The impact music genres play on the behavioral responses of Drosophila melanogaster

Grant Proposal

Grace Qiu

Massachusetts Academy of Math and Science at Worcester Polytechnic Institute

85 Prescott Street, Worcester, MA 01605

Abstract

Autism Spectrum Disorder (ASD) affects the behaviors, communications, and social abilities of millions of people globally. Recently, music therapy has become a non-invasive treatment for individuals with ASD; however, music therapy often uses classical music as the genre of music during therapy sessions, and little is known about the effects of different music genres on ASD-associated behaviors. This study uses *Drosophila* to investigate the impacts of music genres on both wild-type and ASD-induced *Drosophila*. Using standardized *Drosophila* behavioral assays, it is predicted that ASD-modeled *Drosophila* exposed to genres such as pop, heavy metal, or rap will exhibit greater improvements in locomotion, social interaction, and sensory response than those exposed to classical music. Ultimately, this research hopes to advance the knowledge of the relationship between music and ASD-like behaviors and address the need for effective interventions for individuals with ASD.

Keywords: Autism Spectrum Disorder (ASD), music therapy, behavior, music genre, *Drosophila*, behavioral assays

The Impact Music Genres Play on the Behavioral Responses of *Drosophila Melanogaster*

Autism Spectrum Disorder (ASD) is a developmental disorder that affects a wide range of behavioral and communicative abilities in humans; this includes difficulty in communicating and interacting with others, restricted interests, and repetitive behaviors that affect the daily lives of autistic individuals. Common social inability signs of ASD include inconsistent eye contact, unusual tone of voice, inability to adjust to social or verbal cues, and ignoring others (National Institute of Mental Health, 2024). While the cause of ASD remains unknown due to the complex nature of this disorder, this has prompted scientists to explore different therapeutic approaches to improve the quality of life for individuals on the ASD spectrum.

One form of treatment has been music therapy. Music therapy involves the use of music as a therapeutic intervention to address the behavioral and social symptoms of ASD individuals (Applewhite et al., 2022). Music may be a more accessible way of interacting since a musical message does not have to be conveyed verbally, and therapy could be enacted in any comfortable environment for the ASD individual (Pater et al., 2022). However, current music therapy practices only use classical music as a treatment option for autistic individuals. The lack of diverse genres used in therapy may limit the outcomes of music therapy (Fu et al., 2023). This project aims to study the behavioral responses *Drosophila* exhibit when listening to different genres, such as pop and classical. The use of multiple genres of music within the same study allows for a clearer understanding of how

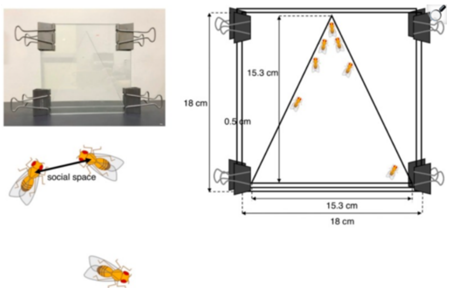


Figure 1: A standardized social behavioral assay. Originally created by Simon et al, it is used to analyze the socializing distance between Drosophila (Ueoka et al., 2019).

each genre of music affects autistic individuals. Using behavioral assays (Figure 1), the study could record the behavioral responses of *Drosophila* while listening to music, and the behaviors after listening to music. The research could also lead to personalized music therapy instead of following the common classical music bias. The study could also show how specific genres of music uniquely impact ASD-induced *Drosophila's* behavioral responses. These results could be generalized to the human population for further research and study.

Drosophila was used in this study as a model organism since 75 percent of human disease-causing gene mutations have *Drosophila* homologues. *Drosophila* also share similar neural pathways as humans (Ueoka et al., 2019; Greenspan, 2012). Utilizing *Drosophila* as a model organism, this study is manageable and replicable, which could lay the groundwork for future *Drosophila* research projects.

Section II: Specific Aims

This proposal's objective is to examine the benefits of different music genres on the behavior of *Drosophila* genetically modified to exhibit traits similar to that of humans with ASD.

The long-term goal is to study the effect music has on the behaviors of ASD-*Drosophila*, where it is expected that ASD-induced *Drosophila* exposed to music genres other than classical will show a greater positive behavioral change than those exposed to classical music. This hypothesis is based on the idea that there is a strong correlation between music and emotion (Ahmad & Rana, 2015; Haering, 2018). Music has been shown to positively impact children with ASD in emotional regulation and social connection (Ferreri & Verga, 2016). The auditory stimuli could affect the behavioral aspects of ASD-induced *Drosophila*, potentially providing different therapeutic benefits. The rationale is that investigating the relationship between music and ASD behaviors will provide insight into the auditory stimuli that can influence those behaviors. This study can provide a way to identify what types of music genres can modify behaviors associated with ASD and to what degree. The work we propose here will use behavioral assays such as locomotion tracking and social clustering analysis to quantify changes in the social behaviors of both wild-type and ASD-induced *Drosophila* (Neckameyer & Bhatt, 2016).

Specific Aim #1: Examine the behaviors of wild-type *Drosophila* and ASD-modeled *Drosophila*

Specific Aim #2: Identify how different music genres can differently affect the behaviors of wild-type *Drosophila* and ASD-modeled *Drosophila*.

The expected outcome of this work is an overarching understanding of how different genres of music can influence ASD-like behaviors in *Drosophila*. Through behavioral assays, the study will observe how *Drosophila* responds to different genres of music, and this could lead to inferences about how certain types of sound might influence behaviors seen in human individuals with ASD.

Section III: Project Goals and Methodology

Relevance/Significance

If the study could identify specific genres of music that produce a more positive behavioral change in the genetically modified *Drosophila*, it could suggest that similar music genres might have similar therapeutic potential for humans with autism (Simpson et al., 2013). The finding could allow for personalized therapy treatments that could prove more effective than standardized music therapy.

Innovation

Common music therapy uses classical music as the auditory stimuli, but there are few studies that have used different genres of music (Pauwels et al., 2014). The combination of using model organism experimentation, music therapy exploration, and a focus on ASD is also rarely seen in behavioral sciences. Unlike previous studies that focus on the use of classical music in music therapy, this study analyzes the effects of different frequencies on the behaviors of ASD-modeled *Drosophila*.

Methodology

Two experimental groups will be used: wild-type *Drosophila* and ASD-modeled *Drosophila*. Behavioral traits will be measured by standard *Drosophila* behavioral assays (Simon et al., 2012). Baseline data will be collected before the wild-type and ASD-modeled *Drosophila* are exposed to any music. Then, *Drosophila* will be placed in chambers equipped with small speakers to play music at consistent volume and frequency (50–70 dB) for one hour a day over five consecutive days. Then, each experimental group will be randomly divided and exposed to randomly selected music genres. After music exposure, the same Drosophila behavioral assays will be used to identify any changes from the baseline data.

Specific Aim #1: Determine the behaviors of wild-type *Drosophila* and ASD-modeled *Drosophila*.

Justification and Feasibility. This aim is justified because it establishes the basic behavioral traits of wild-type *Drosophila*, which allows the researcher to compare the impact of music interventions on wild-type *Drosophila*, and identify measurable parameters to evaluate the effectiveness of music therapy on *Drosophila*. Using wild-type *Drosophila* also ensures the social assay model functions as intended, providing a reliable foundation for future trials that use this assay to assess the behaviors of *Drosophila* are accurate (Ueoka et al.,2019).

Summary of Preliminary Data.

The study ran two trials to gather data for the behaviors of wild-type *Drosophila*.

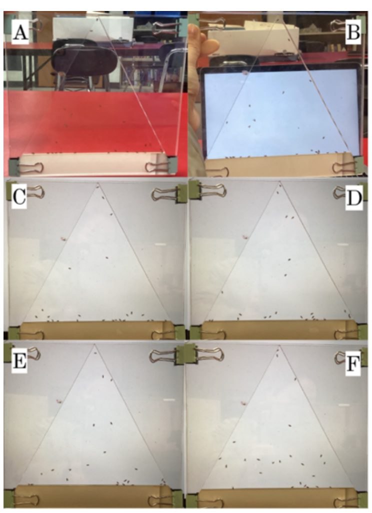


Figure 2: Trial 2. Used a standard behavioral assay to assess the behaviors of wild-type Drosophila melanogaster. After starting data collection, A was taken 5 minutes into the collection. The following images were then taken in 5-minute intervals and F was taken at 30 minutes into the trial.

Both trials had a sample size of 25 (n=25). Multiple human errors occurred at the beginning of trial one, which led to the decision to run a second trial. The group of wild-type *Drosophila* was chilled in a test tube and then put into the behavioral assay. After ten minutes of thawing, data collection began. Pictures were taken on an iPad in 5-minute intervals to record the behaviors of wild-type *Drosophila* (Figure 2). A data table of observations was also made alongside data collection (See

Appendix 1). The researcher recorded any small movements the *Drosophila* made during the 30 minutes on the data table, ensuring that all movement was being recorded. Some notable observations included signs of chasing, clustering, and grooming. The trial to run ASD-induced *Drosophila* has not been conducted.

Expected Outcomes. There are two expected overall outcomes of this aim. The first is to ensure the behavioral assay functions the way it should. The second is to observe the wild-type *Drosophila* and ensure they display typical behavioral patterns such as locomotion and social interactions.

Potential Pitfalls and Alternative Strategies. Errors could also be avoided when setting up the behavioral assay. While conducting Trial 1, the researcher smushed a *Drosophila* while closing the behavioral assay (Figure 3B). Lastly, when knocking the assay against the table to move the flies to the bottom of the assay, the bottom board of the assay came loose and created a gap in the behavioral assay (Figure 3A, 3C). An alternative solution would be to immediately knock the *Drosophila* to the bottom of the assay as soon as they were put in. Therefore, the *Drosophila* would thaw already at the bottom instead of knocking them to the bottom later.

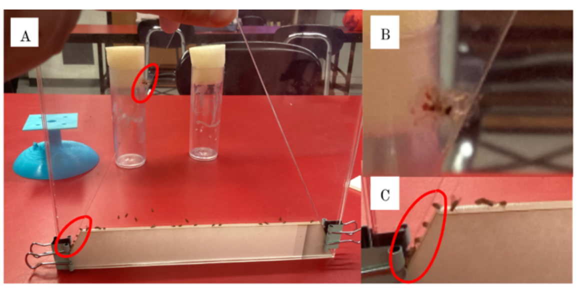


Figure 3: Trial 1. Used a standard behavioral assay to assess the behaviors of wild-type Drosophila melanogaster. Image 3A shows the assay after knocking the Drosophila melanogaster to the bottom. Image 3B is a Drosophila melanogaster that was smushed while being put into the assay. Image 3C shows the gap created when the bottom board moved while the experimenter was knocking the Drosophila to the bottom of the assay.

Specific Aim #2: Identify how different frequencies can affect the behaviors of wild-type *Drosophila* and ASD-modeled *Drosophila*.

Justification and Feasibility. This aim builds upon existing research that music therapy is a beneficial treatment for autistic behaviors in humans (Geretsegger et al., 2014) but addresses a gap in understanding the specific effects of diverse music genres on those behaviors. Using *Drosophila* as the model organism, these behaviors are easily replicable. This aim is also feasible as it uses existing behavioral assays for *Drosophila* and has a relatively easy procedure.

Summary of Preliminary Data.

The researcher is currently gathering data and will revise this section once data is collected. However, a table of observations was created as the *Drosophila* were being exposed to the different genres of music (Figure 4). This captured initial *Drosophila* reactions to the two music genres. Notable behavior differences were captured.

Classical Music (CM)	Wild Type (n=74)	ASD-Induced, second generation (n=15)
	Moved a lot at the start, kept on swarming on the side and the top of the bottle	Moved around the bottle a lot, did not immediately try to climb to the top
	Mostly hovered at the top	Always one or two Drosophila just moving around on the feed
	Little to no pruning until Tchaikovsky	Did not prune a lot at all. In fact, saw maybe 1 or 2 prune in total
	Started pruning later than WT exposed to no classical music	Most sat at the top. Still. Not moving.
Pop Music	Wild Type (population will be collected after all trials)	ASD-Induced, second generation (n=20)
	Started grooming within 3-5 minutes	Also almost immediately started grooming
	Did not move as much as CM WT, but still moved a lot more than ASD	More signs of grooming in total
	All still aggregated to the side/top for the entire exposure	Towards 15 mins, a lot aggregated to the top
	Little to no pruning from middle to end	Later, started spreading out, not all staying at the top
	Very compact and tight, lots of clustering	Very separated, little to no contact with others

Figure 4: A table of observations of the *Drosophila* as they were exposed to two different genres of music. Classical Music was recorded first, and then Pop music.

Expected Outcomes. It is expected that ASD-modeled *Drosophila* will exhibit different behaviors after listening to its genre of music and determine the benefits of music genres on ASD-modeled *Drosophila*. In turn, the results could hopefully be generalized to the behaviors of human individuals with ASD. Then, this data could be used to improve music therapy for a variety of conditions. Once data is collected, the researcher will revise and edit this section to make more appropriate claims.

Potential Pitfalls and Alternative Strategies. External factors such as light source and sound emitted by others in the lab could be a source of error. An alternative strategy would be to run the experiment when there are few to no people in the lab and keep a single light source shining above the assay to reduce the variation in the light source. The human errors mentioned in Aim #1 could also be sources of error for Aim #2.

Section V: Ethical Considerations

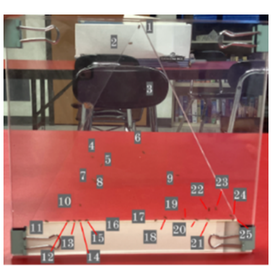
This study adheres to the ethical standards of research by treating *Drosophila* under humane conditions. *Drosophila* will be maintained in optimal conditions and exposed to music calibrated to avoid stress. The research hopes to contribute to non-invasive therapeutic strategies for ASD, aiming to advance human well-being.

Section VI: Timeline

https://docs.google.com/spreadsheets/d/1i87g4rfo63rc1rvvGY4_77XiGdNfeUobb261kQKREt4/edit?gid=1250150457#gid=1250150457

Section VII: Appendix

Appendix 1a



Appendix 1a: Trial 2–5 minutes. The Drosophila are labeled from 1 to 25 to clearly see where they are in the picture

Appendix 1b

# of Drosophila	Time (minutes)	# of clusters	Specific fly	Observation	General Observations
25	5	3	1 and 2	Immediatley flew to the top of the assay Especially fly #1	Although the flies had been thawing for 10 mins before hand, they still seemed sluggish. A lot of them just started to crawl around. Not a whole ton of movement from most Drosophila
25	10	2	4, 5, 7, 8	Clamped together	More Drosophila are waking up. they seem to still mostly be very weak
25	15	2	1, 2, 3	Consistently staying at top of the assay	All the flies are alive. They have all shown signs of movement either by twitching their legs or wings. Seem to be too weak to climb up the plexiglass
25					
25	20	4	N/A	Pairing up more	The drosophila are moving more, socializing more
25	25	4	N/A	N/A	- Bottom cluster of Drosophila break away from each other - Clusters are more obvious - More drosophila are moving up
25					
25					
25	30	3	N/A	N/A	- Almost all Drosophila left the "ground" at somepoint - Drosophila have all showed wiggles/tweaks - All Drosophila have moved! - Stopped due to lab closing
25					
25					

Appendix 1b: Trial 2 Table of observations. The following Drosophila numbers are from Appendix 1a where the researcher labeled the 25 Drosophila. In column four, the term 'fly' is referencing Drosophila.

Section VIII: References

Applewhite, B., Cankaya, Z., Heiderscheit, A., & Himmerich, H. (2022). A Systematic Review of Scientific Studies on the Effects of Music in People with or at Risk for Autism Spectrum Disorder. *International Journal of Environmental Research and Public Health*, *19*(9), 5150. https://doi.org/10.3390/ijerph19095150

Ferreri, L., & Verga, L. (2016). Benefits of Music on Verbal Learning and Memory: How and When Does It Work? *Music Perception: An Interdisciplinary Journal*, *34*(2), 167–182. https://www.jstor.org/stable/26417442

Fu, Q., Qiu, R., Chen, L., Chen, Y., Qi, W., & Cheng, Y. (2023). Music prevents stress-induced depression and anxiety-like behavior in mice. *Translational Psychiatry*, *13*(1), 1–12. https://doi.org/10.1038/s41398-023-02606-z

Geretsegger, M., Elefant, C., Mössler, K. A., & Gold, C. (2014). Music therapy for people with autism spectrum disorder. *Cochrane Database of Systematic Reviews*, *6*(6). https://doi.org/10.1002/14651858.cd004381.pub3

Greenspan, R. (2012). *Looking at autism through the fruit fly*. The Transmitter: Neuroscience News and Perspectives. https://www.thetransmitter.org/spectrum/looking-at-autism-through-the-fruit-fly/

Haering, S. I. (2018). Are music-based interventions a way to improve executive function in autism? *International Journal of Learning and Teaching*, *10*(1), 27. https://doi.org/10.18844/ijlt.v10i1.3143

National Institute of Mental Health. (2024). *Autism spectrum disorder*. National Institute of Mental Health. https://www.nimh.nih.gov/health/topics/autism-spectrum-disorders-asd

Neckameyer, W. S., & Bhatt, P. (2016). Protocols to Study Behavior in Drosophila. *Methods in Molecular Biology*, 303–320. https://doi.org/10.1007/978-1-4939-6371-3_19

Pater, M., Spreen, M., & Yperen, T. van. (2022). Music therapy for children on the autism spectrum: Improved social interaction observed by multiple informants across different social contexts. *Nordic Journal of Music Therapy*, *32*(1), 29–47. https://doi.org/10.1080/08098131.2022.2046628

Pauwels, E. K. J., Volterrani, D., Mariani, G., & Kostkiewics, M. (2014). Mozart, Music and Medicine. *Medical Principles and Practice*, *23*(5), 403–412. https://doi.org/10.1159/000364873

Simon, A. F., Chou, M.T., Salazar, E. D., Nicholson, T., Saini, N., Metchev, S., & Krantz, D. E. (2012). A simple assay to study social behavior in Drosophila: measurement of social space within a group. *Genes, Brain, and Behavior*, *11*(2), 243–252. https://doi.org/10.1111/j.1601-183X.2011.00740.x

Simpson, K., Keen, D., & Lamb, J. (2013). The use of music to engage children with autism in a receptive labelling task. *Research in Autism Spectrum Disorders*, *7*(12), 1489–1496. https://doi.org/10.1016/j.rasd.2013.08.013

Ueoka, I., Pham, H. T. N., Matsumoto, K., & Yamaguchi, M. (2019). Autism Spectrum Disorder-Related Syndromes: Modeling with *Drosophila* and Rodents. *International journal of molecular sciences*, *20*(17), 4071. https://doi.org/10.3390/ijms20174071