admission Exercise, schools select students to fill a certain percentage of their openings using standards for achievement and ability established by the schools themselves. This encourages students to apply themselves in areas they have aptitude or interest in to increase their chances of admission to the school of their choice (MOE, *Nurturing Every Child* 4, 15).

Analysis of Framework

According to Ginsburg et al., one of Singapore's strengths is the problem-solving basis of its mathematics framework (cf.

Figure 1). They contrast this to the less structured approach taken in the U.S.:

> A mathematically logical, uniform national framework that develops topics in-depth at each grade guides Singapore's mathematics system. The U.S. system, in contrast, has no official national framework. State frameworks differ greatly; some resemble Singapore's, whereas others lack Singapore's content focus (xi).

The Singapore framework dictates a small number of topics covered in depth and delineated by grade (see Exhibit 2). Students master content as it is presented and topics are only repeated in later grades at a more complex level. In contrast, the NCTM framework, *Principles and Standards for School Mathematics*, used by U.S. states in developing their states' standards, groups topics within "grade bands" (as in K-2 and 3-5) in broad terms which does not provide sufficient lesson content direction to teachers. In an effort to help states develop a more logical, focused curriculum, the NCTM has published *Curriculum Focal Points for Pre-kindergarten through Grade 8 Mathematics: A Quest for Coherence*, which explicates the most important mathematical concepts, or focal points, for each grade level (1).

North Carolina and Texas have mathematics frameworks similar to Singapore's and that cover a similar number of topics per grade. In the 1990s, education reforms establishing the frameworks in these two states led to considerable improvements in NAEP mathematics scores. Conversely, Florida and Maryland far exceed the number of topics covered by grade in Singapore; they suffer from poor test performance. This implies a connection between focused frameworks with fewer topics covered in-depth and positive test results (Ginsburg et al. xii).

In addition, the Singapore system provides an alternative framework for students who have difficulty with mathematics. This alternative structure covers the same subject matter as in the standard framework but presented in a slower manner. In addition, these students receive help from well-trained teachers. There is no similar alternative framework in the U.S. (xi)

Analysis of Textbooks

"Singapore textbooks build deep understanding of mathematical concepts through multi-step problems and concrete illustrations that demonstrate how abstract mathematical concepts are used to solve problems from different perspectives. Traditional U.S. textbooks rarely get beyond definitions and formulas, developing only students' ability to apply mathematical concepts." Open a typical U.S. textbook, and one is overwhelmed with real-world illustrations; however, they only demonstrate that the concepts in the unit *have* real-world application but do not show students *how* to apply them (Ginsburg et al. xii).

Singapore textbooks focus on application-based development. Illustrations in a Singapore textbook depict the concrete first, followed by the pictorial, and then the abstract. These visual representations of abstract mathematical ideas are of great benefit--especially for those who struggle with mathematics. The illustrations show the student how to "decompose, represent, and solve complicated multi-step problems" (xii).

A comparison model used in Singapore textbooks, known as the bar method, provides the pictorial illustration of mathematical principals. It is also used for complex application problems. For example, figure 2 depicts two typical application problems.

The bar model on the left represents an arithmetic-type application problem:

> Dunearn Primary School has 280 pupils. Sunshine Primary School has 89 pupils more than Dunearn Primary. Excellent Primary has 62 pupils more than Dunearn Primary. How many pupils are there altogether?

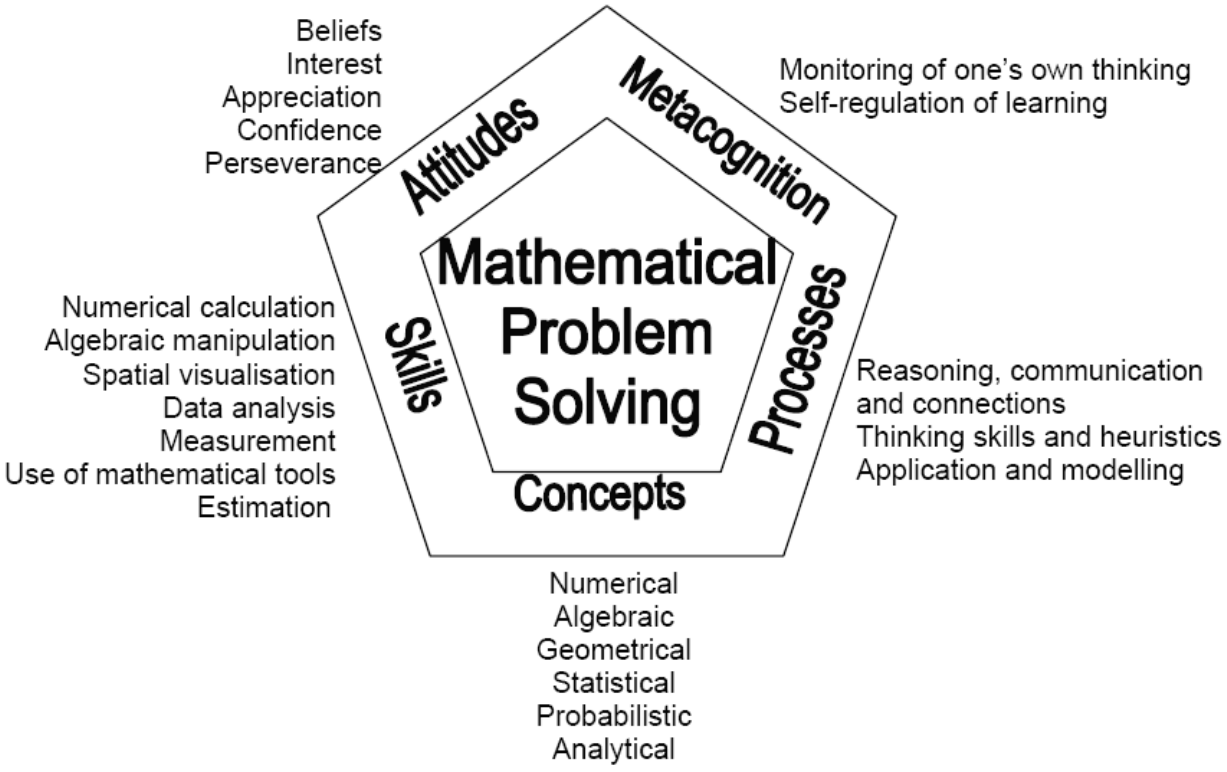

Beliefs
Interest
Appreciation
Confidence
Perseverance
Attitudes
Metacognition
Monitoring of one's own thinking
Self-regulation of learning
Mathematical Problem Solving
Numerical calculation
Algebraic manipulation
Spatial visualisation
Data analysis
Measurement
Use of mathematical tools
Estimation
Skills
Processes
Reasoning, communication and connections
Thinking skills and heuristics
Application and modelling
Concepts
Numerical
Algebraic
Geometrical
Statistical
Probabilistic
Analytical

Fig. 1. Singapore. Ministry of Ed. *Mathematics Syllabus Primary*. Singapore: MOE, 2006. Web. 12 Oct. 2009

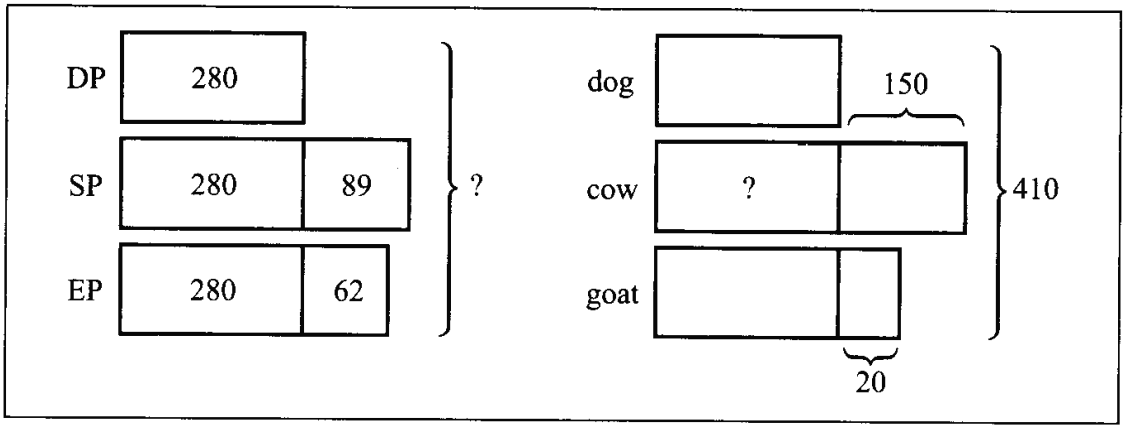


Fig. 2. Swee Fong, Ng, and Kerry Lee. "The Model Method: Singapore Children's Tool for Representing and Solving Algebraic Word Problems." *Journal for Research in Mathematics Education* 40:3 (2009): 282-313. *Academic Search Elite*. EBSCO. Web. 5 Nov. 2009.

The bar model on the right represents an algebraic problem:

A cow weighs 150 kg more than a dog. A goat weights 130 kg less than the cow. Altogether the three animals weigh 410 kg. What is the mass of the cow?

The bar method helps to illustrate the connection between compared quantities. The lengths of the rectangles represent the given and unknown quantities (Swee Fong and Lee 287).

According to Swee Fong and Lee in "The Model Method: Singapore Children's Tool for Representing and Solving Algebraic Word Problems," their study supports a body of research indicating that representational models develop students' higher-order mathematical abilities—particularly for application problems, the bane of most students' mathematics experience. They also determined that encouraging students to discover solutions for themselves added to mathematical competency—especially in solving fractional relationships. Rather than providing a rote algorithm, this method encourages students to think first about the relationships involved and then analyze what is given and what is being asked (287, 311).

Another advantage of Singapore's textbooks is their focus on depth rather than breadth, as outlined in their framework. Students typically finish one lesson centered on one topic per week, achieving mastery of each topic as it is presented. U.S. textbooks, on the other hand, lack focus. In the U.S., textbook authors must meet the varied demands of individual state standards and, as a result, average nearly twice as many topics as a Singapore textbook. Thus, topics are covered in less time and in a less thorough manner (Ginsburg et al. xii-xiii).

Analysis of Assessments

According to Ginsburg et al., "The questions on Singapore's high-stakes grade 6 Primary School Leaving Examination (PSLE) are more challenging than the released items on the U.S. grade 8 National Assessment of Education Progress (NAEP) and the items on the grade 8 state assessments." Indeed, Singapore's PSLE contains as much as double the amount of constructed-response (or free response) questions as the NAEP and state exams. These types of questions reveal a "higher-level cognitive process in mathematics" by asking students to apply their knowledge as a written answer. Typical problems on the grade 6 PSLE are more cognitively challenging, requiring multiple steps that go beyond merely applying a formula (xiii).

Singapore uses their assessments for school, as well as student, accountability. Their "value-added" approach measures the value of the gains a student has made in educational achievement over the student's initial performance. Once students' scores are adjusted based on value-added measures and combined, the school's actual growth is compared with its expected growth. Those schools achieving higher than expected results are rewarded accordingly.

In the U.S., the No Child Left Behind Act (NCLB) utilizes Adequate Yearly Progress (AYP) on state assessments as a growth measure for school accountability. NCLB permits students to transfer out of schools with poor performance on state assessments and into schools demonstrating higher performance. Higher-performing schools may be reluctant to accept these students, as they may have to make greater improvements in their AYP targets in subsequent years due to the increase in the number of low-performing students in their school population. Singapore's value-added measures of progress eliminate this deterrent (Ginsburg et al. xiii).

Analysis of Teacher Preparation

"Singaporean elementary school teachers are required to demonstrate mathematics skills superior to those of their U.S. counterparts before they begin their teacher training. At every phase of pre- and post-

service training, they receive better instruction both in mathematics content and in mathematics pedagogy" (Ginsburg et al. xiv).

Before acceptance to education school, Singapore teacher candidates must pass a rigorous examination. U.S. elementary education majors, on the other hand, were among the lowest of all college-bound students for SAT mathematics scores. Further, they take fewer mathematics courses than most other college graduates (xiv).

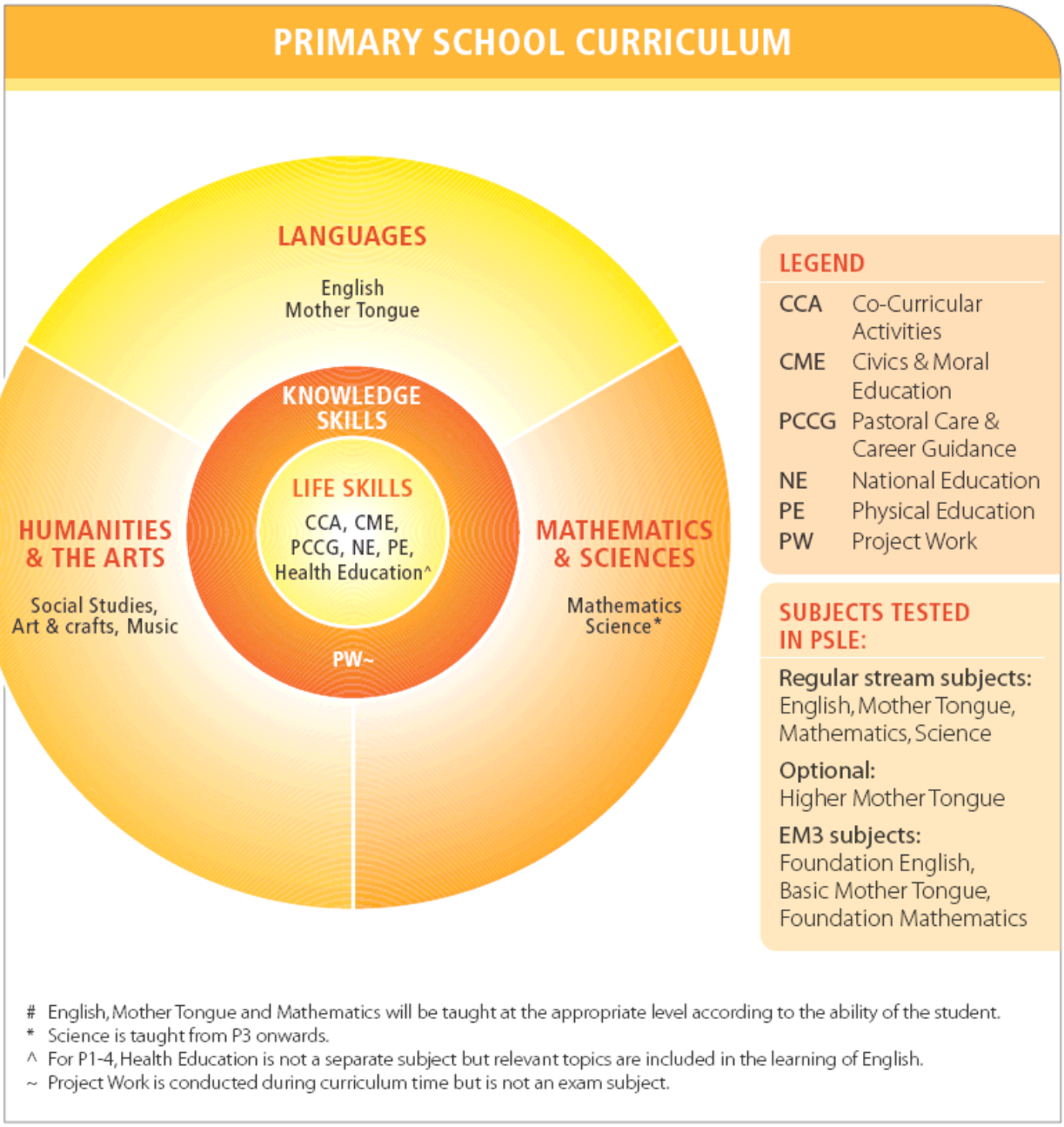
All Singapore teacher candidates participate in a content-driven, one- or two-year Post Graduate Diploma in Education program at the National Institute of Education. They receive instruction on educational principles, methods for teaching their subject, and practical experience. All fees for training are paid by the MOE and they receive a teacher's salary.

Once employed, Singapore teachers are required to complete 100 hours of professional development each year to improve their content knowledge and skills. U.S. elementary school teachers, however, spend about one-fourth of that for professional development, typically in a short-term workshop. For example, teachers in Tracy CA are shown 5-to-15 minute "best practices snapshots" by their fellow teachers (e.g. how to use popsicle sticks to randomly choose students for questioning). While the information is worthwhile, such practices are "widely admitted to be ineffective for *changing practice*" (Ginsburg et al. xiv, emphasis added).

Conclusion

Singapore leads the international community on mathematics assessments. Their system for teaching mathematics outshines the U.S. in several areas. Their focused mathematics framework, based on problem solving, covers fewer topics but in more depth than the U.S. In addition, their textbooks and assessments are more challenging. Further, Singapore teachers receive more mathematics training and professional development. By replicating Singapore's model of exceptional methods, students in the U.S. can develop higher-order mathematics skills and the U.S. will significantly improve its standing on international mathematics exams.

Exhibit 1: Singapore Primary School Curriculum



Source: Singapore. Ministry of Ed. *Nurturing Every Child*. Singapore: MOE, 15 Feb 2006. Web. 12 Oct. 2009.

Exhibit 2: Primary 1 to Primary 6 Syllabus Framework

P1	P2	P3	P4	P5	P6
NUMBERS: WHOLE NUMBERS					
1. Numbe and pla up to 1 2. Cardin ordinal 3. Compa orderin 4. Addition and subtraction of numbers within 100 5. Multiplication of numbers whose product is not greater than 40 6. Division of numbers not greater than 20	3. Multiplication and division within the 2, 3, 4, 5, and 10 times tables	3. Multiplication tables up to 10×10 4. Multiplication and division of numbers up to 3 digits by a 1-digit number 5. Odd and even numbers	4. Multiplication of numbers • up to 4 digits by a 1-digit number • up to 3 digits by a 2-digit number 5. Division of numbers up to 4 digits by a 1-digit number and by 10	up to 4 digits by a 2-digit whole number 4. Order of operations	
NUMBERS: FRACTIONS					
	1. Equal parts of a whole 2. Idea of simple fractions 3. Comparing and ordering like fractions	1. Equivalent fractions 2. Comparing and ordering unlike fractions	1. Addition and subtraction • like fractions • related fractions 2. Product of a proper fraction and a whole number 3. Mixed numbers and improper fractions	1. Addition and subtraction of • mixed numbers, • unlike fractions 2. Product of fractions 3. Concept of fraction as division 4. Division of a proper fraction by a whole number	
NUMBERS: DECIMALS					
				1. Multiplication up to 2 decimal places by a 2-digit whole number 2. Multiplication and division up to 3 decimal places by tens, hundreds, thousands	1. Number notation and place values up to 3 decimal places 2. Comparing and ordering 3. Addition and subtraction up to 2 decimal places 4. Multiplication and division up to 2 decimal places by 1-digit whole number 5. Conversion between decimals and fractions 6. Approximation and estimation 10
NUMBERS: AVERAGE/RATE/SPEED					
				1. Average 2. Rate	1. Time (24-hour clock) 2. Speed
NUMBERS: RATIO/ PROPORTION					
				1. Ratio	1. Ratio and direct proportion
NUMBERS: PERCENTAGES					
				1. Concept of percentage 2. Percentage of a quantity	1. One quantity as a percentage of another

Source: Singapore Topic Matrix For Numbers—Primary 1 to 4 and Primary 5 and 6 (Normal Track). Source: *What the United States Can Learn From Singapore's World-Class Mathematics System.* Washington: American Institutes for Research, 2005. Web. 12 Sep. 2009. Exhibit 3-5.

Source: Singapore Topic Matrix For Numbers—Primary 1 to 4 and Primary 5 and 6 (Normal Track). Source: *What the United States Can Learn From Singapore's World-Class Mathematics System.* Washington: American Institutes for Research, 2005. Web. 12 Sep. 2009. Exhibit 3-5.

Works Cited

Ginsburg, Alan, Steven Leinwand, Terry Anstrom, and Elizabeth Pollock. *What the United States Can Learn From Singapore's World-Class Mathematics System*. Washington: American Institutes for Research, 2005. Web. 12 Sep. 2009.

Martin, Michael O., Ina V.S. Mullis, and Pierre Foy. *TIMSS 2007 International Mathematics Report*. Chestnut Hill: TIMSS & PIRLS International Study Center, 2009. Web. 12 Sep. 2009.

Menon, Ramakrishnan. "Should the United States Emulate Singapore's Educational System to Achieve Singapore's Success in the TIMSS?" *Mathematics Teaching in the Middle School* 5.6 (2000): 345. *Academic Search Elite*. EBSCO. Web. 5 Nov. 2009.

Mullis, Ina V.S., Michael O. Martin, Eugenio J. Gonzalez, and Steven J. Chrostowsky. *TIMSS 2003 International Mathematics Report*. Chestnut Hill: TIMSS & PIRLS International Study Center, 2004. Web. 12 Sep. 2009.

National Council of Teachers of Mathematics. *Curriculum Focal Points for Prekindergarten Through Grade 8 Mathematics: A Quest for Coherence*. Reston: NCTM. 2006. Web.

Singapore. Ministry of Ed. *Desired Outcomes of Education*. Singapore: MOE, 2009. Web. 12 Oct. 2009.

---. ---. *Education in Singapore*. Singapore: MOE, Dec. 2008. Web. 19 Oct. 2009.

---. ---. *Mathematics Syllabus Primary*. Singapore: MOE, 2006. Web. 12 Oct. 2009.

---. ---. *Nurturing Every Child*. Singapore: MOE, 15 Feb 2006. Web. 12 Oct. 2009.

Swee Fong, Ng, and Kerry Lee. "The Model Method: Singapore Children's Tool for Representing and Solving Algebraic Word Problems." *Journal for Research in Mathematics Education* 40:3 (2009): 282-313. *Academic Search Elite*. EBSCO. Web. 5 Nov. 2009.

Ting, Tan Ching. "Policy Developments in Pre-School Education in Singapore: A Focus on the Key Reforms of Kindergarten Education." *International Journal of Child Care and Education Policy.* 1.1 (2007): 35-40. Web.

United States. Dept. of Ed. *The Nation's Report Card: Mathematics 2009*. Washington: NCES. Web. 16 Oct. 2009.

CROSSINGS