DISCUSSIONS
Undergraduate Research Journal of CWRU

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Letter from the Editor

Dear Reader,

Since 2006, Discussions has celebrated and promoted undergraduate research at Case Western Reserve University and other universities all over the world. As a continuance of our tradition and mission, it is my pleasure to introduce the newest issue of Discussions to you.

By taking the time to read this journal, you are promoting Discussions and, in turn, the long hours of research conducted by undergraduates, often without herald or pay. And, in today's society of fluid information and constantly evolving knowledge, taking the time to inform oneself about current research is paramount. In choosing to read the papers of Discussions, you are stepping into an oft-overlooked niche of research, learning about topics to which you may not have been exposed.

The papers within these pages were selected from yet another all-time high in submissions from students across the country. Each article was carefully chosen by a team of peer reviewers before receiving final approval from the editorial board.

For this issue, I am also pleased to present a new research review section, presented as a result of Engineering Science Review coming under the Discussions letterhead this past year. In this new section, papers will examine and evaluate relevant research through a broader lens with the guidance of empirical research.

If you would like to see your research published in Discussions, our next submission deadline is **April 11, 2014**. Visit our website at case.edu/discussions or our Facebook page for submission guidelines and more details. Feel free to contact us on our website with any questions.

As we continue to grow in size and prestige, I encourage anyone interested in research or the publication process to find ways to get involved with our publication. We accept submissions from around the world and distribute around the country; our organization's success has increased exponentially in recent years. Reach out to me personally at jmb345@case.edu or askdiscussions@case.edu to learn how to get involved.

Finally, as this is my first journal as editor in chief, I would be remiss if I didn't recognize the amazing work of my predecessor, Nathan Kong. His diligent work took our journal to new heights and established our journal as a national presence. I would also like to thank Sheila Pedigo and the entire SOURCE office for their continued support.

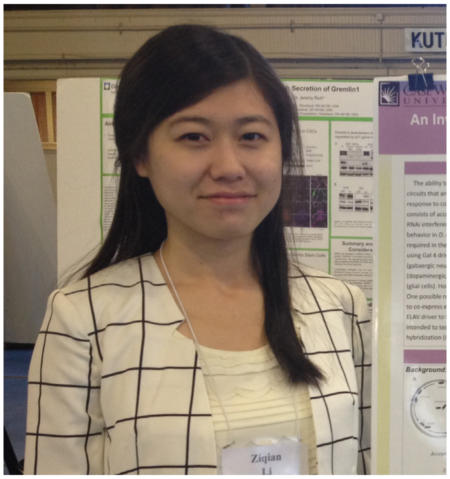
Thank you for taking the time to read our journal, and I hope you enjoy the fantastic articles within.

Sincerely,

Jack Behrend

Jack Behrend
Editor-in-Chief, Discussions Research Journal

An Investigation of Novel Genes Involved in Female Decision-Making in *Drosophila melanogaster*



ABSTRACT

In animals, the ability to make decisions is dependent on brain circuits that are organized and maintained by the activity of genes. In *Drosophila melanogaster* (the fruit fly), one such decision-making process is the female response to courtship – either accepting or rejecting a male mate. Previous studies using RNA interference (RNAi) and a ubiquitous GAL4 driver have led to the identification of seven novel genes that are required for female mating behavior: CG1571, CG14419, CG7423, CG33223, CG12200, CG11878, and CG32598 (Chu and Sousa-Neves, unpublished). Previously, knockdown of these genes in specific types of neurons in the brain using different drivers (GAD (gabaergic neurons), CHA (Cholinergic neurons), PLE (dopaminergic neurons), DDC (dopaminergic/serotoninergic neurons), ELAV (all post-mitotic neurons) and REPO (glial cells)) did not produce a significant reduction in the female acceptance rate. One possible reason for this result is that the level of knockdown could have been insufficient. Thus, each RNAi was co-expressed with UAS-Dicer2 under the control of the neural-specific Elav>GAL4 driver to further down-regulate the targeted genes. Concomitantly, in-situ hybridization (ISH) was used to test whether these genes are expressed in the central nervous system. The results show that the expression of the genes CG7423 and CG11878 in the central nervous system is necessary for normal mate-accepting behavior in *D. melanogaster* females.

INTRODUCTION

Animals are not only born with characteristic body plans, but also with sets of innate behaviors, or instincts, which consist of stereotyped responses to environmental stimuli (Tinbergen, 1951). In *Drosophila melanogaster*, commonly known as the fruit fly, the female response to courtship is an innate behavior that involves accepting or rejecting the courting male. By receiving and analyzing various visual, auditory, olfactory, and chemosensory signals from the courting male, *D. melanogaster* females are able to discriminate between males from their species and males from different species and then accept or reject the male mates (Hall, 1994 & Greenspan, 1995). This decision-making process is determined by circuits in the central nervous system, which are established and maintained by the expression of genes. Therefore, decision-making process can be studied at the genetic level by knocking down or altering genes in *D. melanogaster* females and observing the resulting behavioral phenotypes.

D. melanogaster is an ideal test subject due to the ample resources available for genetic analysis – mutations and deficiencies stocks are readily publicly available, and its genome has been mapped out as well (Mackay, Heinsohn, Lyman, Moehring, Morgan, & Rollmann, 2005). Additionally, all seven of the genes identified by Chu and Sousa-Neves are in the w^{1118} genetic background.

Ziqian Li

Ziqian Li is a senior student in Case Western Reserve University majoring in biology. She was transferred from China as a junior student. She is interested in genetics and neuroscience. Therefore, she chose to do research with Rui Sousa-Neves using *Drosophila melanogaster* to study genes related to behavior. In future, Ziqian would like to enter graduate school study nutrition and become a registered dietitian.

Acknowledgements

I would like to thank to Rui Sousa-Neves, Claudia Mizutani, Rachel Giesey, Yanming Chu, Joseph Schinaman.

The GAL4/UAS system is a useful genetic tool to perform gene knockdown experiments. This system has two components, a driver line, which consists of transgenic flies that express GAL4 in the pattern of a resident gene, and an upstream activation sequence (UAS) that is fused with a gene of interest (Elliot & Brand, 2008). In our case, the gene of interest is an interfering RNA (RNAi) used to knock down specific genes. In the process RNAi, the micro mRNA precursor that is transcribed from the transgene folds back on itself, triggering Dicer to recognize and cleave the double stranded mRNA. Micro RNAs generated from the cleavage will then bind to target mRNAs, allowing Dicer to cut the mRNA, therefore reducing the level of expression of (specific genes/a specific gene). Hence, the GAL4/UAS-RNAi system allows the knockdown of genes in a specific type of cell or tissue (Elliot & Brand, 2008).

In a previous study by Chu and Sousa-Neves, seven genes were identified that are required for the normal behavior of *D. melanogaster* females. This study found that knocking down these seven genes in different types of cells in the brain using six GAL4 drivers did not produce any significant reduction in the female acceptance rate; this could possibly be the result of an insufficient level of knockdown. Thus, in this study, UAS-Dicer2 was co-expressed under the control of the Elav>GAL4 driver, which targets all post-mitotic neurons, to further down-regulate the seven genes and test whether these interventions produce deficits in acceptance. Additionally, the brains of wild-type female virgins were stained with the probes of the seven genes using in-situ hybridization (ISH) to observe whether these genes are expressed in the central nervous system.

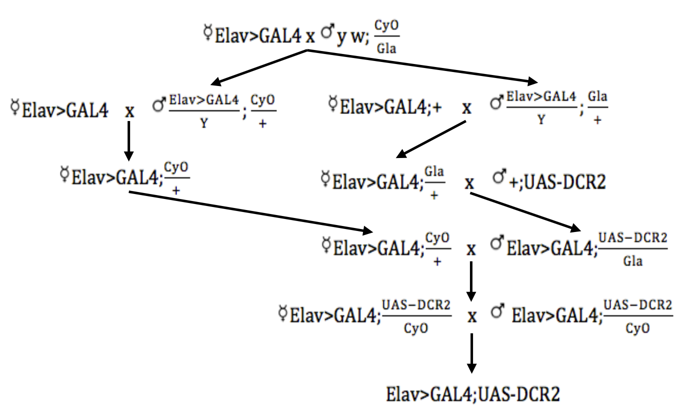


Figure 1. Scheme of crosses to obtain co-expressed UAS-Dicer2 under the control of the Elav-GAL4 driver.

MATERIALS AND METHODS

Construction of the D. melanogaster stock, genotypes, and controls

UAS-Dicer2 was expressed with the Elav>GAL4 driver. In order to get double homozygotes of Elav>GAL4; UAS-Dicer2, we started from the cross of Elav>GAL4 with y w; CyO/Gla. CyO and Gla are second chromosomes with multiple inversions that prevent recombination and carry lethal recessive mutations; thus, they serve as balancers through the crosses. CyO flies have the phenotype of curly wings, while Gla flies have glazed eyes. These phenotypes enable the selection of flies with the desired genotypes. From the first cross, male flies with curly wings (Elav>GAL4/Y; CyO/+) and glazed eyes (Elav>GAL4/+; Gla/+) were crossed with Elav>GAL4 females. From these crosses, females with curly wings (Elav>GAL4; CyO/+) were crossed, and females with glazed eyes (Elav>GAL4; Gla/+) were crossed, separately. Next, Elav>GAL4; Gla/+ females were crossed with UAS-DCR2 males to obtain male flies with Elav>GAL4, UAS-DCR2 and Gla. To make a stable line with both constructs, the male progeny that had glazed eyes (Elav>GAL4; UAS-DCR2/Gla) were crossed with the curly-winged females (Elav>GAL4; CyO/+) from the previous cross. Then, these curly-winged progeny (Elav>GAL4; UAS-DCR2/CyO) were crossed and flies with wild-type wings (Elav>GAL4; UAS-DCR2) were selected (Figure 1).

Wild-type, w^{1118} and first generation (F1) female virgins of the cross w^{1118} Elav>GAL4; UAS-Dicer2 were used as controls. The F1 of the cross w^{1118} with Elav>GAL4; UAS-Dicer2 has the same genetic background as the crosses of Elav>GAL4; UAS-Dicer2 with seven UAS-RNAi lines.

All of the stocks were reared on medium composed of cornmeal, yeast, propionic acid, and agar, and were kept in an incubator at 25 °C on a 12 hour/12 hour light/dark cycle.

Experimental Crosses

We used the males carrying Elav>GAL4; UAS-Dicer2 driver and crossed them with virgins from the seven UAS-RNAi lines as well as the w^{1118} stocks. Female virgins were collected in the F1 of the crosses for a period of nine to fourteen days after the day that the male and female were put together in order to make sure that no F2 were present in the tests. All of the crosses were reared on the same medium and kept in incubators with the same environmental conditions as the controls.

Pair Mating

Counting from the day the adult fly came out of the pupa, a three- to six-day-old F1 female virgin was tested with a three- to six-day-old wild-type (Canton-S) male virgin in a chamber and video-srecorded for one hour to observe their behavior. In these pair-mating experiments, it was recorded whether the female accepted or rejected the male; from this data, the acceptance rate of each cross was calculated. In addition, the courtship index (CI) was calculated as a measurement of female sex appeal. The CI is defined as the total duration of the male's performance of any steps of courtship and is calculated as a fraction of the 10 minutes observed. This measurement was taken to determine whether any mating deficits were due to a lack of female attractiveness to the males as opposed to rejection of males by the females. To determine the significance, a test for two proportions with Fischer exact test was performed using Minitab 16 software (State College, PA, USA).

Brain staining and imaging

Brains were dissected from three- to six-day-old wild-type (Canton-S) female virgins. Before staining, the brains were fixed in 4% formaldehyde and stored in methanol overnight at less than -20°C. On the first day of staining, probes that have complementary sequences to the mRNAs generated for the seven genes of interest were separately added and incubated with seven different brains. On the second day of staining, primary antibodies with different haptens, which recognize and bind to the probes, were added to the brains. On the last day of staining, secondary antibodies carrying fluorescent dyes that recognize and bind to the primary antibodies were added to the brains. At last, the brains were imaged under a confocal microscope using different wavelengths to observe the expression of each gene in the central nervous system.

RESULTS

Out of the seven genes tested in post-mitotic neurons, only the knockdown of the genes CG7423 and CG11878 significantly reduced the female acceptance rate (Figure 2A). Since the CIs show no significant differences between any females that have been tested (Figure 2B), the reduction of the acceptance rate must be caused by female rejection rather than a lack of female attractiveness.

From images of the in situ hybridization of the central nervous system with probes targeting the seven aforementioned genes, it can be seen that three are expressed in the female's central nervous system. They are CG7423, CG11878 and CG12200 (Figure 3). Gene CG7423 encodes an ankyrin repeats, which mediate protein-protein interactions; gene CG11878 encodes an ecdysteroid kinase, which is an enzyme that phosphorylates ecdysteroids (insect

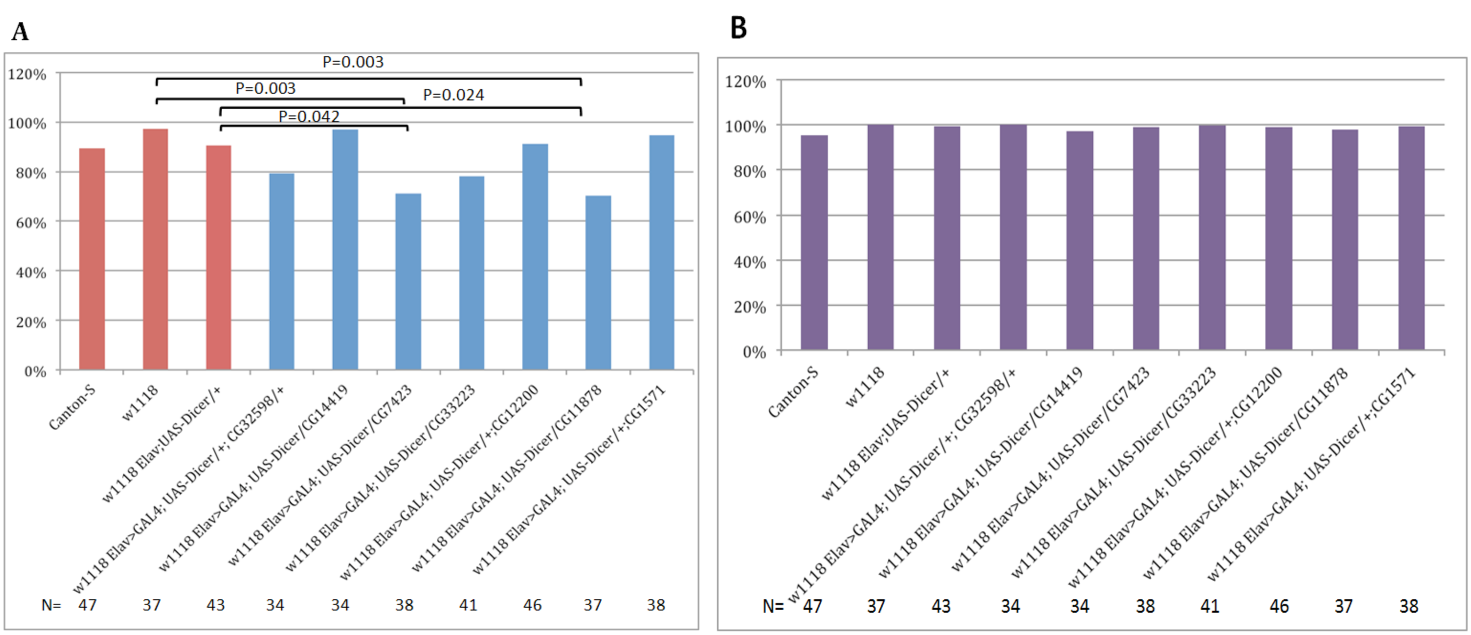


Figure 2. The knockdown of two genes in post-mitotic neurons produces significant female acceptance deficits but does not interfere with sex appeal. A) Acceptance rate of the RNAi knockdowns under the control of the post-mitotic driver Elav>Gal4 with UAS-Dicer2 co-expression. P-values were tested under 99 % confidence interval. B) Note that these females are as attractive as the controls, and thus, the effect of the RNAi is on female behavior.

growth and moulting hormones) to form physiologically inactive ecdysteroid 22-phosphates; and gene CG12200 encodes a C3HC4-type of zinc finger domain.

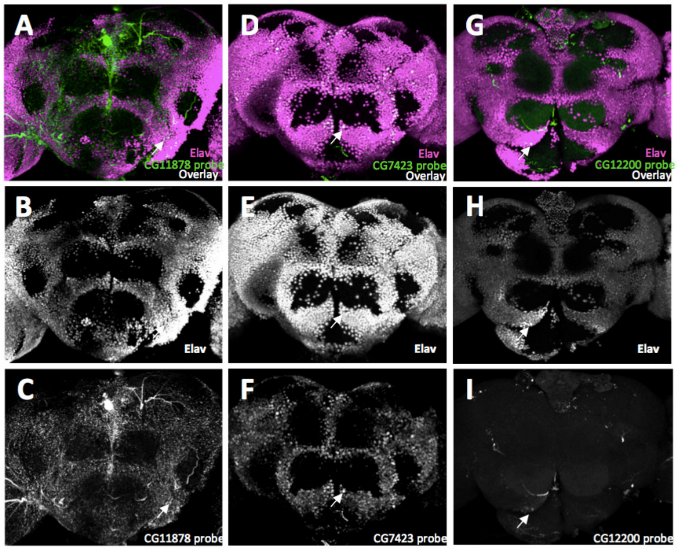


Figure 3. The genes identified are expressed in post-mitotic neurons. A, D, G are in multiplex in situ hybridization of female brains with CG11878, CG7423 and CG12200, and Elav antibody stainings. Note the expression of Elav in cell bodies and the regions of where the expression of each RNA probe coincides with Elav (arrows). B, E, H are Elav channel in gray scale. C, F, I are CG11878, CG7423, (Chu.Y., unpublished data) G12200 channel respectively in gray scale (Giesey, R., Unpublished data).

DISCUSSION AND CONCLUSION

From the pair-mating tests, it can be seen that the expressions of CG7432 and CG11878 in post-mitotic neurons in the central nervous system are required for normal accepting behavior in *D. melanogaster* females. In addition, ISH of the brain shows that the genes CG7423 and CG11878 are expressed in the central nervous system, which further supports the conclusion above.

In contrast, although the expression of CG12200 in the central nervous systems of *D. melanogaster* females was detected, no significant reduction of the acceptance rate was observed in the pair-mating test following the knockdown of gene CG12200. Thus, the expression of this gene in post-mitotic neurons is not required for accepting behavior in *D. melanogaster* females. There are two possible reasons for this result: First, the expression of CG12200 is required in other tissues for normal accepting behavior in *D. melanogaster* females, or second, CG12200 is required in neural precursors, which do not express Elav.

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Evolution of the Interstellar Medium of Luminous Infrared Galaxies Since z=1

ABSTRACT

In general, redshift can be said to be a measure of time as well as a measure of distance and the shifting of characteristic spectra resulting from atomic transitions. This allows the use of data on far away, redshifted galaxies to study galaxy evolution, for these far away galaxies represent younger galaxies. This study attempts to examine the evolution of the molecular gas fraction in such galaxies; the impact of the evolution of these molecular gas fractions on the evolution of star formation rates (SFRs), which are known to increase since a redshift of one (i.e., approximately half the current age of the universe,) and a redshift of zero (i.e., present day). Molecular gas fractions were studied by proxy of study of dust emission; that is, molecular gas fractions were estimated through fitting spectral energy distributions (SEDs) to sets of COSMOS (Cosmic Evolution Survey) data, then using these SEDs to estimate the dust masses of each galaxy, which were then converted to molecular gas masses. In general, the results of this study agree with the hypothesis that decreasing molecular gas fractions have caused the known decrease in SFRs with the passage of time. In addition, these results seem to be in agreement with the trends suggested by previous studies of CO transitional spectra, which are known to be tracers of star formation (Combes et al. 2011; Combes et al. 2013; Daddi et al. 2010; Geach et al. 2011; Tacconi et al. 2010).

INTRODUCTION

The phenomenon of redshifting occurs, in general, when light waves increase in wavelength, shifting original spectra towards the increasingly red region. Redshift often occurs when one views or receives information from a very distant source; the expanding universe causes the source of this light or information to move away from the viewer, resulting in increased wavelengths. This redshift is often denoted by the variable "z," such that

$$1+z = \frac{\lambda\_observed}{\lambda\_emitted}$$

(where λ is representative of wavelength). In terms of the expansion of the universe, redshift can thus also be understood as a measure of time.

A redshift of 1 (i.e., z=1,) corresponds to a time at which the universe was roughly half of its current age, and is generally agreed to demarcate a shift in the typical processes involved in galaxy evolution. Galaxy interactions, merger rates, typical galaxy morphologies, and star formation rates (SFRs), for example, can all be said to have exhibited fundamental changes since z=1 (Combes et al. 2013). In addition, it was around this era in which galaxies began

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Zaarah Mohamed is a junior studying physics at Case Western Reserve University. She is most interested in nuclear and particle physics as well as astrophysics, and hopes to study one of these topics in depth through conducting research as a graduate student.

Acknowledgements

I would like to thank my research advisors, Kimberly Scott and Kartik Sheth, who provided me much valuable advice and guidance during my summer research at the National Radio Astronomy Observatory. In addition, I would like to thank the National Radio Astronomy Observatory, the National Science Foundation's Research Experiences for Undergraduates (REU) program, and my fellow summer 2013 REU students who worked alongside me at the National Radio Astronomy Observatory.

to assemble in the familiar Hubble sequence. The underlying processes that caused these changes, however, are not very well understood.

The evolution of the interstellar medium (ISM), which consists of the dust and molecular gas within a galaxy, is closely related to these larger scale changes. In relation to the aforementioned shift in SFRs, molecular gas is directly involved, as it is the fuel of star formation; it can thus be said that molecular gas fractions have some relationship to any observed changes in SFR. However, it must also be noted that star formation efficiency (SFE) and changes in SFE also affect SFR. Regarding galaxy-related changes during the critical epoch around z=1, such as changes in galaxy morphology, interactions, and merger rates, it is the gas of the ISM that forms the stars which, along with much of the dust of the ISM, are involved in the formation of galaxies. An understanding of the evolution of the ISM is thus a vital component of any understanding of cosmological evolution, especially the aforementioned evolutionary shifts that occurred around z=1.

It can logically be predicted that, since stars form from the molecular gas of the ISM, the fraction of molecular gas within the universe would decrease as time passes and more stars are formed. Though the potential effects of changes in SFE also have effects upon changes in SFR, this decrease in molecular gas, since z=1, can also ostensibly be said to correspond with the decrease in SFR, since z=1, as less molecular gas means that there is simply less fuel with which stars can form. Several studies have attempted to examine the CO spectra associated with the molecule's rotational transitions, which are known to be tracers of molecular gas (and therefore tracers of star formation). In particular, recent studies of CO [2→1] observations suggest empirical evidence for a tight correlation between SFR and gas mass (Daddi et al. 2010), and several other observations of molecular gas suggest a decrease in molecular gas with the passage of time (Combes et al. 2011; Combes et al. 2013; Daddi et al. 2010; Geach et al. 2011; Tacconi et al. 2010) as well as a decrease in the gas content of galaxies by a factor of about five to eight between z=0 and z~1-2 (Daddi et al. 2010; Tacconi et al. 2010). All of these studies, however, have been conducted on very small samples (i.e., 5-39 galaxies, for the aforementioned studies), and thus the observed trends can only be correlated. Causation cannot be inferred. Many of these studies additionally focus upon galaxies at fairly specific redshifts, and it is therefore increasingly difficult to discern whether or not the trends indicated by the composite of these studies represent real and definitive relationships. Several also focus upon very luminous galaxies (e.g., Combes et al. 2011; Combes et al. 2013), thus making it increasingly difficult to discern the evolution of the molecular gas fraction in an average galaxy. In addition, direct CO [1→0] measurements are simply not possible for redshift ranges ~0.3-1 due to issues of instrument sensitivity and spectral coverage, though the specific range of redshifts within this redshift desert may vary slightly depending on the specific instrument. The Geach et al. (2011) sample, for example, contained IRAM Plateau de Bure interferometric readings for galaxies at a redshift ~0.4, though data was taken for only five galaxies.

In order to further understand the evolution of the ISM as well as to further investigate the expected trend, this project uses a large sample of intermediate redshift (z<1) galaxies in order to estimate molecular gas fractions. As direct molecular gas observations are not possible for these purposes (due to the desired large sample size and the aforementioned "redshift desert"), data from previously compiled COSMOS (Cosmic Evolution Survey) catalogs are used. The approach taken involves the fitting of spectral energy distribution (SED) models, which fit curves to flux density vs. frequency plots of data points, to the data in order to derive relevant parameters with which to estimate dust masses. Dust masses are then used to calculate molecular gas masses through a constant assumed dust-to-gas mass ratio. These molecular gas masses can then be used to estimate gas fractions, and these gas fractions are compared by redshift values in order to determine whether or not gas fractions can definitively be said to increase with increasing redshift within this redshift range. Far-infrared luminosities (LFIRs) and SFRs for each galaxy are also calculated in order to examine some of the properties of the sample as well as to compare to literature values.

DATA SAMPLE

Data processing and analysis was carried out in Python using Canopy, an integrated IPython package manager and analysis environment. The original sample of data comes from the COSMOS xid catalog, which is a compilation of flux density readings and errors on these readings from several sources, for a total of 39,331 galaxies. This catalog includes readings at 13 wavelengths (24 um, 3.6 um, 4.5 um, 5.8 um, 8.0 um, 100 um, 160 um, 250 um, 350 um, 500 um, submillimeter wavelengths, and radio wavelengths). The 24 um components are MIPS (Multiband Imaging Photometer/Spitzer Space Telescope) readings while all data from 3.6 to 8.0 um are IRAC (Infrared Array

Camera/Spitzer Space Telescope) readings, all data from 100 um to 500 um are SPIRE (Spectral and Photometric Image Receiver/Herschel Space Observatory) fluxes, and all radio data comes from the Very Large Array (VLA), operating at 1.4 GHz. All galaxies listed in this catalog were initially detected at either 24 um or at radio wavelengths (1.4 GHz). Note that the COSMOS v2.0 catalog was also used, though only to complement the COSMOS xid catalog as the primary source of data through providing stellar masses and errors on these masses for each galaxy from the xid catalog.

In order to refine the sample so as to retain only valuable and useful information, the signal-to-noise ratio at both 24 um and "radio" wavelengths were therefore calculated first. Data was deemed useful and was retained in the sample only for galaxies that had a signal-to-noise ratio of at least five for either the 24 um reading or the radio reading. After this preliminary cut, the signal-to-noise ratio was calculated for each reading attributed to each of the remaining galaxies. The threshold signal-to-noise ratio here was three; individual readings at each wavelength were deemed useful and retained within the sample if they reached this threshold. The final sample of useful data thus included wavelengths, flux densities, and errors (for flux density) for each individual reading that had a signal-to-noise ratio of at least three, provided that these readings corresponded to a galaxy with a signal-to-noise ratio of at least five in either the 24 um MIPS (Multiband Imaging Photometer/Spitzer Space Telescope) reading or the radio/1.4 GHz reading.

ANALYSIS METHODS

SFRs are dependent upon variables that include a solid angle parameter, a redshift parameter, a luminosity distance parameter (derived from the redshift parameter and constants associated with some standard cosmology), and the integral of a modified blackbody emission component, which introduces two additional parameters. Dust masses are dependent upon a redshift parameter, a flux density at a specific wavelength, a luminosity distance, and a modified blackbody emission component (see equations below). While redshifts for each galaxy as well as wavelengths, flux densities, and margins of error associated with these flux densities are included in the aforementioned data sample, parameters such as solid angles and temperatures are not, nor are the additional β and frequency parameters introduced by the blackbody emission components of these equations. In order to obtain these parameters as well as to obtain the integrable curve needed to estimate SFRs, it was necessary to fit spectral energy distributions (SEDs), or curves representing flux density vs. frequency, to each galaxy.

Fitting of SEDs was carried out so as to fit to the flux density equation (see below) using the Levenberg-Marquardt method, a numerical algorithm for least squares fitting, through Python's scipy.optimize.leastsq routine. Only data points at wavelengths of at least 70 um were considered to be valid for the fitting of SEDs. As there are four variable parameters in the flux density equation (β, νc, omega, and T in the equation below) and least squares minimization requires an overdetermined system of equations, only galaxies with give or more "good" (i.e. above 70 um in wavelength and still remaining in the sample after the previously detailed cuts) data points could be used for the purposes of curve fitting. This, however, returned many non-physical values for parameters, and upon further inspection of the effects of each parameter upon flux density, it was discovered that many are degenerate. Subsequently, two of the parameters were fixed to reasonable expected values and fitting then occurred for all galaxies with at least three "good" data points. For these fits, β was fixed to a value of 1.5 and to a value of c/(200 um). The final sample thus contained 452 galaxies.

$$S_{\nu_o} = \frac{\Omega_s B_{\nu_r}(T)(1-e^{-\tau_{\nu_r}})}{(1+z)^3}$$

where

$$\tau_{\nu_r} = (\frac{\nu_r}{\nu_c})^\beta$$

Equation Set 1. Equations used for fitting

This is the flux density equation used for least square fitting of SEDs to each galaxy. Flux density is dependent upon four free parameters: solid angle (Ω), temperature (T), and a threshold frequency (νc) and an exponent (β) that relate to the optical depth (τ), or density, of the dust. Upon the discovery that these parameters are degenerate, β was fixed to 1.5 and νc was fixed to ~1.5 THz (i.e., c/(200 um)), according to reasonable values suggested by literature (Casey 2012), leaving only two free parameters for which to perform fits: solid angle and temperature. Note that optical depth, which indicates the transparency of a medium, is described such that τ <<1 is said to describe an "optically thin" (or relatively transparent) medium while τ →1 is said to describe an optically thick (or less transparent) medium. Note also that B(T) represents the Planck function, and thus B(T)(1-e τ) represented modified blackbody emission.

After fitting parameters to all galaxies in the final sample, dust masses and luminosity (LIR) values were then calculated using the relationships shown above. Gas

$$L_{IR} = \frac{4\pi\Omega_s D_L^2}{(1+z)^4} \int_{c/(1000\mu m)}^{c/(8\mu m)} B_{\nu_r}(T)(1-e^{-\tau_{\nu_r}})d\nu_r$$

$$SFR = 1.72 \times 10^{-10}(\frac{L_{IR}}{L_{sol}})$$

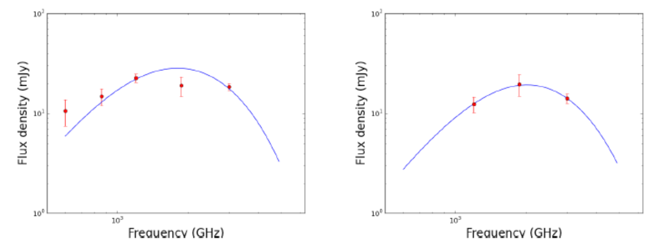
Equation Set 2: Equations used for derivation of LIR and SFR

masses and SFRs could then be calculated using the values for these two quantities, respectively (i.e., using dust mass to derive gas mass and LIR to derive SFR). A conversion factor (dust-to-gas mass ratio) of 0.01 was used for the conversion between dust mass and gas mass. Considering the fact that dust-to-gas mass ratios are actually dependent upon metallicity and no such information was available for this sample, a ratio of 0.01 was chosen due to the fact that it seemed to be a reasonable, mid-range conversion factor considering previous literature (Draine et al. 2007). Gas fractions were calculated using these gas masses and the corresponding stellar masses for each galaxy, as listed in the COSMOS v2.0 catalog. Plots including SFR vs. redshift and gas fraction vs. redshift were then made in order to examine various relationships. Finally, in order to further examine these relationships through comparison to previous literature, a LIR cut that limited LIR to values between 1e11 Lsol and 4e11 Lsol (similar to the values found in Geach et al. 2011) was made for the sake of comparison with existing literature, and the aforementioned relationships were then reexamined. A similar luminosity cut according to the range of luminosities in Combes et al. 2013 was also attempted, however, using their requirement that log(LFIR) be greater than 12.45 left a sample of only nine galaxies, which would again present the same problems regarding small sample size, which should be avoided.

RESULTS

Regarding the results of SED fitting, mean values for the parameters Ω (solid angle) and T (temperature) were about 1.52e-13 +/- 2.86e-14 sr and 45 +/- 2 K, respectively, while median values were 8.96e-14 +/- 1.23e-14 sr and 44 +/- 2 K, respectively. The values for both of these parameters seem reasonable considering that all data comes from point sources – thus rendering the omega parameter more or less a normalization factor rather than a wholly physically meaningful parameter – as well as the fact that the relevant molecular gas should be expected to be relatively cold. Additionally, these temperature values are in agreement with average values calculated from CO line survey data for small samples of Ultra Luminous Infrared Galaxies (ULIRGs) within a similar redshift range (Combes et al. 2011; Combes et al. 2013).

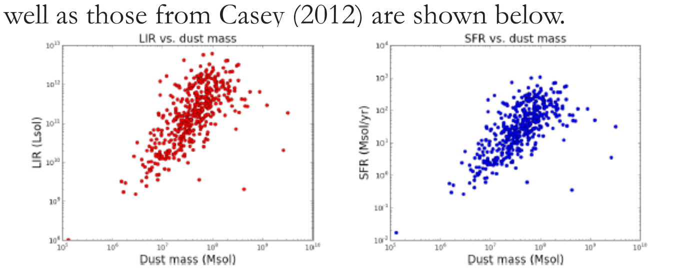
Two sample SEDs are shown below. In general, most SED models seemed to fit the data rather well, with a mean reduced chi-squared value of 2.14 and a median reduced chi-squared value of 0.92. Note that better (i.e., closer to unity,) reduced chi-squared values could be obtained when SED fitting was carried out without constraining any parameters, but the results of such curve fitting often yielded non-physical parameters due to their degeneracy within the flux density equation.



(a) Sample SED for a galaxy with 5 data points, z∼0.96, and T∼57K (b) Sample SED for a galaxy with 3 data points, z∼0.44, and T∼44 K

Figure 1. Sample SED Fits

Concerning estimates for LIR and SFR, mean values were about 4.73e11 +/- 1.83e11 solar luminosities and 81 +/- 0.0054 solar masses/year, respectively. Estimates for these quantities provide further evidence of reasonable SED models through comparison of plots of LIR versus dust mass and SFR versus dust mass with corresponding plots as they appear in a study focused purely upon far-infrared SED fitting (Casey 2012). These original plots as well as those from Casey (2012) are shown below.



(a) L_{IR} vs. dust mass plot for comparison to Casey 2012 (b) SFR vs. dust mass plot for comparison to Casey 2012

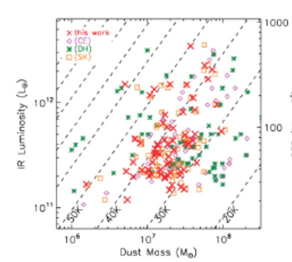


Figure 2. SFR vs. dust mass and L_{IR} vs. dust mass from this study, plus analogous plot from Casey 2012 for comparison

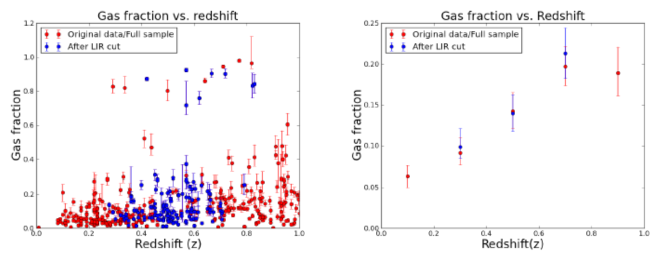
Dust masses had a mean value of about 8.05e7 +/- 1.59e7 Msol and a median of about 5.18e7 +/- 6.49e6 Msol. Molecular gas masses had a mean of about 8.05e9 +/- 1.59e9 Msol and a median of about 4.18e9 +/- 6.39e8 Msol. LIR had a mean value of about 4.73e11 +/- 3.15e7 Lsol and a median value of about 1.83e11 +/- 1.36e7 Lsol. SFR had a mean value of 81 +/- 0.0054 Msol/yr and a median value of 32 +/- 0.0023 Msol/yr. Gas fractions had a mean of about 14 +/- (2.0-2.3)% and a median of about 9.3 +/- (1.6-1.8)%.

Note, however, that these values are meant only to show the general distribution of properties for the galaxies within this sample. Taking errors into account (through using these errors to weight individual data points) may change the idea of the average values of the sample. For example, the weighted mean of for gas fraction was 2.6 +/- (0.37-0.39)%, which is quite different from the unweighted mean of 14 +/- (2.0-2.3)%. In order to properly take into account the errors for each reading, plots for the purposes of actual analysis of the data utilized weighted means rather than unweighted means where averaging was necessary.

Scatter plots of gas fraction versus redshift initially revealed fairly little definitive evidence for the hypothesized trend, for, while higher redshift values did appear to have more data points with higher gas fractions, the vast majority of the data points were clustered together near the x-axis (below). Nonetheless, binning by z-values (in intervals of 0.2 z from z=0 to z=1) and then plotting the mean of the gas fractions for each bin generally revealed the expected trend.

After the luminosity cut based upon the Geach et al. sample (2007), this trend appeared much the same. The redshift bins corresponding to first and last redshift bins from the original sample are not plotted, as the first bin is empty after the luminosity cut while the last bin contains very few galaxies. The analogous scatter plot created after the luminosity cut did somewhat more clearly suggest a rise in gas fraction between z=0 and z=1, though, as before, most data points were clustered near the x-axis and no definite trend could immediately be discerned.

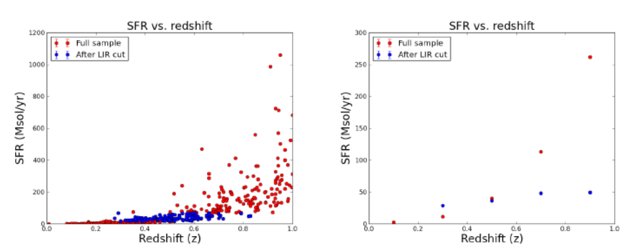
Similar statements can be made about the SFR vs. redshift plots, shown below. The original scatter plot shows that the minimum SFR increases with increasing redshift or increasing time, which suggests a positive correlation between SFR and redshift. However, data points are much less dense as redshift increases (or with consideration of points in time that are further in the past) and more clustered together as redshift approaches zero, or as times closer to the present are considered. Binning this data, as previously mentioned, clearly indicates an increase of SFR with increasing redshift. After cutting out the luminosity, the scatterplot suggests more clearly that increased SFR corresponds to increased redshift. However, though the same general trend – increasing SFR with increasing redshift – can still be seen in the binned plot, it suggests quite a different rate of increase. This is most likely due to the differing ranges of SFRs before and after the luminosity cut.



(a) Scatter plot of gas fraction vs. redshift (b) Binned plot of gas fraction vs. redshift

Figure 3. Plots of gas fraction vs. redshift

Attempts to bin by LFIR were also made after the luminosity cut in order to determine whether this trend was consistent across a range of luminosities. This required using four evenly spaced luminosity bins across the range 1e11 Lsol – 4e11 Lsol. This binning method revealed that the aforementioned fgas vs. redshift trend is generally consistent across several ranges of luminosities in that fgas does indeed increase as redshift increases. It should be noted, however, that the last bin did not seem to show quite as definitive a trend as the others (i.e., while it showed a general increase, the last redshift bin actually has a lower gas fraction than the previous bin). The fact that it deviates slightly from the general trend could be a result of the small sample size of galaxies within this bin, as the attributes of any single galaxy within a small sample size has a greater effect upon the overall attributes of the bin than it would in a bin that contained more galaxies.



(a) Scatter plot of SFR vs. redshift (b) Binned plot SFR vs. redshift

Figure 4. Plots of SFR vs. redshift

The same LFIR binning for SFR vs. redshift revealed that the relationship between SFR and redshift was not at all consistent across these bins, as only two or four LFIR bin showed the expected increase in SFR with increase in z. However, each of these LFIR bins was found to span only two redshift bins when SFR vs. redshift was plotted.

It is for this reason that binning by LFIR was also attempted using the data from the original sample (before the luminosity cut). This required creating six evenly spaced LFIR bins between 9.8e7 Lsol and 1e12 Lsol, a range chosen to exclude extreme outliers (so as to allow a reasonable number of galaxies in each bin), yet still include most of the sample. Concerning the relationship between the gas fraction and redshift, this again revealed a general increase. However, a few LFIR bins did not show a consistent increase, but rather had one data point that deviated slightly (similar to the aforementioned trend in SFR vs. z). Concerning the relationship between SFR and redshift, as before, binning by LFIR revealed a general increase in only two LFIR bins, though only one LFIR bin spanned more than two redshift bins (while two spanned only one redshift bin).

DISCUSSION AND CONCLUSIONS

In general, it can be said that the suspected relationship between gas fraction and redshift has been verified considering the above plots showing mean gas fractions across five redshift bins. Both with and without the LFIR cuts intended for the sake of comparison with literature values, it seems this study's calculations regarding gas fraction vs. redshift were generally in line with expectations considering previous literature including Geach et al. (2011), Leroy et al. (2008), Daddi et al. (2010), and Tacconi et al. (2010), as can be seen in the plot below,

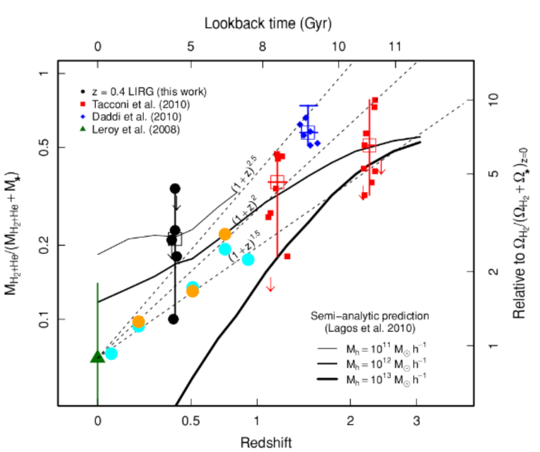


Figure 5. Plot from Geach et al. (2011) with data points from this study superimposed. Light blue data points represent full sample while orange data points represent sample after L_{IR} cut.

which contains a plot from Geach et al. (2011) with data points from this study superimposed into the image (below).

It can also generally be said that the SFR is shown to increase with increasing redshift and that, as both gas fraction and SFR increase with increasing redshift, gas fraction does seem to have a large effect upon SFR, as expected. However, due to the specifics of the COSMOS data catalogs, only general SFRs could be calculated while SFRs per unit volume could not. Therefore, while this study suggests agreement with previous studies that have examined this relationship (Madau et al., 1996) in that it suggests an increase in SFR with increasing redshift, it is not in complete agreement with previous studies because previous studies actually evidence a decline in SFR density since z~1. In addition, it must be noted that while gas fractions have been noted to have a large influence upon SFR and changes in SFR, changes in SFR have also been said to have notable influence upon SFR, though examination of this factor was beyond the scope of this particular study.

Attempts to examine the consistency of these trends across a range of luminosities were also made, both before and after the Geach et al. (2011) based luminosity cut intended for purposes of comparison with existing literature. However, as binning by luminosity and then attempting to recreate the previous plots of gas fraction vs. redshift and SFR vs. redshift produced plots that generally spanned too few redshift bins to discern and definitive trend, it is uncertain whether these trends do, in fact, hold over a range of luminosities.

FUTURE WORK

In relation to the aforementioned problems of this study examining only SFR instead of SFR density, future studies involving different data catalogs could potentially use the same procedure to examine gas fractions and SFR densities in order to perhaps verify the trends resulting from this study. In addition, in relation to the aforementioned problems concerning binning by luminosity, future studies could also decide upon luminosity bins ahead of time and thus select samples such that each luminosity bin will have contain a reasonable range of redshifts so as to determine whether the conclusions of this study hold across a range of luminosities. As SFRs are also said to be related to stellar masses, the same could be done with a number of stellar mass bins in order to determine whether the conclusions of this study hold across a range of stellar masses, though it would likely be quite difficult to cultivate a sample such that both its mass bins and its luminosity bins have sufficient numbers of galaxies in each redshift bin.

Future studies could also be much improved if metallicities for specific galaxies could be taken into account, as this study simply assumed a constant dust-to-gas mass ratio. Alternatively, the practice of assuming a more or less constant dust-to-gas mass ratio could also be evaluated if the procedure is repeated for data samples that include metallicity values.

In addition, the validity of this study's method could be examined through comparison with future CO [1→0] measurements that will soon be enabled by ALMA (the Atacama Large Millimeter Array). Through comparing gas fractions and the relevant trends derived from direct measurements with the gas fractions and trends derived here through an assumed dust-to-gas mass ratio, the validity of estimating SFRs and gas masses through dust emission can be properly evaluated. If estimating gas masses, gas fractions, and SFRs through their relationships to dust emission is determined to be a valuable and valid method, future estimates of such quantities could be made through taking measurements of dust emission and then calculating these quantities, thus saving coveted integration time on ALMA and other instruments (in comparison to attempts to estimate molecular gas fractions through collection of data on CO spectra).

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DISCUSSIONS
Undergraduate Research Journal of CWRU

ENGINEERING & SCIENCE REVIEW

Case Western Reserve University’s Engineering and Science Review (ESR) was a student magazine that brought cutting-edge research news to campus. Established in 1958, ESR’s mission was to highlight the work of top researchers from across the country primarily through review, human-interest pieces, and news articles. They did so in an exemplary fashion for over 55 years before joining Discussions to bring the work of undergraduates to the campus community and abroad.

In honor of their storied history, Discussions presents a new review section. The following pages will contain the work of undergraduates who have formulated holistic reviews of various topics through extensive study. Using the research of others, these authors will present new theses, new directions, and new ideas on relevant issues.

With great pleasure, Discussions presents its first ESR review section.

The Sino-American Rivalry and the Future of the Asia Pacific Trade Architecture

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Siri Sung is a senior studying International Studies at Yonsei University. She is interested in the Asia Pacific and the security-trade nexus. She will continue her studies at the Graduate School of International Studies at Yonsei after obtaining her undergraduate degree. Her passions include rock climbing and surfing.

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ABSTRACT

How will the rise of China and the subsequent American "pivot" of reengagement with Asia affect the trade of the Asian region? The Asia Pacific is characterized by a lack of supranational institutions and bilateral preferential trading agreements, which make up the "noodle bowl" syndrome. How will this "fragile" regional economic architecture be affected by the two great power politics? Some say China's rise will not affect the international order, while others, namely realists, predict confrontation and conflict. I test the theoretical propositions of hegemonic competition against the case of the Trans-Pacific Partnership (TPP), a free trade agreement among at least 11 different countries led by the United States. I argue that the Sino-American rivalry in Asia creates competition for the influence over the future of the Asia Pacific trade architecture and thus forming a "divide" in the region.

INTRODUCTION

Asia is a peculiar region. The membership and paradoxical contests of traditional regional integration theories leave much room for scholarly interpretation. This paper will not only focus on East Asia and the ASEAN+3 countries, but also the Asia Pacific. With the creation of the East Asian Summit in 2005, membership question has further become opaque (Camroux, 2012). Takashi Terada argues that ASEAN+3, once the "main vehicle" of integration, has been rendered obsolete in regard to U.S. re-engagement with Asia. President Obama, "America's Pacific President," signed the Treaty of Amity and Cooperation (TAC), consequently joining the East Asia Summit (EAS). The Asia Pacific region should be defined to include the U.S. and other Pacific-rim countries such as New Zealand and Australia.

Asia Pacific does not have rule-based frameworks or supranational institutions. In place of institutionalization exists an entangled web of bilateral preferential trading agreements (Pempel, 2005). The proliferation of bilateral PTAs, what scholars call the "noodle bowl" effect, characterizes the region. "Noodle bowls" increase the cost of transaction, creating complex patterns of discrimination while also undermining the multilateral trade system. The lack of regionalism creates opportunities for power politics such as competition between the United States and China.

The rise of China and the subsequent "re-engagement" of the U.S. are the main shifting geopolitical dynamics affecting East Asian regionalism. While some say that the rise of China and the consequent United States "pivot" will have a minimal effect on trade architecture, this article tests against the theoretical propositions of the rise of China based on the case study of the Trans-Pacific Partnership (TPP) – the U.S.-led trans-Pacific free trade agreement. The TPP is a stepping stone to the FTAAP (Terada, 2013). It is significant in its potential to become a trans-Pacific agreement that will effectively address the noodle bowl problem and reach broader and deeper integration. U.S. trade policy in the region is met with China's different and incompatible regional trade policy. I argue against theoretical propositions of harmonious and peaceful coexistence between the great powers, as the Sino-American rivalry will create competition to influence the future of Asia Pacific's trade architecture. I will first look at the political and economic significance of the TPP and discuss whether it is indeed a U.S. led initiative to "check" China. Next, I will argue that the TPP is in competition with China's own trade policies. This will be followed by a discussion of the implications for the future of the regional trade architecture.

THEORETICAL PROPOSITIONS

The International relations theory presents different and distinct theoretical propositions for the rise of China. The realist lens predicts a future of conflict. In accordance to power transition theories, the rising power of China will be dissatisfied with the existing order, leading to the creation of a new world order. As a result of direct conflict, a hegemonic war may pursue. Similarly, offensive realism argues that a state becomes more expansive with an increase in power. Offensive realists like Mearsheimer argue that the rise of China will eventually lead to China's displacement of the United States influence and power in East Asia and also an increase in armed conflict (Mearsheimer, 2001). Defensive realists stop short of direct conflict but predict strategies of balancing.

In contrast, others disagree with the zero-sum perspective of the region and argue that an increase in China's regional influence will not lead to a decline in U.S. power (Shambough, 2004, Medeiros and Fravel 2003). Scholars examining the rise of China through the liberal lens may predict cooperation as a result of economic interdependence between U.S. and China. Scholars underscore the costs of conflict with the U.S. for China. Optimistic intuitionalists argue that China will not oppose the current institutions of the U.S.-led order but rather seek to gain more influence (Ikenberry, 2010). China will not challenge the existing order because the existing order was greatly conducive to its rise. China has joined international institutions created by the hegemon, such as the United Nations and the World Trade Organization. It seeks to gain more influence in setting the agenda and assuring neighbors of its peaceful rise. China will not want to overthrow the institutions of an existing order that it is a part of, and therefore will "support" U.S. power and influence. While the liberalist projection of cooperation and peace may be held on the international level, the story is different on the regional level. On the regional level, China and the U.S. are in competition with one another; the geopolitical rivalry is far from cooperation.

China has openly opposed the U.S. hub-and-spokes security structure and thus its security commitment to the region. In 1997 it called for an elimination of bilateral U.S.-alliances because they were an unnecessary vestige of the Cold War. For China, the region is defined as East Asia with the U.S. excluded. China is not an advocate of U.S. presence in the region much more its policies or institutions. The U.S. regional strategy of "re-engagement" or "pivot" to Asia may be interpreted as an initiative to constrain Chinese influences. China has become more assertive in its foreign policy in accordance with its meteoric rise of material capabilities, but unlike offensive realist predictions, it has not completely displaced the U.S. China cancelled its call for elimination of alliances shortly after and it has yet to assert itself as the regional hegemon with the construction of the modern version of the tributary system. China has been employing strategies to resist U.S. policy impacts on the region. While direct conflict seems unlikely, there will be adequate balance and competition between the two powers.

This competition is manifested in the competitive and incompatible regional trade policies of the two great powers. First, the U.S. is pushing for the Trans-Pacific Partnership (TPP) as its cornerstone of its regional trade initiative and its "pivot" to Asia. China, on the other hand, wants "anything but the TPP," and it is developing the Regional Comprehensive Economic Partnership (RCEP) as well as trilateral free trade agreements between China, Japan, and Korea (CJK). The RCEP and CJK initiatives will employ standards more acceptable to China's state of economic development, while the TPP will utilize high standard of liberalization focused on domestic regulation.

CASE STUDY: TRANS-PACIFIC PARTNERSHIP

I will evaluate the Trans-Pacific Partnership (TPP) as the manifestation of the Sino-American rivalry. I will argue that the TPP will create competition between two trading blocs, one led by U.S. and another by China. The TPP began as the Trans-Pacific Strategic Economic Partnership between four countries: Singapore, New Zealand, Chile, and Brunei. The economic impact of this original "P4" as it is called was expected to be negligible because of the small amount of trade between the countries and the fact that their economies were already open. In 2008, the Bush administration joined TPP negotiations along with Australia, Peru, Vietnam, and eventually Malaysia. The TPP is a free trade agreement between at least 11 countries: Australia, Brunei, Canada, Chile, Malaysia, Mexico, New Zealand, Peru, Singapore, the Unites States, and Vietnam. Japan recently joined negotiations last month (Cooper and Manyin, 2013). The direct economic impact may remain small because of existing bilateral agreements and the size of member country economies. However, its significance is not in economic gains but in its role as a stepping-stone for a regional framework such as the Free Trade Agreement of the Asia-Pacific (Capling and Ravenhill, 2013).

U.S. MOTIVATIONS BEHIND THE TPP

The TPP has both economical and geopolitical significance for the U.S. The economic motivations behind the TPP are consistent with the U.S.'s trade policy in the region manifested in APEC as well as bilateral FTAs such as the KORUS FTA. The TPP aspires to be a high quality, in-depth free trade agreement, motivating the U.S. to pursue the TPP. The U.S. has long pursued a legally binding and discriminatory mechanism of a free-trade area in the Asia Pacific. Furthermore, the TPP aims to be a "21st century agreement" (emphasized by Baldwin) by creating a comprehensive arrangement that addresses domestic regulation rather than market access. It will also "fix" the existing "noodle bowl" problem and attempt to "multilateralize regionalism" by binding the existing bilateral agreements (Capling and Ravenhill, 2011).

Economic objectives such as the "21st century agreement" and "multilateralizing regionalism" aside, the TPP embodies key geopolitical motivations of the United States. First, the TPP is part of the American "re-engagement" with Asia. The Obama administration jumped aboard the TPP initiative as part of its strategy to "pivot" the region. (Capling and Ravenhill, 2011). According to the Congressional Research Service report, the TPP initiative is the cornerstone of the U.S. "pivot" to Asia.

> "It is the leading trade policy initiative of the Obama administration and a core component of administration efforts to rebalance U.S. foreign policy priorities toward the Asia-Pacific region by playing a more active role in shaping the region's rules and norms." (CRS 2013).

A more significant geopolitical motivational approach for the TPP may be to check and constrain Chinese influence in the region. This is a point of contention with a significant answer bearing in mind that if the TPP is a successful check on China, the implication would be that the trade policies between the U.S. and China are indeed incompatible and are in competition.

According to Terada, the TPP is not targeted towards China. It is essentially up to China to participate, and the U.S. is not denying Chinese membership into the TPP (Terada, 2013). Also, the high standards of TPP that China does not favor are not targeted towards China as they are consistent with U.S. trade policies such as APEC and bilateral FTAs. Yuan, a writer for the Center for Strategic and International Studies argues that the TPP was not a U.S. creation and that the U.S. was invited by New Zealand to join negotiations. Also, the U.S. did not join until 2008 because it was still optimistic about the WTO Doha Round. Yuan quotes Ambassador Schwab, stating that the decision to launch negotiations was irrelevant in regard to "containing China." Yuan argues that the goal of the U.S. is to integrate China into the regional trade system rather than to exclude it. Furthermore, the TPP is an attempt to incorporate China into the WTO system and its trade rules while at the same time discouraging it from weakening existing trade rules (Yuan, 2012).

The TPP will set a high standard for trade and be a "21st century agreement" with standards unacceptable to China and other developing countries in the region. With its labor and environment standards, one could argue that it is indeed effectively denying China's membership. It can be seen as a symbolic confrontation between the Beijing Consensus and the Washington Consensus. Whether the TPP was targeted towards China or not, I argue that China's threat perception of the TPP leads to confrontation. The U.S. push for a TPP has created a competition for the future of Asia's trade architecture. This is due to the perception of the TPP.

CHINESE PERCEPTION OF THE TPP

China claims it is being denied membership to the TPP because it's economy cannot aptly handle the high standards the TPP aims to enforce. China has problems with the standards on environment, labor, and state-owned enterprises. China cannot join the TPP without reform of its state-owned enterprises. Therefore China perceives the TPP as an intentional "check" on Chinese influences by creating a Chinese excluded trading bloc in the Asia Pacific. Unlike Terada's argument that it is up to China to join or not, the U.S. push for TPP will be perceived by China as an act that must be countered. China will opt not to join not because of economic motivations but to not acquiesce to the U.S. "soft confrontation."

Chinese scholars posit that TPP is "undercutting the East Asian regional integration process that China has propelling for over a decade, posing a great challenge to China's rise in the future" (Xiangyang, 2012). The TPP has a broader membership as it is based in the Asia Pacific rather than the preferred regional membership of East Asia by China. China prefers East Asia as the sole members of the region so China could exercise more influence. Indeed, the TPP, with a broader membership base, will undermine Chinese initiative of ASEAN+3 and also the RCEP. Also, the Chinese regional integration process has been a proliferation of low quality bilateral PTAs. With the TPP as a much more comprehensive and high standard agreement, it would render Chinese initiatives obsolete. Furthermore, U.S. inclusion of the regional integration process itself could be seen as undercutting the Chinese initiatives. The U.S. has not always been an eager leader in the regional integration process and China would prefer the U.S. stay in the Pacific and out of East Asia.

Also, China fears the costs that the exclusion would have on its economy due to trade diversion. Countries that are excluded from a free trade agreement "lose out" on exports because they are faced with tariffs (Baldwin, 2011). China will have to compete with TPP member countries, namely the developing countries in the same state of economic development, and the TPP will grant preference to the exports of the TPP member countries. Chinese exports would compete with exports from other TPP countries and Chinese exports to the U.S. would decrease. Chinese economy would suffer due to exclusion from the TPP.

However, the direct economic impact of the TPP is predicted to be minimal. China will not have to worry about trade diversion as the developing countries of the TPP have a small volume of trade, thus will have a minimal impact on China (Yuan, 2011). Baldwin is also skeptical about trade diversion stating that most RTAs have reverse trade diversion (Baldwin, 2011). The U.S. has a history of using PTAs for foreign policy and security objectives. Most of its PTA partners are irrelevant to economic impact with the exception of NAFTA (Capling and Ravenhill, 2011). China sees the TPP in the same context; the U.S. already has bilateral trade agreements with most of the TPP members. Therefore the implementation of the TPP will have a greater impact on China in geopolitical terms. TPP will create an environment of U.S.-led policies and countries will lean towards the U.S.. This means countries may choose sides – whether to join the TPP or join the U.S..

Vietnam joined the TPP despite similar labor and environmental issues as China as well as state-owned enterprises. Why would Vietnam join the TPP? Vietnam joining the TPP implies that the Chinese economy is stable enough to join the TPP as well. The persistent rivalry between China and Vietnam may have led Vietnam to hope to balance Chinese influence through the TPP. Traditional U.S. allies such as Philippines and Thailand are being replaced by potential "China-balancers" such as Vietnam and India. China will have to decide whether to hedge U.S.-led TPP with RCEP or acquiesce to the U.S. and the "21st century agreement." However, my prediction is that China will not join the TPP in an act of balancing the U.S. Until of late, China was reluctant about multilateral regional trade regimes in East Asia, and has preferred the smaller framework of the ASEAN+3 for East Asia regional integration where it can exercise more influence. China's Ministry of Foreign Affairs noted, "Taking ASEAN + 3 cooperation and SCO as two focal points, China will make pioneering efforts to set up regional cooperation and push for the establishment of a regional cooperation framework conforming to the characteristic of regional diversity." In response to the TPP negotiations, however, China has been promoting the ASEAN Regional Comprehensive Economic Partnership (RCEP) or ASEAN+6 FTA originally proposed by Japan and the trilateral FTA with South Korea and Japan.

TWO COMPETING TRADE ARCHITECTURES: IMPLICATIONS FOR THE REGION

The American and Chinese strategies on regional trade are incompatible and in competition. The case of the TPP supports the theoretical projection of the realist school of continual balancing. Rivalry will persist and two competing trade blocs will divide the region. This will lead to hinder further multilateralization of the region and draw a line in the regional trade architecture. Balance between the two superpowers and the mitigation of competition seems unlikely. Terada proposes Japan as the mediator of the U.S. and China. However, "binding" two different quality free trade agreements seems highly unrealistic and unfeasible. Trading blocs with different levels of liberalization and standards cannot be bound by a member country. The utilization of the free trade agreements is dependent on negotiations of the TPP as well as the corporations and its production networks of a country. While it is true that Japan's production networks will benefit through RCEP, Japanese interest in balancing China and its alliance with the

U.S. may be possible motivations to join the TPP. Also, there is little room for middle powers like Korea to balance the two superpowers on the regional level.

TPP may enlarge to include more than 11 countries in the future, but it will not become the regional trading bloc that it aspires to be. FTAAP does not seem more plausible in the aftermath of the TPP. China will not acquiesce to the American led trading bloc, but instead continue to develop its own initiatives such as RCEP and CJK. It seems unlikely that all or most countries will become members of the TPP. The RCEP will not successfully be the single regional trading bloc as countries will want to balance China along with the U.S. ASEAN does not move as a whole and ASEAN policies cannot be expected to be the "match-point" play for either the TPP or RCEP. Individual countries like Vietnam may continue to choose sides, but ASEAN as a whole will not choose a side. Historically, ASEAN has preferred a balance of power rather than one power dominance, adding more support behind the argument of the persistence of a fragmented region. The TPP case shows that the U.S. is not yet ready to welcome and offer its influence to China in the regional level unlike predictions of a "negotiated order" by Schweller and Xiaoyu Pu.

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Comparative Analysis of Teleost Fish and Humans: The Evolutionary Impracticality of Hermaphroditism in Humans

Rodrigue Lembvem

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ABSTRACT

Hermaphroditism is a widespread sex allocation strategy among teleost fishes that occurs in several forms including sequential (protogyny and protandry) and bidirectional sex change. Incidences of hermaphroditism in humans are pathological and rare. This paper attempts to explain the impracticality of sex change in humans using previous published literature on hermaphroditism in teleost fishes. Humans do not exhibit indeterminate growth, a precondition for selective pressures in favor of sex change. They also demonstrate extensive paternal care, a trait that selects against hermaphroditism, and makes sex change in humans an evolutionary impracticality. Due to these ecological features, pure gonochorism is favored over hermaphroditism in humans.

Keywords: hermaphroditism, indeterminate growth, determinate growth, size-advantage model.

INTRODUCTION

Sex determination is a fundamental topic in evolutionary biology. Despite the rapid advances made in the understanding of sex-determining mechanisms in the last decade, the evolution of these mechanisms remains confusing (Oldfield, 2012). Sex chromosomes provide a mechanism for sex differentiation in most major animal models, including humans. (Mank & Avise, 2009). This bias produces the common misconception that sex chromosomes are the predominant mechanism of sex allocation in animals, when in fact, teleost fishes clearly highlight that sex can be conferred in a variety of ways (Mank & Avise, 2009). Hermaphroditism is a derived mechanism of sex determination, which has been documented in about six percent of all surviving teleost families (Erisman *et al.*, 2013). It is expressed as sequential sex change. Among the sequential hermaphrodites are protandrous, protogynous, and bidirectional sex changers (Avise & Mank, 2009). In protandrous species, individuals function as males first then later change to females. The reverse is true for the protogynous species (Oldfield, 2005). In bidirectional sex changers, males and females within the same population can change sex more than once in their lifetime (Erisman *et al.*, 2013). Synchronous, or simultaneous hermaphrodites, are a non-sex changing species that can simultaneously produce egg and sperm, and these include selfing, and out-crossing species (Avise & Mank, 2009). Protandrous sex change has been documented in anemonefish such as *Amphiprion clarkia* (Pomecentridae). A local breeding community usually consists of a dominant female, several smaller males, and juveniles; should the dominant breeding female die, one of the males transforms into a female to take her place (Avise & Mank, 2009). Protogynous sex change is exhibited by wrasses (Labridae), parrotfishes, and other reef fishes (Avise & Mank, 2009). In the bluehead wrasse (*Thalassoma bifasciatum*), "primary," or juvenile, males and females display an initial phase coloration with a yellow dorsal stripe and a series of lateral green blotches separated by white bars. When the males become "secondary," or large breeding, they display a non-reversible terminal phase coloration with a bright blue head and green body (Avise & Mank, 2009). Males in the terminal phase consists of males who either arose from the initial phase or females who changed sex to become terminal phased males This is seen typically within a few days following the death of a large breeding terminal phase male from the local breeding community (Avise & Mank, 2009). Bi-directional sex change has been successfully induced in aquaria in several species across multiple families, however, under natural conditions, it has only been observed in gobies (Gobiidae) (Erisman *et al.,* 2013). Synchronous hermaphroditism is a relatively rare form of sex allocation which is observed only in about a dozen fish families, most notably in the Serranidae, Cirrhitidae, and Gobiidae (Avise & Mank, 2009).

While the adaptive marvel that is hermaphroditism has been extensively documented in teleost fish, occurrences of such a phenomena in mammals, especially humans, are pathological, unnatural, and sporadic. I hypothesize that the several ecological factors that characterize teleost fishes and are foreign to humans make it easier and more advantageous to adopt hermaphroditism, and explain the lack of and impracticality of sex change in humans. Teleost fishes, unlike humans, exhibit indeterminate growth, an essential precondition for the evolution of sex change, and show relatively little paternal care, a trait which seems to select against hermaphroditism.

THEORETICAL MODELS FOR SEX CHANGE

Several sex allocation theories have been developed to explain modes of sex determination. The size-advantage model is the most widely accepted theory of the adaptive significance and evolution of sex change (Erisman *et al.*, 2013). According to this theory, an individual may change sex if such a change results in an increase in its future reproductive fitness (Oldfield, 2005), and it predicts separate sexes, or gonochorism, when the reproductive fitness of males and females do not differ (Erisman *et al.,* 2013). It forecasts protogynous sex change when large males monopolize mating (Warner & Lejeune, 1985), and when the reproductive fitness of males increases as a function of size and age, faster than that of females (Avise & Mank, 2009). Protandrous sex change is predicted when circumstances become reversed (Avise & Mank, 2009). Over the years, relatively newer theoretical investigations into sequential hermaphroditism have refined the size-advantage model to include other factors beyond body size, which affect an individual's future reproductive fitness, and diverge with sex (Avise & Mank, 2009). These factors include, but are not limited to, population density, population body size ratios, sex ratios, mortality, and other life-history tradeoffs (Warner, 1984, Avise & Mank, 2009). Predictions of this model have a great deal of support in incidences of protogynous sex change and androdioecy, which should occur in polygynous mating systems in which larger breeding males monopolize mating (Erisman *et al.,* 2013).

Also tied to the size-advantage model is the hypothesis that extensive paternal care may preclude gain in reproductive fitness for large breeding males, therefore reducing selection pressures for protogynous sex change (Warner & Lejeune, 1985). Warner and Lejeune (1985) tested this hypothesis under natural conditions in four species of the Mediterranean wrasse (genus *Symphodus*). Each species exhibits a different level of paternal care . They found that sex change was absent in *Symphodus ocellatus* and *Symphodus roissali,* whose larger males construct elaborate nests, ventilate eggs, and engage in territorial defense. The reproductive success for these males is relatively low due to long periods spent in nest construction and egg tending (Warner & Lejeune, 1985). Occasional sex change was observed in *Symphodus tinca*, where larger males are relatively more successful in mating thanks to relatively little paternal care, which involved only rudimentary nest building, no egg ventilation, and minimal spawning interference. They also found that in *Symphodus melanocercus*, sex change was a common occurrence. The larger males of this species spawn at a much higher rate than small males, thanks in part to the fact that they neither build nests nor defend them; they also can spawn on a daily basis . From the results of this study, we can begin to comprehend the costs involved in adopting sex change (Warner & Lejeune, 1985).

INDETERMINATE GROWTH

Theoretically, for sex-change to be adaptive, the relationship between reproductive success and size or age should differ between sexes (Warner & Lejeune, 1985). Predictions of this model are confirmed in teleost fish. Many teleost fish show that the reproductive fitness of functioning as either a male or a female changes during the lives of individuals according to their body sizes or ecological circumstances (Mank *et al.*, 2005). Teleost fishes are able to conform to the size-advantage model due to indeterminate growth, which allows them to continue to grow past sexual maturity, albeit at a decreasing rate. In some fish species, female fecundity increases massively with age and size, but this is usually not true for males, as they can produce enough sperm to fertilize countless eggs even at a small size (Avise & Mank, 2009). This disparity in the reproductive fitness between the two sexes, as a function of size or age, catalyzed by indeterminate growth, causes fish to conform to the size-advantage model, and therefore meet the precondition for the evolution of sex change. Keeping all other variables constant, protandrous sex change should exhibited by these fishes (Avise & Mank, 2009). In many more fish families such as wrasses, parrotfishes, damselfishes, angelfishes, basses, and gobies, mating systems are exhibited in which larger males tend to monopolize the spawning of females (Warner, 1984). In this situation, smaller males tend not to spawn at all, while females of a similar size have no trouble finding mates (Warner, 1984). This causes a situation in which the reproductive fitness of small females is greater than that of small males, and larger males enjoy relatively high mating success. The disparity of individuals beginning as females and maximizing fitness later by switching into males when they become larger should be favored; it is driven by indeterminate growth and makes sex change adaptive (Warner, 1984).

PATERNAL CARE

Prolonged mating and parental care usually requires lots of energy and a massive time commitment (Warner & Lejeune, 1985). Paternal care usually limits the number of offspring a male can be expected to produce in any one period (Warner & Lejeune, 1985), since the opportunity cost of time spent nurturing offspring is time lost from mating others (Gonzalez-Voyer *et al.,* 2007). Therefore, while paternal care tends to increase the survivorship of offspring, it may eliminate the potential of extremely high values of reproductive success for the dominant males that exhibit such paternal care (Gonzalez-Voyer *et al.,* 2007). Granted that based on the size-advantage model, sex change should be less common or nonexistent where large males have less of an opportunity to monopolize mating (Warner, 1984), paternal care should select against hermaphroditism since the relative rewards of being a dominant breeding male are not that great (Warner & Lejeune, 1985). Evidence of this theory is provided in the multicolored *Bodianus eclancheri*, which appear to have no apparent significant relationship between dominance and size and sex, and show no evidence of sex change in the adult stage (Warner, 1984), while *S. melanocercus* which exhibit little parental care, and have a massive potential for mate monopolization, show evidence of sex change (Warner & Lejeune, 1985).

DISCUSSION

While hermaphroditism is adaptive in teleost fish because different species conform to some variation of the size-advantage model, it is not the case with humans because they exhibit determinate growth and more or less attain a definite final height after sexual maturity (Abbassi, 1998). In humans the size and age-specific male and female reproductive expectations do not differ significantly and thus do not meet the essential precondition for the evolution of hermaphroditism. Predictions of the size-advantage model therefore favor pure gonochorism (dioecy) in humans. Sex change is more or less a mechanism meant to capitalize on relatively higher fertility rates at larger sizes, and enhance success at small sizes (Warner & Lejeune, 1985). Teleost fishes have a massive reproductive potential, which increases significantly with size and age. This means that males can potentially fertilize hundreds to thousands more eggs at larger sizes, per mating, than they would at smaller sizes. This is the driving force behind the differences in reproductive fitness between sexes of teleost fishes, which allow them to adhere to the size-advantage model. In humans, the reproductive potential is not only dramatically lower than in teleost fishes, but more or less the same among males, regardless of size. This low reproductive potential restricts differences in reproductive success between sexes and ensures that the the size-advantage model presents a significantly greater economic payoff in teleost fishes than it could for humans.

Sex change may be adaptive when the size-advantage model holds true; when large males tend to monopolize mating, but the ability of large males to dominate access to females can depend in part on the amount of time and energy each mating requires (Warner & Lejeune, 1985), and the degree of parental care required for the successful rearing of young (Emlen & Oring, 1977). Much like determinate growth, extensive paternal care limits mate monopolization, and curbs reproductive potential. In this light, humans, who exhibit extensive paternal care relative to teleost fish, have very little potential for mate monopolization. Additionally, like the multicolored *B. eclancheri*, humans show a relatively insignificant relationship between mate monopolization and size and sex. Since human ability to monopolize mates is restricted by extensive paternal care, sex change should not be favored in this species.

CONCLUSION

Teleost fishes display a great deal of evolutionary diversity with respect to the variety of sex determining mechanisms exhibited. This paper shows that hermaphroditism, a derived sex allocation strategy in teleost fishes, is evolutionarily impractical in humans due to determinate growth and extensive paternal care. Both ecological features ensure very little to no gains in reproductive fitness as a function of size and age. For this reason, humans fail to meet the required precondition for the evolution of sex change, which dictates that for sex change to be adaptive, the relationship between reproductive success and size or age, should vary between sexes. Going by this ultimatum of the size-advantage model, pure gonochorism instead of hermaphroditism should be, and is, favored in humans.

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Question and Answer with Professor Anthony Jack, Assistant Professor of Cognitive Science, Philosophy and Psychology

Written By Mike McKenna

Professor Anthony Jack's research, titled "fMRI evidence of reciprocal inhibition between social and physical cognitive domains" was published in the journal *NeuroImage* and became the basis for his future work.

Jack found that a person must juggle between analytical and empathetic reasoning, as there are neural constraints to doing both at the same moment. With these findings, Jack suggests that established theories must be reworked.

Q: Your most recent work spans a wide range of topics, from cognitive perspectives on how to best coach individuals to the impact of soldiers dehumanizing their enemies. Is there anything you look for in your research topics?

A: I never would have expected that my work would span such a wide range of topics. I was really interested in the topic of consciousness and how to apply it in a way that probably seemed quite mundane in psychological methodology. As I was working in brain imagining, I noticed this big phenomenon. From there, my collaborators have opened up other vistas to ways that I could apply the fundamental thing I was always interested in. It's been hugely fun. I often sit down and think, "How could it really be?" I must be talking nonsense that my theory applies to all these things.

Q: Going off that theme of collaboration, you have worked with Dr. French from the Inamori Center. I know you've done dehumanization research in the past, but how was that experience unique from your prior work?

A: I worked previously with a philosopher in St. Louis who was very interested in ethics. That started to open my eyes to this ethics angle. When Dr. French and I got some results and started talking about them, I thought, "Ooh, there's something that really fits here." What has really been amazing and a really good experience for me is how applied her angle is. Extremely significant, life or death issues, such as why we go out and willingly sacrifice ourselves or how we end up doing things that are really unethical, like committing war atrocities.

Q: To what extent did your research find that dehumanization is needed in warfare?

A: We ended up arguing that a certain controlled type of dehumanization is absolutely necessary because of what we ask our troops to do is so extreme. If you don't wear a mask of some coldness, you may be actually hurting yourself more. There are some people who suggest we should train our troops to love our enemies, but we actually think that's a bit sick.

> *There's too much bottom line thinking and not enough individual encouragement.*

Q: What are the implications from your coaching research?

A: With the work with [Distinguished University Professor and a Professor in the Departments of Organizational Behavior, Psychology and Cognitive Science] Professor [Richard E.] Boyatzis, the sense that we're coming from is that in business culture, the importance of the more compassionate or empathetic approach [of management or coaching] is not sufficiently culturally reinforced. There is too much bottom line thinking and not enough individual encouragement. And we can see that movement already in teachment. This university is all about students. We're into teaching and helping people flourish. That's part of a cultural movement and understanding how to do that effectively, that's really the goal.

Q: Do you think your research provides data to culturally supported ideas?

A: I think we still are a culture that privileges analytic thinking at the cost. My model says that both are essential and I think we tend to see them as at war at each other, while we see it is juggling between resources in effect. So I think the culture has become very analytical. These theories have been out there forever. In that broad brush, we are bringing a scientific basis to these ideas. My hope is that that in the end we will be influential, since when you're talking to people who have an analytic mindset, you have an in to them.

The Mechanisms behind Flight Trajectory in Fruit Flies: An Interview with Dr. Jessica Fox

Written By Pranoti Pradhan

Dr. Jessica Fox is one of the newest additions to the Department of Biology at Case Western Reserve University. Her current research addresses with the visual identification of small moving targets in flying animals.

Q: What made you interested in researching sensory information processing in insects?
A: I've always had an interest in insects. They're just right for research – not so many neurons, but neurons are at the exact amount. Some animals have too little, and some have too many. Fruit flies have 100,000 neurons, where you can actually use the neural circuits to understand their behavior. They are simple enough to study, yet complex enough that they're compelling. It's a good way to combine neuroscience and animal behavior.

Q: In your most recently publication, you studied how the fruit flies adjust their gaze for a small moving figure instead of an independently moving wide field ground. How exactly did you achieve this?
A: The flies were tethered to pins and shown different stimuli: moving background and moving figure. We recorded their wing movement and head movement, observing how much they were steering. We crossed correlations between the figure and ground and the head and ground, and then looked at which correlation is strongest. The wings always steer towards the moving background, but the head focuses on the moving figure. Whenever they are moving through space, the eyes stabilize the background and if anything is moving against the background it will pop out. We disconnected the head and wings, and concluded that they are independent.

They are simple enough to study, yet complex enough that they're compelling.

Q: What is the difference between re-orienting the head versus re-orienting the flight trajectory and why is this important for fruit fly behavior?
A: Flies have a unique method of flying that is unlike any other flying organism. Flies don't have muscles in their wings, so only the thorax flaps. They steer their muscles inside the thorax and stabilize their head while the body moves in different parts. Flies first move their wings and body then re-orientate their heads, to minimize vision blur. The reorientation of their head versus their wing flight trajectory is different. Both perform different functions, but come together to perform flight.

Flies have a unique method of flying that is unlike any other flying organism.

Q: Where do you believe your future research and findings will take you?
A: We know that the halteres are really important and we want to determine the advantages in having halteres versus having wings. We also want to investigate the correlation between the head and the wings, and their roles in flight of the fruit fly in her future projects. Halteres seem to function similarly in all flies, and we know that it evolved from a wing, but we want to know the functional aspect. We plan to conduct experiments where we manipulate the halteres receptor, allowing us to determine whether fruit flies can still function and perform flight without this structure. The evolution of this structure is also unclear. However, everyday application is the main goal. The motor flight and vision pathways of insects are the key to further mastering everyday autonomous vehicles.

Q: Any closing thoughts?
A: Neuroscience is an exciting field in which to be. Case Western Reserve University is performing research in neuroscience that has never been performed before.

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