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# CANADIAN JOURNAL OF UNDERGRADUATE RESEARCH



Volume 1 Issue 1 - April 2016

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# Letter from the Editors

There are few today who would doubt the importance of research. The process of academic inquiry and the contributions of thousands of people have supplied us with tools for managing disease, building cities, and preserving the past. We have come to a stronger understanding of the particles that make up our universe, the power of art, the power of language, the intersectional nature of social inequality, and the dangers of unsustainable resource consumption. Research has played no small role in altering the parameters of human experience over the past century, and our understanding of how that experience can be reconciled with the greater motions of the world.

Until the last twenty years, it was relatively unusual for students to engage in real-life research at the undergraduate level. But few experiences can prepare students so thoroughly for the challenges of both collaborative problem-solving and independent project development, and with increasing momentum, research activities are becoming a more common entry in the curriculum vitae of many graduate school-hopefuls and others interested in developing their career prospects.

Despite the fact that research is becoming a part of the general undergraduate experience, there are limited avenues through which undergraduate students can share their work. With the Canadian Journal of Undergraduate Research (CJUR), we are hoping to create a platform for the global undergraduate community to communicate its research with a public audience. CJUR will also provide an arena in which a diverse chorus of perspectives will weigh in on the complex, multidisciplinary problems that define the next frontier in human understanding and praxis.

What follows here is a call-to-arms: CJUR is an initiative run by undergraduates and for undergraduates, and we believe that everyone has something to add to the discussion. Whether you have completed your own research project or want to share updates from a particular field of study that interests you, we urge you to submit your primary research articles, reviews, commentaries, or perspective pieces. Be a part of the conversation! We look forward to seeing your name in print.

Sincerely,

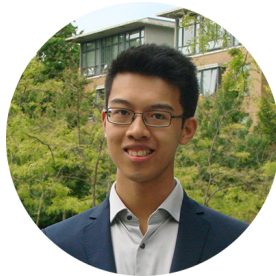
Sophia Ly, Kevin Ng, and Cody Lo  
Editors in Chief

# Editorial Board

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## ARTICLE

# Longitudinal Analysis of the Spread of Happiness in Social Networks

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## INTRODUCTION

In 2004, the World Health Organization (WHO) expressed an increasing emphasis on recognizing happiness as a vital component of health (Pronczuk-Garbino, 2005). However, there is a stark lack of research investigating how happiness is affected by those around them. It has long been known that emotions such as happiness and sadness can be easily transferred between individuals in close social contact (Hatfield et al., 1994). While the exact mechanism of this transfer and the timeframe over which this takes place is lesser understood (Fowler & Christakis, 2008). Fowler and Christakis (2008) conducted a study investigating the spread of happiness in social networks. They followed 4739 individuals over a 20 year period (1983-2003) and assessed their happiness using a validated four item scale and mapped the relationships amongst individuals. Over time they found visible happiness “clusters” and that those surrounded by happy people were more likely to become happy in the future. Statistical testing suggested that this relationship was due to the spread of happiness and not the tendency of similar individuals to associate with each other. Our group sought to add knowledge to this topic by working collaboratively to examine how happiness varies within social networks and the factors which influence happiness at both an individual and social level.

## METHODS

We constructed a social network in NodeXL on Windows 8.1 comprised of 50 individuals that were close friends or family of at least one of the group members. In NodeXL, we characterized all individuals by age (15-24, 25-34, 35-54, 55+) as well as characterized the relationships between individuals (classmate in SPPH 302, classmate not in SPPH 302, relative, roommate/significant other, non-UBC friend, and other). To preserve participant privacy, each member was assigned a code name in the data analysis. Our method for assessing happiness follows closely to previous research done in the field (Fowler et al., 2008, Burt, 1987). We randomly sampled a total of 20 individuals to complete paper surveys about their happiness level. Each individual gave informed consent prior to participation. The survey consisted of four questions that were rated on a scale from 0 to 3 based on the participant's subjective opinion at the time of survey.

The questions asked were as follows:

1. I felt that I was just as good as other people
2. I felt hopeful about the future
3. I was happy
4. I enjoyed life

A rating of 0 corresponded to an answer of “rarely, or none of the time (less than one day)”; a rating of 1 corresponded to an answer of “some or a little of the time (1-2days)”; a rating of 2 corresponded to an answer of “occasionally or a moderate amount of time (3-4 days)”; and a rating of 3 corresponded to an answer of “most or all of the time (5-7 days)”. To assess the longitudinal variations in happiness, all 20 selected participants were approached to be surveyed twice. The first survey was completed between October 9th - October 13th, and the second between November 16th - November 20th.

We assessed the happiness of individuals by adding the scores of the participants for the 4 constructs to obtain a total happiness score out of 12. Using NodeXL and Microsoft Excel 2013, we plotted the total happiness score for all individuals surveyed at both timepoints. To assess how happiness varies over time, we calculated the change in happiness between the two time points for all individuals surveyed and plotted the results using NodeXL. The changes in happiness were separated into 5 qualitative categories for the purposes of our analysis: large increase (increase of 4 or more points), small increase (increase of 2-3 points), no change, small decrease (decrease of 2-3 points), and large decrease (decrease in 4 or more points).

## RESULTS

Of the individuals surveyed in our network, 100% of those approached responded to all the questions in the survey. Additionally, all participants (n=20) completed the survey for the second time point. The mean happiness score out of 12 after the first survey was 9.25 (n=20), and 8.75 (n=20) after the second survey. Figure 1 illustrates the absolute score for the first survey, while Figure 2 illustrates the scores of the second survey.

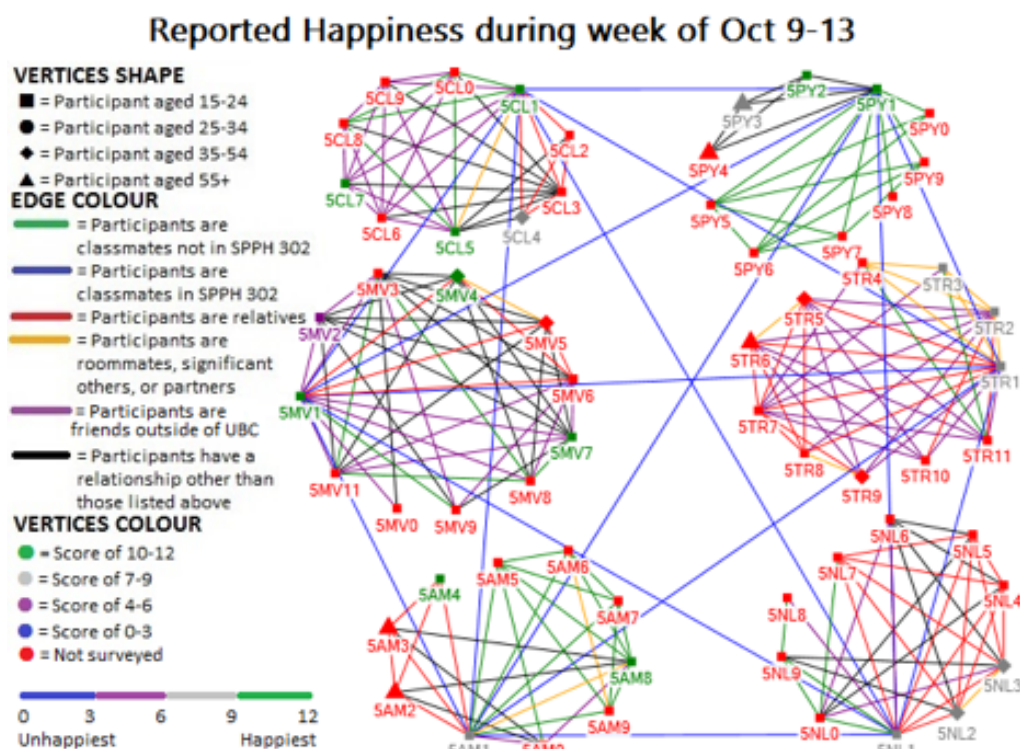
survey. The mode score out of 12 after the first survey was 10 ( $n=20$ ), and after the second survey it was 9 ( $n=20$ ). The range of the happiness score after the first survey was 7-11 and after the second survey it changed to 6-12. There was a mean difference of 2 points between the two survey time points (Fig. 3). We found that 50% of participants surveyed decreased in their happiness score, 25% increased, and 25% remained the same. These number of individuals increasing or decreasing in their happiness score are represented in Figure 3.

## DISCUSSION

In this study, most of the participants' level of happiness decreased while a smaller proportion had no change or an increase in their happiness. A general decrease in happiness was the most prominent trend. We suspect that this relationship was not due to chance or other unpredictable individual factors for a number of reasons we will discuss. Rather, we believe that the changes in happiness seen were due to interactions between those who are part of the same social network.

According to Fowler and Christakis (2008), happiness is, to an extent, contagious and is not simply due to the tendency of similar individuals to associate with one another. They also found that those who are central within a social network of mainly happy people are likely to be happier themselves. Our results were in accordance with these findings; as the happiness of those within a social network decreased, the happiness level of the group member who was central to those relations also decreased. We noted that this relationship was especially apparent between participants who presumably spend a lot of time together, such as relatives or roommates. Feelings of happiness and joy can be transmitted between individuals through the expression of emotion (Hatfield et al., 1994). Therefore, we postulate that analogous feelings of unhappiness can also be easily spread through similar mechanisms involving close social contact.

Some explanations for an increase in happiness even when the central member of a network showed a decrease in happiness include geographical separation or professional relationships. This is supported



**Figure 1.** Happiness clusters in the social network constructed ( $n=60$ ) of students in SPPH 302 and their close friends and family for the week of October 9th 2015. Each node represents one person while lines between nodes indicate relationship. Node colour denotes level of happiness as indicated by the survey. Colour of vertices indicate the types of relationships between individuals.

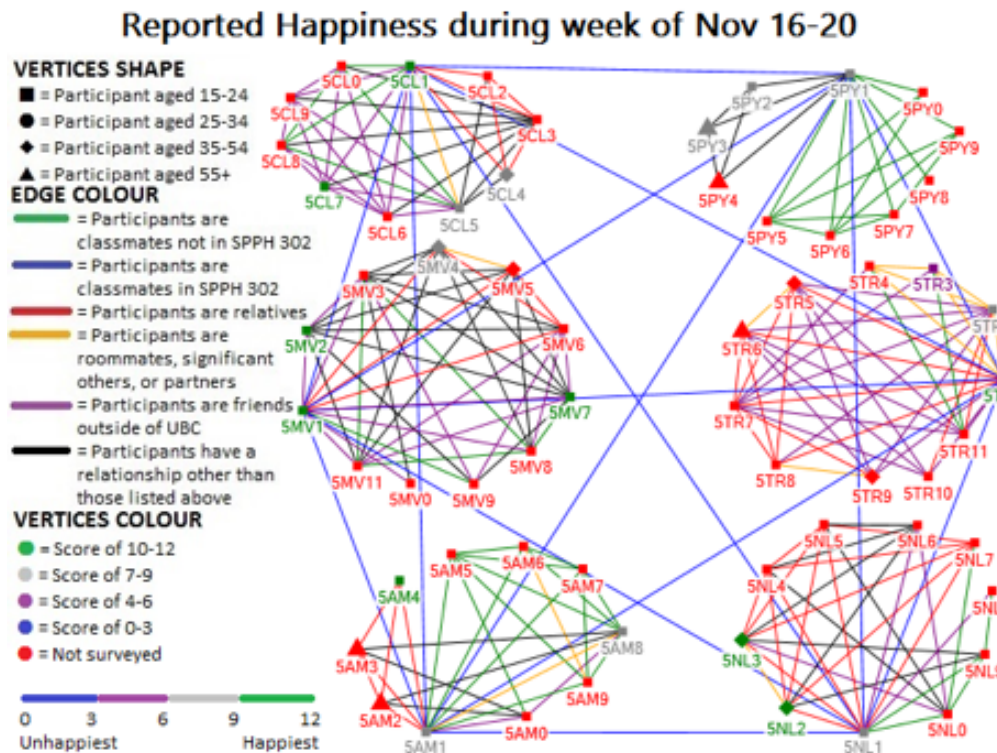


Figure 2. Happiness clusters in the social network constructed ( $n=60$ ) of students in SPPH 302 and their close friends and family for the week of November 16th 2015. Each node represents one person while lines between nodes indicate relationship. Node colour denotes level of happiness as indicated by the survey. Colour of vertices indicate the types of relationships between individuals.

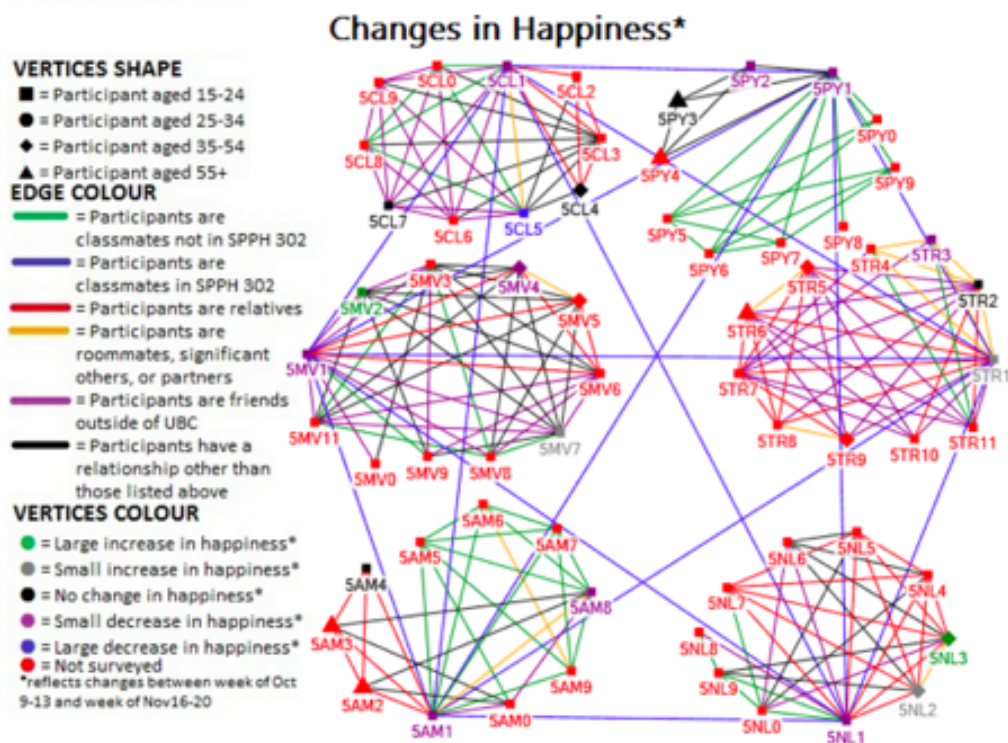
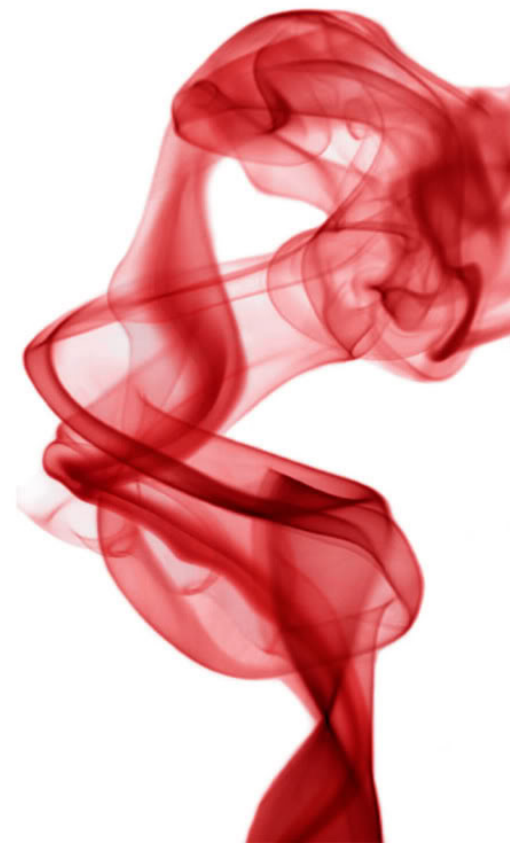


Figure 3. Changes in happiness reported in the social network constructed ( $n=60$ ) of students in SPPH 302 and their close friends and family between the weeks of October 9th and November 16th 2015. Each node represents one person while lines between nodes indicate relationship. Node colour denotes level of happiness as indicated by the survey. Colour of lines indicate the types of relationships between individuals.



by Fowler and Christakis (2008) who showed that co-workers do not seem to have any significant effect on each other's happiness. Ronald Burt (1987) also found that in some cases a negative impact from strangers can play a larger role on an individual's happiness than the positive impact of significant relationships. His findings could explain why there were some disparities in happiness clusters amongst some social networks, some discrepancies could be due to an external negative impact from a stranger.

All in all, we learned that there is a relationship between happiness and one's social network, and that happiness clusters within a social network are not simply coincidence, but are a result of the relations within said network. Similar to Smith and Christakis (2008), we saw that health is not independent of the health of those around you, but is actually interconnected. This study could have been improved by recruiting a larger sample as it could have resulted in a more representative mean and smaller standard deviations. Depending on the relationships between the participants, the descriptive statistics would likely change because a sample of 20 people is likely not representative of a whole population. In future studies, the survey could be more comprehensive to gain a greater insight into one's happiness. Participant's could also be surveyed more than twice and over a longer period to better elucidate the changes in happiness. It would be interesting to conduct further studies on whether other emotional characteristics such as stress can diffuse through social networks as well. The methodology to study stress may be similar to the methods used in this study to measure happiness, since they are both subjective measures of individual experience. A proposed way to alter the experiment in order to investigate social trends such as frequency of using verbal slang may be to take baseline measures of frequency of use, and then over a time frame of months, have the investigator use specific slang more often around the participants and see if frequency of use increases in the participants. The same method can be applied to investigate lifestyle choices.

The conclusions and patterns drawn from this study on social networks undoubtedly have implications for public health. Our study demonstrates visible clusters of happy and unhappy people. Illness may lead to individuals or groups of individuals to be unhappy. We

postulate that clusters of unhappy people could be correlated to clusters of ill or unhealthy people. This may expose patterns in health status and help solve the issues of certain disease pandemics such as obesity. Additionally, a treatment that improves the health and happiness of one person might have an effect on others, thus leading to an overall healthier population.

As defined by the WHO, public health is all organized measures, both public and private, to prevent disease and promote health among the population as a whole. In this sense, our project very clearly fits with the goals of public health. In studying these networks and connections we can create programs or target clusters of people who are at high risk of being unhappy or unhealthy. These network analyses study the majority of the population and with increasing sample size may accurately reflect the needs of the entire population. Other definitions of public health include monitoring of health. We believe that monitoring is an exceptionally important part of public health since it allows for a direct observation of the needs of the public. Social network analysis becomes a useful tool in reviewing public data and the applications in public health hold great potential.

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**ARTICLE****Interpreting Vergil's "Orpheus in the Underworld": Comparing Structuralism and Carl Jung's Archetypal Theory****Sean Okawa**

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The myth, "Orpheus in the Underworld" from Vergil (*Georgics*, 4.453-4.527, translated in Trazskoma et al., 2004) is one of the many myths to feature the concept of *katabasis*, defined as "descent to the Underworld" (Herrick, 2014). This myth can be analyzed by two different approaches: The first is structuralism, and the second is Carl Jung's theory on the "collective unconscious" (Dowden, 1992, pp. 17-23). Despite the validity of both methods, I will, in this paper, argue that Jung's archetypal theory better unveils the intent and drive behind this myth. In the 1950's, Claude Levi-Strauss developed a methodology to uncover the meaning of myths: he believed that myths were a way by which the ancients raised cultural concerns and assuaged them. This perspective was coined as "structuralism" and involved deconstructing myths into their central, interrelated ideas; these ideas were then addressed individually (Levi-Strauss, 1963, pp. 213). On the other hand, Jung's archetypal theory is based on the "collective unconscious", the belief that all members of the human race have a subconscious set of ideas or "archetypes" which become expressed through myth. This expression may differ from culture to culture, and interpretations may vary. However, the core meaning is retained across cultures (Dowden, 1992, pp. 17-23).

The myth "Orpheus in the Underworld" portrays the protagonist, Orpheus losing his wife Euripides to the Underworld. A grieving Orpheus journeys to the underworld in a vain attempt to rescue his wife. Orpheus "[enters] the jaws of Taenarum, the deep doorway of Dis, and the grove shrouded in black terror" (*Georgics* 4.453-4.527). He passes through the many tiers of underworld security and reaches Plouton successfully. Orpheus successfully convinces Plouton to send Euripides up to the mortal realm, though Plouton issues one condition: Orpheus must not look back as he and Euripides leave the underworld. Tragedy strikes when Orpheus is "seized

by a sudden madness" and succumbs to the desire to look upon his lover; "his hard toil was wasted, his compact with the pitiless tyrant broken" (*Georgics* 4.453-4.527). The punishment for this is Euripides's return to the Underworld and eternal separation from Orpheus. He is overcome with grief for the rest of his life, until, he is brutally murdered (*Georgics* 4.453-4.527).

If the method of structuralism is applied to the myth of Orpheus, one can see that cultural problems are both addressed and rationalized. The myth is analogous with the real life concept of losing a loved one to death or going to great lengths to save a loved one. A possible interpretation of the myth may be that in ancient times the Greeks created the myth of Orpheus in order to express their feelings of despair at the demise of their lover. This myth was an attempt to document the fragility of human life and how every human being at some point becomes victim to life's natural biological processes. When citizens hear of, and can identify with an honourable, pitiable, and valiant main character, they can rationalize regarding the fact that nobody on earth escapes life's calamities.

Though this interpretation is valid, one could also argue that "Orpheus in the Underworld" does not fully accomplish what a myth should from the view of structuralism. The myth of Orpheus may address the need to portray a cultural concern, but does not necessarily alleviate this concern. For example, if the intent of this myth was to help the reader come to terms with, and more peacefully accept the concept of death, it does not fully succeed at this goal. The morbid, depressing and traumatic ending could have been made happier, or supported by justification, contrary to the existing reality of Orpheus. On the other hand, this myth can be much better explained if viewed from the psychoanalytic perspective that

our collective unconscious is trying to teach us a lesson, primarily that journeys to the underworld are unsuccessful.

Carl Jung's "collective unconscious", when applied to this myth, would state that the concept of katabasis is an archetypal event that fascinates the collective human subconscious. Jung would argue that in order to grieve the loss of a loved one, a person could fantasize or dream about attempting such a rescue. This concept is common in Greek mythology and even throughout other mythologies around the world. Most notable is the myth "Death of a goddess" from Japanese mythology. In this story, the goddess Izanami dies in childbirth and her husband Izanagi journeys to save her. Similar to Orpheus, Izanagi cannot resist the desire of seeing his loved one and fails to bring her back (Chamberlain, 1932, pp. 40-47). These two myths not only share the concept of katabasis but there is a recurring theme that their journeys are not successful. Jung might argue that this could be attributed to human beings' innate knowledge regarding, and subsequent desire to teach, the lesson that there is an overarching force that decides for us when we are to leave existence on earth.

Of course, Jung's archetypal theory also has its limitations in the interpretation of this myth. There are myths within both Greek mythology and other mythologies which defy the hypothesis of unsuccessful journeys including, but not limited to: Heracles' rescue of Theseus, Odysseus' journey to the underworld, and Persephone's partially successful return (Mikellidou, 2015). However, most of these successful examples centre on the characters journeying to the underworld willingly and returning (not in Persephone's case), making it ambiguous whether conducting katabasis results in death. The supposition that katabasis may not result in the death of the heroes themselves, could possibly support the argument that those who die naturally as in the case of Euripides cannot return to the mortal realm. These arguable differences between the outcomes to these journeys to the underworld do not change the fact that the fundamental concept of katabasis is thoroughly repeated in mythologies around the world. This reaffirms that there is some merit in applying Jung's hypothesis of the human "collective unconscious" to the myth of Orpheus. Therefore, I maintain that despite its own weaknesses, Jung's archetypal theory is the more prominent approach to

this myth.

In conclusion, although both the methods of structuralism and Jung's psychoanalysis have their respective applicability and limitations, the concept of the "collective unconscious" is closest to the myth.

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**ARTICLE****Oxytocin-Induced Balance of Cortical Inhibition and Excitation Facilitates Behavioural Changes in Pup Retrieval by Mice****June Yue Dong**

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**ABSTRACT**

Across species, oxytocin (OT) has been identified as a neuromodulator of social interactions and maternal behaviour. The timing, location, and method of how oxytocin alters neural activity, however, are not well characterized. In order to elucidate oxytocin's mechanism of action, Marlin et al. (2015) investigated differences in pup retrieval among maternal female mice (dams), naïve virgin mice, and experienced virgin mice, as well as the role of oxytocin in eliciting or modifying their behaviours. As muscimol inhibition of the left auditory cortex (AI) prevented pup retrieval, so systemic application of oxytocin accelerated maternal reactions to pup vocalizations. Neural responses to vocalizations confirmed lateralization of responses in the left AI of experienced adult mice. Further, Marlin et al. (2015) observed that current-clamp and cell-attached recordings of the left AI in dams and experienced virgins demonstrated precisely timed combinations of excitatory and inhibitory activity as a response to pup calls. Finally, optogenetic oxytocin stimulation paired with pup vocalizations resulted in the balancing of size and time of inhibition with excitation. These results indicate synaptic balance as the mechanism that allows oxytocin to enhance salience of socially relevant auditory information.

**INTRODUCTION**

For decades, oxytocin has been known to affect behaviour in mammals. Produced in the paraventricular nucleus (PVN) and the supraoptic nucleus of the hypothalamus, oxytocin functions both as a peripheral hormone and neuropeptide (Gimpl et al. 2001). The hormonal functions of OT include triggering lactation and parturition. Its study in neuroscience, however, has generally focused on social behaviours such as bond formation and parenting, as well as its effect on cognition (Churchland et al. 2012).

During the 1980s, social neuroscience studies on oxytocin focused on its part in maternal rodent behaviour. OT injection was discovered to be conducive to nest building (Fahrbach et al. 1984), but maternal behaviours were blocked by OT receptor antagonists (Fahrbach et al. 1985). While OT knockout (KO) mice did not demonstrate abnormalities in maternal behaviour, (Nishimori et al. 1996) OT receptor KO mice showed maternal behaviour deficits (Takayanagi et al. 2005). Parallel to this research were investigations on the effects of auditory cues, specifically the social stimuli emitted by pups, on maternal behaviour. Low frequency pup vocalizations were found to induce maternal nest building (Ehret et al. 1986), and ultrasonic pup vocalizations were found to induce a search and retrieval process (Ehret 2005). Mouse mothers (dams) would retrieve pups even after vocalizations stopped, and would retrieve mice based on audio recordings of ultrasonic vocalizations, in the absence of pup emitted calls (Ehret 2005). Further, virgin females who hear those vocalizations do not exhibit pup retrieval, and have a lower signal-to-noise ratio of neural response in the AI than dams (Liu et al. 2006). Yet, an earlier study by Pedersen et al. in 1982 observed the interesting phenomenon of virgin female rodents participating in pup retrieval pups after being cohoused with a dam and her pups, or if the virgin female was administered oxytocin centrally (Pedersen et al. 1982). In order to elucidate the role of oxytocin, in particular its spatial-temporal profile and mechanism of action, Marlin et al. merged the two existing paths of inquiry on the respective roles of oxytocin and vocalizations on pup retrieval behaviour (Marlin et al. 2015). They assessed experimental female wild-type mice receiving systemic oxytocin injections, wild-type mice receiving saline vehicle injections, and oxytocin-IRES-Cre mice optogenetically stimulated for release of endogenous oxygen for their amount of time to retrieval.

to label oxytocin in the AI of virgins for immunohistochemical analysis. In experienced animals, the GABA agonist muscimol was injected into the left or right AI to inactivate those regions and compare behavioural differences. In naïve animals, oxytocin receptor antagonists or optogenetic AI stimulation were used to evaluate behavioural differences. Finally, Marlin et al. made *in vivo* and *in vitro* voltage-clamp recordings as well as *in vivo* whole-cell recordings in the AI of dams, naïve, and experienced virgins while playing recorded ultrasonic pup vocalizations, as well as during pairing of these vocalizations with topical oxytocin or optical stimulation of the AI.

## RESEARCH OVERVIEW

### SUMMARY OF MAJOR RESULTS

#### *Oxytocin Accelerates Acquisition of Pup Retrieval*

Systemic oxytocin administration or optogenetic stimulation of virgin C57BL/6 female mice led to more animals exhibiting pup retrieval than saline-injected control animals, within 12 hours of co-housing, as opposed to 2 days. Isolated animals displayed similar results, with more oxytocin receiving virgins retrieving, and retrieving faster than those given saline.

#### *Oxytocin Receptor and Pup Retrieval Auditory Cortex Lateralization*

The OXTR-2 antibody, which does not label cells in OT receptor KO animals, was expressed significantly more in the left auditory cortex of dams as well as naïve virgins compared to the right. Muscimol inactivation of the left but not right AI in experienced females impaired retrieval, while oxytocin administration or optogenetic stimulation of the left AI alone in virgins facilitated earlier retrieval than saline-infused animals. However, in animals that were already experienced in pup retrieval, neither the OTA or L-368,899 OT receptor antagonists affected performance.

#### *Cortical Responses to Pup Calls*

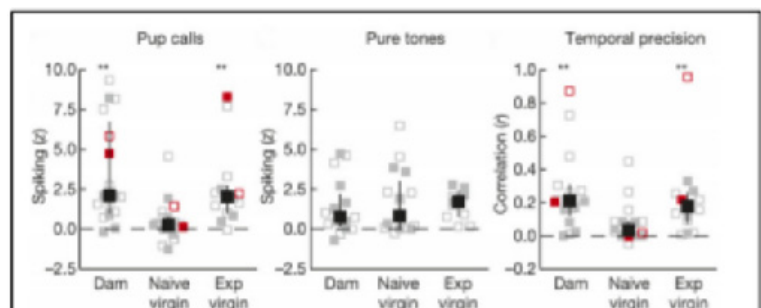
Experienced animals exhibited precise left AI spiking as evoked by pup calls during whole-cell recordings, and these responses were stronger than those displayed by inexperienced animals.

#### *Neuromodulation by Oxytocin*

Voltage-clamp recordings showed co-tuned and precisely timed cortical reactions in the form of excitatory post-synaptic currents (EPSCs) and inhibitory post-synaptic currents (IPSCs). The temporal profiles of EPSCs and IPSCs and neuronal spiking were highly correlated with pup calls in experienced animals. Inexperienced animals, however, showed no correlation of temporal precision or spiking with pup calls. This mismatch was seen as differences in patterns of inhibition and excitation. Optogenetic pairing of oxytocin with pup calls resulted in a reduction of IPSCs evoked by vocalizations, an alteration occurring in seconds and localized to the left AI. On the other hand, EPSCs were increased, and IPSCs were not increased until forty-five minutes later, balancing the excitation with inhibition and allowing for both IPSC and EPSC strength and reliability. Spike timing increased in precision with IPSC and EPSC pattern matching immediately, but matching trial-by-trial did not occur until after an hour.

## DISCUSSION AND CONCLUSIONS

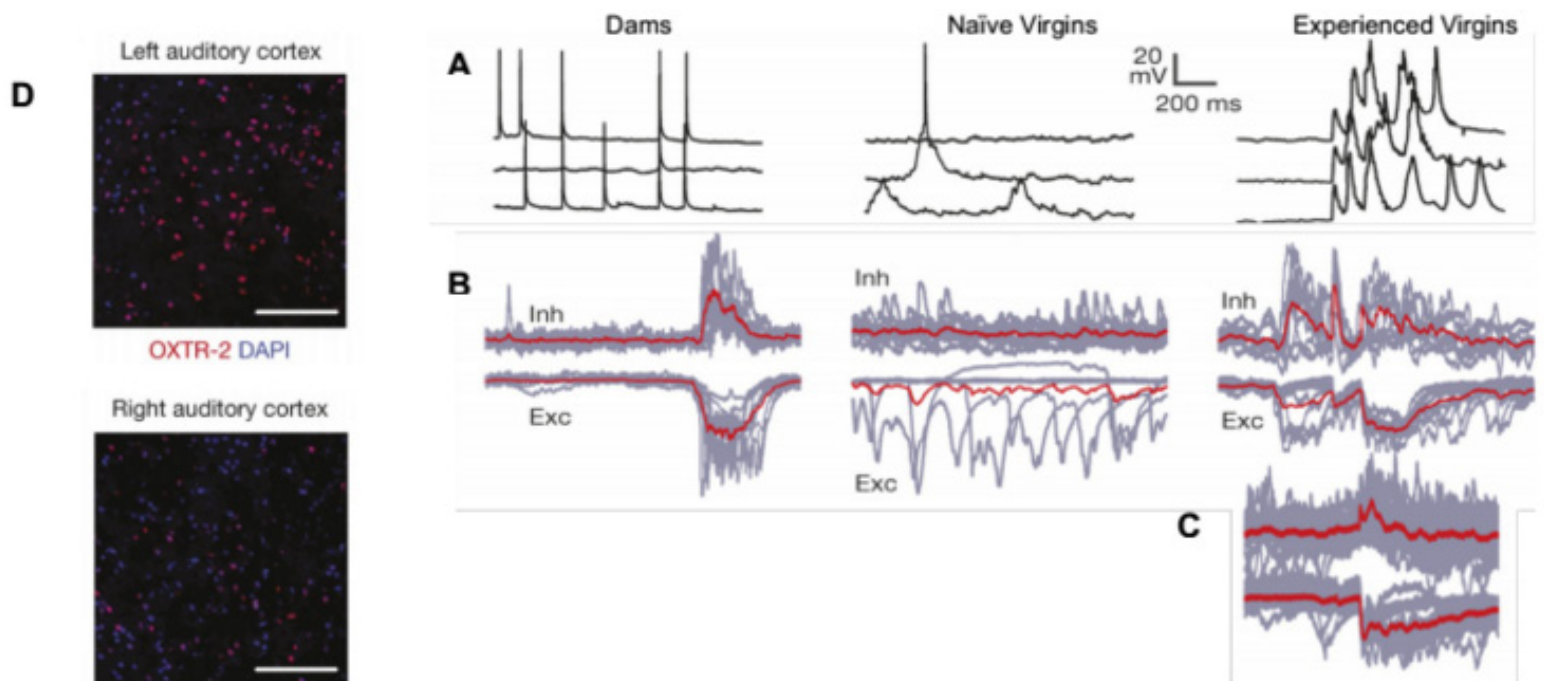
Identifying behavioural differences in time to pup retrieval between experienced and inexperienced animals provided a basis for understanding how oxytocin might play a role in changing neural circuitry or synaptic connections to create a robust response to ultrasonic pup vocalizations. Marked



**Figure 1. Spiking and Temporal Precision in Experienced Female Left AI.** Red indicates analyzed example cells. Current-clamp recorded responses were standardized using z scores for spiking evoked by pup calls and pure tones demonstrating significant differences in spiking from dams ( $n = 17$ ,  $P < 0.0004$  vs.  $n = 17$ ,  $P > 0.7$ ), and experienced virgins ( $n = 14$ ,  $P < 0.006$  vs.  $n = 11$ ,  $P > 0.6$ ) as compared to naïve virgins ( $n = 20$ ). There were no significant differences between experienced and inexperienced animals listening to pure tones. Trial-by-trial time correlation in dams ( $n = 17$ ,  $P < 0.002$ ) and experienced virgins ( $n = 14$ ,  $P < 0.012$ ) were significantly higher than in naïve virgins ( $n = 20$ ). (Marlin et al. 2015)

similarities between oxytocin mechanisms and those in the rest of the brain, murine or human, provide insight to how neuropeptides can influence the brain. The functional lateralization of pup retrieval to left auditory cortex in mice brains reflects oxytocin receptor expression. This result must be considered in context of human temporal lobe speech processing, which is also lateralized to the left side (Ehret 1987). Similarities in evolutionary use and location of oxytocin neurons in murine and human brains may be important in translational research on oxytocin and its effects. The antagonist-independent performance of experienced animals in pup retrieval suggests that oxytocin receptors are only required for acquisition of retrieval behaviours, but not for maintenance of this behaviour thereafter. Such a mechanism is analogous to the function of NMDA receptors in long-term potentiation induction and not maintenance (Malinow et al. 1989). This is valuable in showing that pup retrieval is a lasting memory, and supports Marlin et al.'s model of oxytocin and cortical plasticity. From the voltage-clamp recordings, and based on the changes in pup retrieval behaviours over time with oxytocin application, they directly demonstrated that the function of oxytocin is to cause changes in brain states, such that

responses evoked by pup calls become robust and temporally precise. The way by which oxytocin effects these changes is first an immediate reduction of AI inhibition in order to increase the salience of pup calls followed by gradual balance of excitation and inhibition for enhanced long-term spiking. Previous research finding that 30-40% of parvalbumin-positive and somatostatin-positive inhibitory interneurons express oxytocin receptors suggested that oxytocin influenced cortical inhibition (Nakajima et al. 2014). The inhibitory balancing effect of oxytocin on pup retrieval is congruent with these findings. Significantly, this suggests that innate social behaviours that can be improved by experience, such as pup retrieval, are governed by a neural circuit which is modulated through cortical inhibition and excitation by neuropeptides such as oxytocin. This addresses a critical question stemming from large bodies of work supporting both possibilities regarding whether OT influences high-order cognitive processes, or influences global states (Churchland et al. 2012). Marlin et al.'s findings seem to indicate that oxytocin has a broad effect on the saliency of sensory signals, rather than directly triggering complex social behaviours per se.



**Figure 2.** Spiking and Patterns of Excitation and Inhibition in Experienced Female Left AI. **(A)** Current clamp recordings in dams and experienced virgins demonstrated z-scores  $> 4.0$  and trial-by-trial average correlations of  $r > 0.20$ , while naïve virgins had a z-score of 0.1 and  $r$  of -0.04. **(B)** Balanced inhibitory and excitatory post-synaptic currents are characteristic of experienced animals and dams. **(C)** As virgins become experienced at pup retrieval through cohousing, they develop neutrally similar patterns. **(D)** Changes are lateralized to the left auditory cortex, where oxytocin receptors are expressed. (Marlin et al. 2015)

## ANALYSIS AND FUTURE DIRECTIONS

In an experiment examining the effects of a specific actor, negative controls are necessary to show that oxytocin plays a role in pup retrieval at all. Muscimol inactivation is a well-used treatment for inactivation, but is also known to spread (Allen et al. 2008). While the right and left AI of mice are too far apart for cross lateral contamination, it is possible that muscimol spread inactivated other regions of the brain than AI. In order to confirm, fluorophore-conjugated muscimol molecules have been developed to visualize locations of muscimol, and can be used to ascertain the spatial precision of its injection (Allen et al. 2008).

Further, *in vivo* recordings were performed on isoflurane-anaesthetized animals in order to prevent noise from movement, or sudden drops in recordings due to activity of the animal. While isoflurane-anaesthetized *in vivo* recordings are stable, they can dampen signals and are mostly used for sensory perception responses (Margrie et al. 2002). There may be differences between iso-flurane anaesthetized and awake animals especially in cortical changes and neuromodulation based on processing of auditory information, which should be investigated by using awake animals during recording.

Additionally, while the use of optogenetically stimulated AI for oxytocin ensures precise localization, there is individual variability in endogenous oxytocin release (Andari 2015). An interesting future experiment could examine whether there is a correlation between levels of oxytocin release and speed of pup retrieval behaviour acquisition, or even differences in effectiveness and duration. Some other interesting directions for the future include examining the role of olfaction in pup retrieval, and differences in paternal behaviour compared to maternal. While auditory cues are sufficient to trigger pup retrieval, this is also true of olfactory signals (Ehret 2005; Cohen et al. 2011). Olfactory cues may even be enhanced by oxytocin (Wacker et al. 2012). It is likely that both olfactory and auditory signals combine to effect pup retrieval behaviours.

One way to test for this in the future would be to combine Marlin et al.'s study with Kiyokawa et al.'s 2014 study on social olfactory cues of conspecifics. Rather than using a sound-attenuated chamber for the mice to play pup vocalizations and make electrophysiological recordings, the experiment can use pups to odorize the chamber for electrophysiological recordings, and finally combine the odorization and sounds to investigate the dual effects.

While non-conspecific pups placed in the same cage as a dam are cared for, paternal mice often attack stranger pups (Dulac et al. 2014). Notably, some of Marlin's naïve female virgin animals also mauled pups during pre-screening. Considering the increased maternal behaviour caused by oxytocin, as well as the sexually dimorphic effects of oxytocin, it would be interesting to look at how oxytocin may affect paternal or aggressive naïve virgin mouse behaviour (Insel 2010). Oxytocin could potentially have a socializing or calming effect, which is especially useful these naïve outliers were not included in the data analysis.

As OXTR-2 was carefully designed by Marlin et al. an synthesized for low cross-reactivity, and based on the western blot assay and lack of cell labelling in oxytocin knockout animals, this antibody has demonstrated clear specificity for oxytocin receptors. It can be widely used to localize oxytocin receptor expression throughout the brain in mice, in order to map and identify density of oxytocin receptors across wild-type and manipulated animals. It is also possible to adapt OXTR-2 for rats to perform comparative studies. Finally, to validate Marlin et al.'s proposed mechanism of action for oxytocin to enhance pup retrieval, an experiment could be performed which mimics the inhibitory and excitatory patterns of activity through direct stimulation. Not only could this help validate their model, it would also elucidate any other effects of oxytocin by virtue of comparison.

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## ARTICLE

# Accuracy of the Binomial Asset Pricing Model Using Daily Volatilities

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## INTRODUCTION

The binomial asset pricing model is well established, having been developed in 1979 by John C. Cox, Stephen A. Ross, and Mark Rubinstein [1]. In their paper "Option pricing: a simplified approach", they propose that stock prices can be modeled by probabilities of price increase or decrease by a set amount in a time period depending on the volatility of the stock [1]. While they used constant volatilities for their calculations, it has been identified by many other scholars that the assumption of constant volatility reflects the market poorly [2, 3], and that stochastic volatility serves the purpose better. This article compares the accuracy of the model stock prices using daily volatility values with using a constant volatility to historical stock prices in attempts to show that daily volatility rates represent the market better.

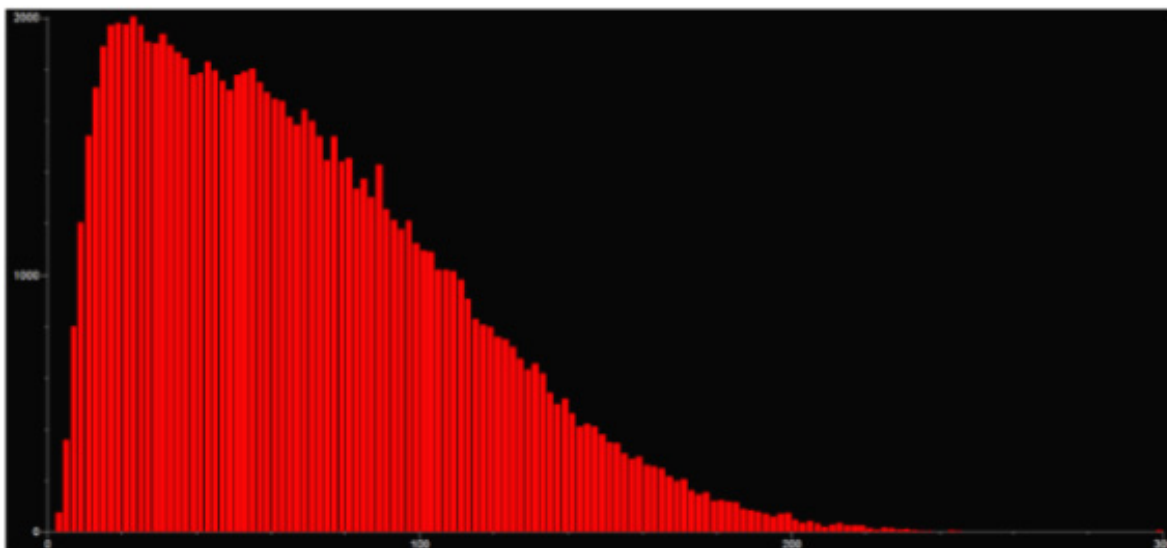
## DISCUSSION

The binomial asset pricing model assumes that stock

prices "S" will either increase or decrease a fixed amount each set trading period [4]. The probability of increase "p" (1), the stock price increase "u\*S" (2), and the stock price decrease "d\*S" (3) are all dependent on the stock volatility " $\sigma$ ". The time increment " $\delta t$ " represents the amount of time between each price change in the model. The risk-free continuous compounding rate of return "r f" represents the average rate of return from a very stable investment. This article had used the average 10 year Canadian Treasury bill return rate for r f, which is 6.4% [5].

A random number generator was used to determine whether the stock price would go up or down, depending on whether the number was bigger or smaller than p respectively, to simulate the stochastic process of price changes. Daily volatilities were calculated by taking the standard deviation of the return rate "r" (4) of the stock over a period of time (5). The daily volatilities used were calculated using the return rates of the previous 5 trading days in Eq.

**Figure 1.** Histogram of the  $X^2$  values generated from 100,000 runs of the binomial asset model for Apple with daily volatilities. The x-axis represents the  $X^2$  values and the y-axis represents the frequency of occurrence of  $X^2$  values that fall within discrete intervals of size 2.



5. Stocks were modeled given their initial open prices “ $S_0$ ”, their volatilities, the time period between price changes “ $\delta t$ ”, and the total amount of time for the model to run.

To show that daily volatilities would reflect stock prices better than a constant average volatility in the binomial asset pricing model,  $X_2$  quantify the accuracy of the model, where “ $S_{his}$ ” was the historical stock price and “ $S_{mol}$ ” was the model stock price.  $X_2$  used because there were discrete numbers of data points generated. The  $X_2$  recorded was the average of the  $X_2$  from one run of the model, so it reflects the accuracy of a single execution of the model.

The confidence was determined by the 3 sigma uncertainty “ $\sigma X$ ” (7), of the  $X_2$  where this value represents the consistency of the accuracy of the model. The  $\sigma X$  was calculated from the array of  $X_2$  by running the model “ $a$ ” times.

To distinguish the distribution of  $X_2$  values, the Anderson-Darling test was used to test for normality [6]. The results of the test showed that the distribution of  $X_2$  values does not follow Gaussian or lognormal distribution. The distribution of values can be seen in Figure 1.

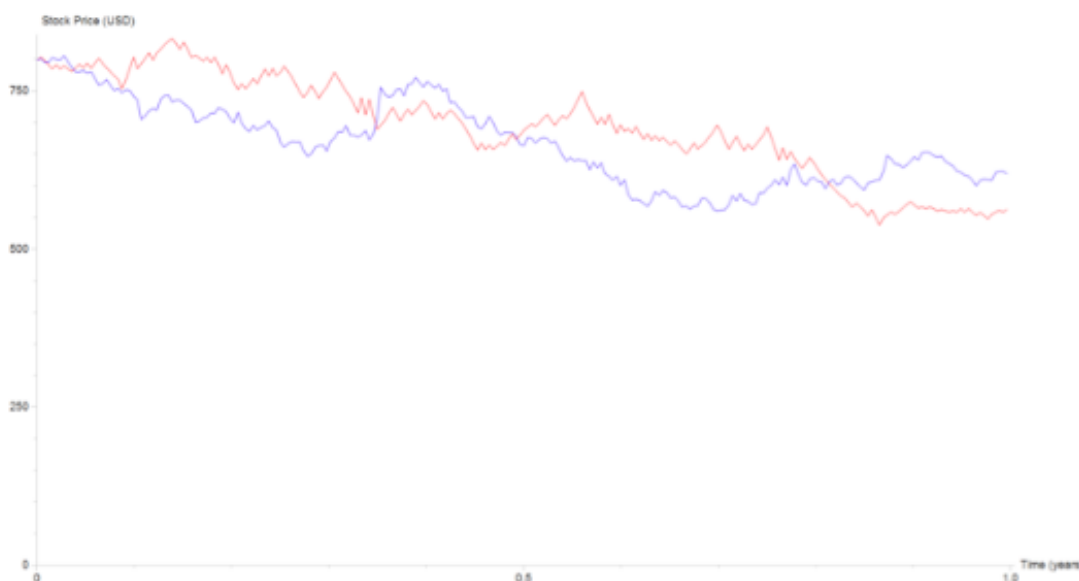
From Figure 1, the distribution appears to be skewed. The shape of the distribution looks like half

of a normal distribution, although there was a drop of the frequency of  $X_2$  can be explained by the fact that  $X_2$  were always positive and that they were non-zero because it was very unlikely that the model matches the historical data exactly. The confidence “ $C$ ” of the uncertainty measurement can be calculated by integrating the distribution curve, by modeling it with a function “ $f(x)$ ” (8), as seen in Eq. 9. “ $f(x)$ ” has scalable quantities “ $\omega$ ” and “ $\tau$ ” in order for it to better fit the distribution. Although  $f(x)$  does not match the distribution of  $X_2$  error was negligible as it was too small.

Using this method of analysis, the model was run one million times with daily volatilities and with a constant average volatility, over the period of time which the stock was to be modeled, to determine the average  $X_2$  stocks, Apple, Google, General Motors, CIBC, and RBC. The historical volatility and stock prices used were from March 2012 to March 2013 for all these stocks.

There appears to be a general trend that the model data fits the historical data better within a shorter period, from where it diverges away. Reading the graphs of the model data with the historical stock price does not provide a clear indication of whether using daily or constant average volatility values were better. An example of the graphs produced can be

**Figure 2.** Graph of the predicted stock price, in red, using non-constant volatilities of Google stock with the actual stock price in blue for reference. The data was taken from March 2012 to March 2013.



seen in Figure 2. The results of the model runs were summarized in Table 1. "C" was calculated for all the stocks, and the average "C" was reported in Table 1 as well.

It seems that in Table 1, the uncertainty for X<sup>2</sup> constant volatility were always smaller than the uncertainty for X<sup>2</sup> using daily volatility values. This may be the result of the fluctuations in the probability of price increase when non-constant volatility values were used, because there were more permutations of stock values compared to when there is a constant probability of price increase.

It also seems that there was a difference in X<sup>2</sup> as Google and Apple in Table 1. This was because the X<sup>2</sup> price changes, and higher stock prices result in bigger price changes because price changes were proportional to the initial stock price. Hence X<sup>2</sup> greater for stocks with higher stock prices.

In conclusion, it also appears that using daily rather than constant volatility rates, as seen in Table 1, decreases the accuracy of the binomial asset pricing model significantly with 99.6% confidence, because the X<sup>2</sup> the  $\sigma_X$  found. One way to explain why using daily volatility rates may result in a decrease in accuracy compared to using a constant average volatility rate was because by keeping p updated with current volatility rates, the price should reflect similar degrees of changes with historical prices.

However in periods of high volatility, the u and d values are also very high or low so the model price can move away from the historical price. Then if a period of low volatility follows, the u and d values approach closer to 1 again, so it would be difficult for the model

price to converge to the historical price, and it would remain far away from the historical prices. Having a constant volatility means that there would be constant u and d factors. Hence the model with a constant volatility would have a better chance of converging towards the historical price, resulting in lower X<sup>2</sup>.

The model was imperfect in both cases, when using an average volatility value and when using daily volatility values. One of the major reasons why the model prices do not match historical prices was because much of stock prices are governed by supply and demand, where the majority of investors may be relying on other sources, such as a Q4 report, as an indication of whether the stock will provide satisfactory returns. These other sources may contradict what the model was proposing, so the model will move away from the market stock prices.

## SUMMARY

The binomial asset pricing model was more accurate when an average volatility was used rather than daily volatilities. Periods of high volatility may explain this phenomenon. As big changes occur in the stock price during periods of high volatility, the volatility drops low again so any previous big changes made will be hard to reverse, resulting in a significant gap between the model stock price and the historical stock price. This result suggests that using daily volatility values in the binomial asset pricing model may not portray a stock value as accurately as an average volatility would in the binomial asset pricing model with 99.6% confidence. It is important to realize this fact, although it may seem counterintuitive, because derivative or stock traders can continue

**Table 1.** Summary of the X<sup>2</sup> values and the 3 sigma uncertainties of the X<sup>2</sup> values which represent the accuracy of the binomial asset pricing model for when constant volatility and non-constant volatility rates were used. Average confidence "C" was 99.6%.

Ticker Name	Company	Constant Volatility		Daily Volatility	
		X <sup>2</sup>	$\sigma_X$	X <sup>2</sup>	$\sigma_X$
NASDAQ: GOOG	Google	18.90192278	0.054569335	22.71550222	0.069359596
NASDAQ: AAPL	Apple	66.08307438	0.118808071	68.79427304	0.128888542
NYSE: CM	CIBC	0.930710811	0.002492370	1.18358985	0.003446640
NYSE: RY	RBC	1.068702943	0.002752178	1.278136009	0.003478875
NYSE: GM	General Motors	1.40828497	0.003534972	1.575716295	0.004277933

using average volatility values in their pricing models in order to increase the accuracy of their price predictions. Suggestions for future research topics include why using daily volatility values results in less accuracy and precision in predicting stock prices, or how bigger volatility fluctuations affect the binomial asset pricing model.

## ACKNOWLEDGEMENTS

We would like to thank Dr. James Charbonneau for providing his invaluable time and resources on finance and computing. We would also like to thank many peer reviewers for taking their time to edit the article.

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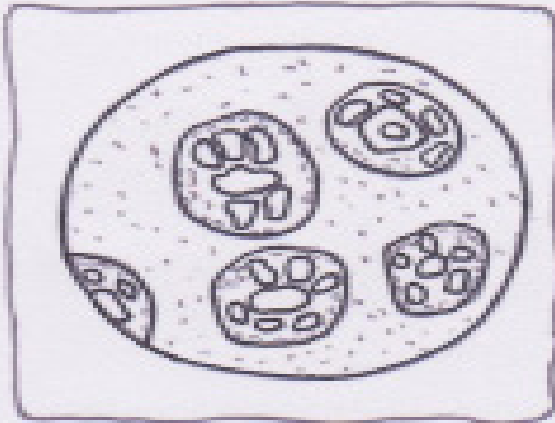
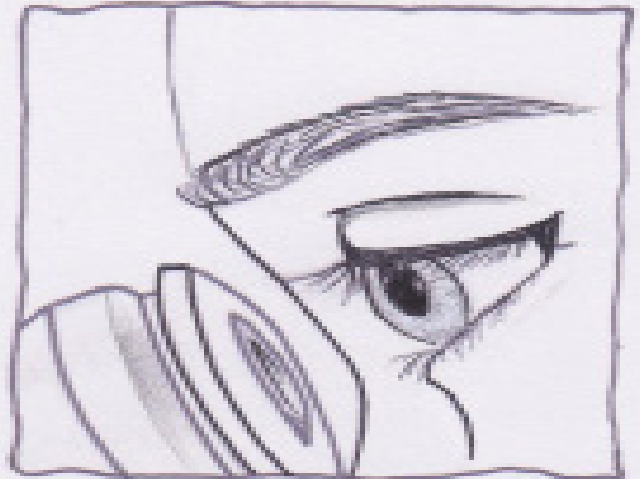


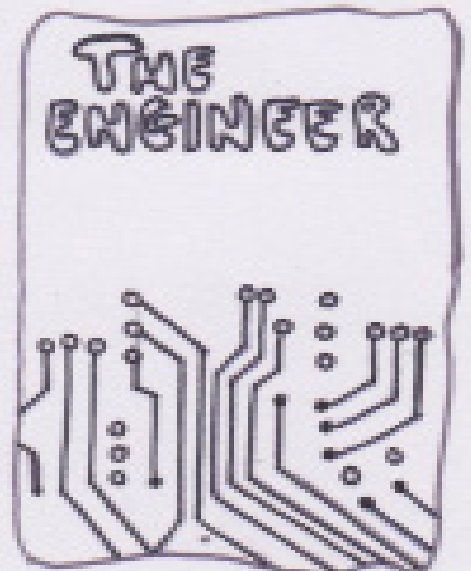
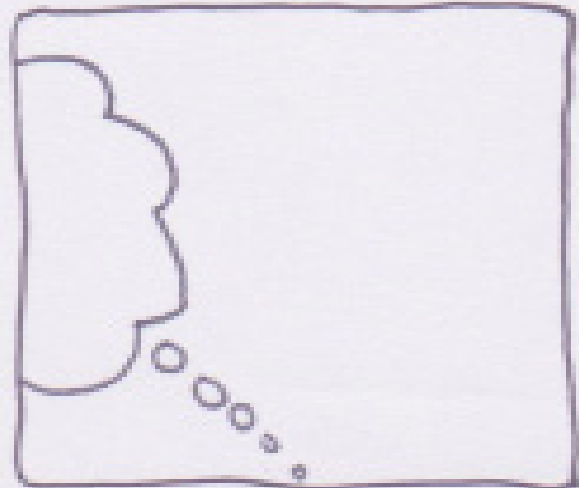
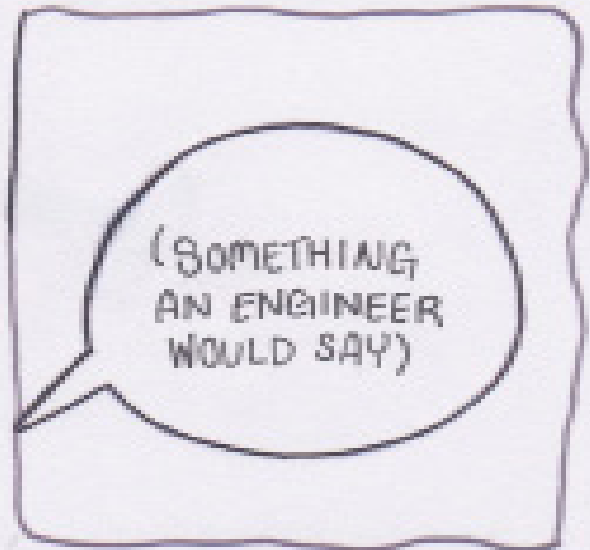
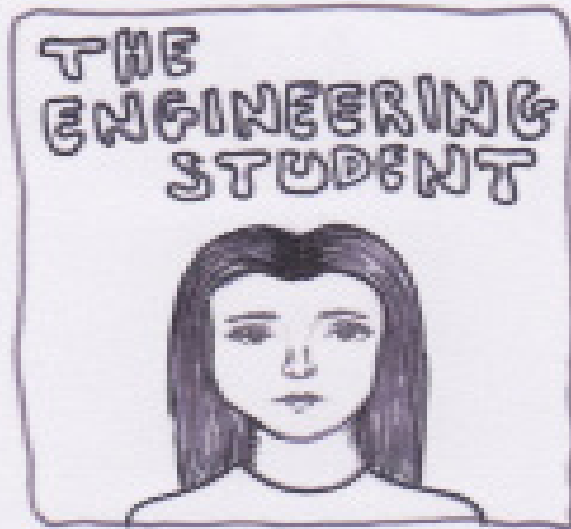
# COMIC

## Cells in the eyes of a Scientist, Artist, and Engineer

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