It's, Like, Just Science: Exploring the Use of the Discourse Marker *Like* in Casual Scientific Communication

Presented as a Senior Thesis in Linguistics

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Table of Contents

Abstract

Discourse markers (DMs) are a grammatical category that include words that contribute non-content meaning to an utterance, including *um* and *like*. DMs are often heavily linked to prescriptivist teachings because of the association that they impede the perceived credibility of the speaker. In this study, I conduct a quantitative analysis on the impact of the English DM *like* on the ability of participants to remember and understand scientific information presented to them in an audio format. I examined four different *like* frequencies: zero, low (10 *like*s per 1000 words), medium (50 *like*s per 1000 words), and high (100 *like*s per 1000 words). I found that there were only marginal differences between the performance of participants who heard different frequencies of *like* around a given piece of information. However, I found that there was a significant difference in the standard deviations for participant performance at the highest *like* frequency, indicating that while lower *like* frequencies tend to have a more consistent impact on the performance of participants, the highest frequency causes both strongly positive and strongly negative impacts on different participants' performance. I propose that the familiarity of different *like* frequencies in everyday contexts impacts this difference in standard deviation. Therefore, while there is no universal correlation between *like* frequency and listener comprehension, the frequency of *like* does have an impact on how the listener responds to the scientific audio.

1 Introduction

"The right word may be effective,

but no word was ever as effective

as a rightly timed pause."

-Mark Twain

Language is a powerful way speakers establish their position, authority, and relatability in the world. One tool in spoken and signed languages is the prosody of the utterance: the rhythm and flow of a sentence. Speakers can say the same content in a variety of different ways — by including pauses, or a change in inflection, or a verbal stumble — and end up completely changing how their statement is received and perceived by the listener. In this thesis, I focus on one example: discourse markers (colloquially known as “filler words”).

Discourse markers are a contentious topic among prescriptivists. When searching for “filler words” on Google, the predominant results are all aimed at helping the readers eliminate filler words from speech, claiming that, like Mark Twain claims, verbal pauses are preferable to filling the pause with an unnecessary word. Prescriptive opinions propose that discourse markers (DMs) harm the speaker’s credibility, which makes DMs particularly policed in academic or other formal settings.

DMs appear across human languages, and are often used unintentionally. This makes the prescriptivism of DMs particularly complicated, because although they do not contribute to the content of the sentence, DMs *do* contribute to the prosody and other aspects of the sentence, including marking new information or establishing connections with other members of a conversation. As such, removing all DMs from speech is not only going against natural human speech tendencies, but also may be removing more meaning from the sentence than simply the sounds *um* or *like*.

Scientific communication often falls on the boundary between highly academic and professional, and casual and conversational. On the one hand, scientific communication is often predicated on presenting technical information in a way that makes the speaker appear credible and intelligent, prioritizing the perception of the speaker. On the other hand, some efforts have been made to center the audience in scientific communication, prioritizing making the speech easily understandable in order to widen the audience. Currently, much of casual scientific communication (i.e., conference poster sessions, university class presentations) perpetuates the former idea, prioritizing appearing "intelligent" or "put together" in order to accomplish a particular goal (gain clout in the field, successfully network, receive grant funding, get a good grade, etc). While some people are breaking away from this system to prioritize the audience, the stigma against using DMs in scientific communication exists, begging the question: What are we gaining — or what are we losing — by eliminating DMs in technical scientific communication?

A body of literature exists tracing current DM usage patterns in various different languages including English and French. However, there is a gap in the literature for studies that directly investigate the relationship between DMs and listener comprehension. In this thesis, I investigate the role of the English discourse marker *like*, specifically asking how the rate of *like* usage in spoken scientific communication impacts the listener's comprehension and recall of the audio. In my study, I asked participants to listen to a six-minute audio recording about a complex concept in astrophysics.

I found that there are very minimal differences in listeners' performance in comprehension tasks after listening to audio stimuli that contained different frequencies of *like*, ranging from zero *like*s to 100 *like*s per 1000 words. However, I found significant differences in the standard deviations for listener performance. Specifically, I found that there are lower standard deviations in performance for stimulus sections that contained zero or low rates of *like*, while the performance for sections of audio stimuli with high rates of *like* showed much more variability. These trends continue when looking at only direct recall questions, and when looking at application-based comprehension questions. I attribute this variability in standard deviation to the amount that the listener is accustomed to hearing a given rate of *like* in their everyday life. Formal, scripted communication frequently contains zero *like*s, and casual conversations contain a frequency of *like* that is similar to the lower frequencies used in this study. Therefore, since listeners are on average more used to hearing these frequencies of *like*, their collective response to *like* seems to be more unified. On the other hand, the higher frequencies of *like* used in this study are significantly higher than the rate that naturally comes up in casual conversation, likely causing the listener to pique their attention. This increased attention may cause positive effects (allowing the listener to pay closer attention to the content of the audio) or negative effects (causing the listener to be distracted by the presence of *like*).

Through this study, I propose that there is not one clear relationship between *like* frequency and listener comprehension, but rather that there are differences in how variable listener responses are to different *like* frequencies.

2 Background on Discourse Markers in Speech

2.1. Discourse Markers

Although discourse markers appear across human languages (Fraser, 1999), it is difficult to craft a clear definition. One challenge is that the category of "discourse marker" includes a diversity of words and phrases that serve different functions, are used in different contexts, and have different connotations. Representative examples of discourse markers (DMs) are shown below in sentences (1) - (5), with DMs in bold.

(1) A: I'm pretty hungry. B: **So**, do you want to split a banana split?

(2) I think. **Therefore**, I am.

(3) **Well**, we've been here ever since my dog took a liking to flan.

(4) The painting has this big, **um**, splotch on the left side that's either paint or melted crayon.

(5) I have to go in **like** seven minutes or I'll be late for my scuba lesson.

Schourup (1999) proposes a set of three criteria that unify all DMs: connectivity, optionality, and non-truth-conditionality. Connectivity refers to the DM's function to relate two utterances together. Sentences (1) and (2) show this property clearly: the DMs link two distinct sentences, whose meanings are connected and build on each other. For sentence (1), these two sentences are spoken by separate people, but this does affect the connectivity. Sentence (3) is more abstract. Schourup claims that DMs can connect to implied utterances, which may come in the form of body language or other physical stimuli. For example, the speaker in sentence (3) may be saying this sentence in response to raised eyebrows as they sit with their dog at a bakery, or in response to a hand gesture to start telling a story. The presence of the DM *well* explicitly connects the following sentence to whatever stimulus preceded it.

Sentences (4) and (5) seem to be a slightly different category of DM. Rather than connecting distinct thoughts, or even distinct clauses, the DMs in these sentences seem to double as verbal disfluencies, or words that disrupt the flow of communication (Allwood, 2017). It could be argued that these DMs still are connecting two sides of the same thought, but rather than bridging the gap between clauses, they bridge the gap between what would otherwise have been an unfilled verbal pause.

The second criterion Schourup proposes is optionality, in that removing a DM should not impact the syntactic nor semantic viability of the sentence. This rule does not claim that DMs are redundant, though. Instead, it suggests that while DMs may guide the listener towards a particular interpretation of the utterance, that interpretation is still possible without the DM (Schourup, 1999, p. 231). For example, in example (2), *therefore* tells the reader that there is a causality between *I think* and *I am*. Omitting *therefore*, it is still possible that the thinking is directly leading to the being, although it is also possible that these are unrelated statements. The important, necessary benchmark is just that sentence (2) is still grammatical without *therefore*. Likewise, we can see that for sentences (1), (3), (4), and (5), removing the DM has no impact on the grammaticality of the sentences.

Finally, DMs are thought to not contribute to the truth condition of the utterance, which means that the mental image the listener constructs should be the same whether the utterance contains a DM or not: everything that is true in one construction should be true in the other, and everything that is false in one construction should be false in the other (Schourup, 1999). While this criterion fits with sentences (1) - (4) and many other possible examples of DMs, this is not exactly the case for sentence (5). If we were to omit *like* from sentence (5), there exists a truth condition that the speaker must have exactly seven minutes before they would be late.

Specifically, if we briefly consider Grice's maxims, this truth condition comes from the fact that if the speaker knows they have a different amount of time before being late, then saying *seven minutes* is violating the maxim of quality (say what is true), and if the speaker is unsure whether they actually have seven minutes versus six or eight or ten, then saying *seven minutes* is violating the maxim on quantity (provide as much information as possible, without breaking the maxim of quality) (Grice, 1975). Therefore, looking at sentence (5) without the *like*, it is true to say that the speaker has exactly seven minutes to get ready before being late. However, looking at sentence (5) as written, *like* actually does change the truth condition of the sentence by indicating that the number given might be an approximation. Does this mean that *like* in sentence (5) is not a DM? Or, while Schourup's criteria serve as a useful baseline, are there other rules that might be able to account for this discrepancy?

Many scholars have adopted slightly altered rules that mostly center on one single criterion: that they must establish relationships between topics or grammatical units (Fraser, 1999; Fuller, 2003; Hellermann & Vergun, 2007; Jones et al., 2022). In essence, they argue that the most important characteristic of a DM is how it relates to the other parts of the sentence, similar to Schourup's connectivity. There seems to be some amount of agreement that DMs need to connect two parts of an utterance, whether semantically or prosodically. Within this broad category, however, there are a number of functions that the DM can have in the sentence. Among others, DMs can mark focus, establish common ground, modulate turn taking, maintain the conversational floor, fill pauses, and indeed mark approximations, shown in sentences (6) - (11).

(6) If you want to make a down payment on a canoe, you need, **well**, a lot of money. *focus*

(7) Can you move my rook two spaces to the left? **You know**, I think I'm playing pretty well this time. *common ground*

(8) A: Oh my gosh did I tell you about what happened at the party last night— B: **So**, I don't really care about that. *turn taking*

(9) What was saying? **Uh**, maybe it was something about dachshunds? *maintaining conversational floor*

(10) I guess I was, **um**, learning how to surf or something? *fill pauses*

(11) You're, **like**, the coolest person I've ever met. *approximation*

Different DMs can take on different sets of functions. For example, the DM *like* in sentence (11) makes the sentence equivalent to, "I think you are the coolest person I've ever met," or "You're maybe the coolest person I've ever met." *Like* introduces hedging into the sentence in a way that *um* in sentence (12) cannot:

(12) You're, **um**, the coolest person I've ever met. *fill pause, **not** approximation*

In this thesis project, I focus on the DM *like*.

2.2. Varieties of Like

Like has many grammatical roles in English, including but not limited to verb, noun, adjective, preposition, conjunction, and adverb. Among these roles, a subset are discourse markers and a subset are not (**Figure 1**). Therefore, it is first necessary to parse the specific roles of *like* as a DM before we can start investigating its impact.

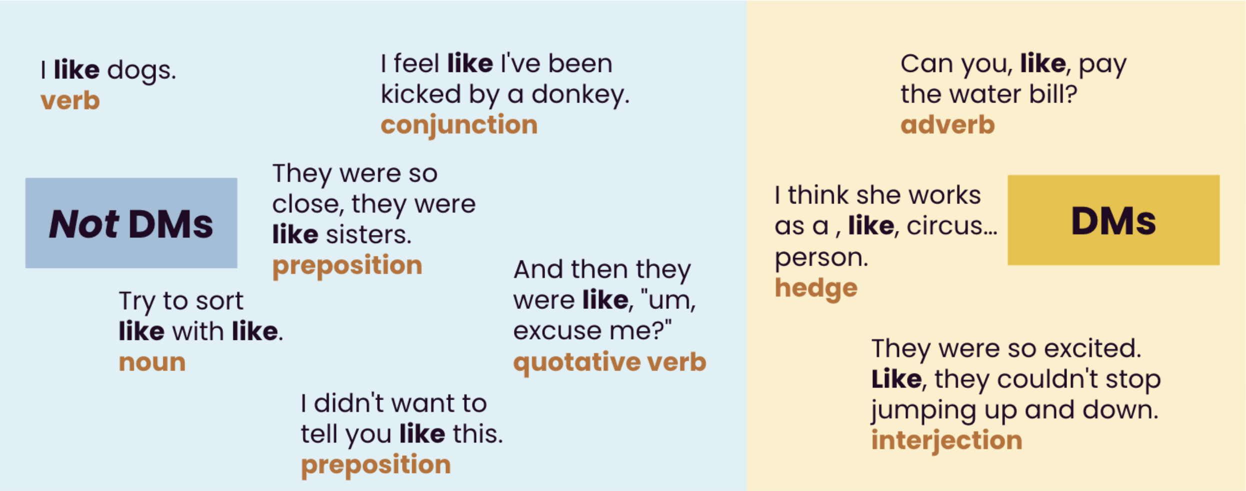

Figure 1. The English word *like* can take on a variety of grammatical roles, including content-providing roles and discourse markers.

Like is a common discourse marker in English, mostly occurring in spoken language. In her 2017 PhD dissertation, Ludivine Crible found that L1 English speakers use an average of 55 DMs per thousand words in casual conversations, many of which were *like*. This frequency changes in different contexts, the highest being an average of 62 DMs per thousand words in phone calls and the lowest being an average of 14 DMs per thousand words in newscasts (Crible, 2017).

Jones et al. (2022) narrows in on the list of possible DM roles for *like*, specifically providing four overarching categories: 1) marking important or new information, 2) marking loose or approximate information, 3) marking reformulated information, or 4) marking quotative information. Many of these roles can also be taken by other DMs, which is why they overlap with previously mentioned roles proposed by scholars for DMs more broadly. Representative examples for Jones's four varieties of *like* are shown below in sentences (13) - (16):

(13) Can you, **like**, pay the water bill? It's due tomorrow. *importance*

(14) I think she works as a, **like**, circus… person. *looseness/approximation*

(15) They were so excited. **Like**, they couldn't stop jumping up and down. *reformulated*

(16) I woke up and was **like**, “uh oh, I did not get enough sleep last night.” *quotative*

Not only do sentences (13) - (15) fit with Jones's definition of a DM, but they more or less fit with the definitions provided by other scholars as well (Fraser, 1999; Fuller, 2003; Hellermann & Vergun, 2007; Jones et al., 2022; Schourup, 1999). We can see that each *like* links two parts of the same thought, bridging a gap that would otherwise be an unfilled silence. We can also see that they fulfill Schourup’s criteria of optionality; they can all be removed from the sentence without changing the grammaticality of the sentence. Sentence (16) notably can*not* remove the *like* and maintain grammaticality, which puts the quotative use of *like* in a slightly different category from the others. The quotative form of *like* is also the only one that cannot be exchanged for a different discourse marker; many DMs including *um* and *well* can mark importance, *I think* and *I guess* commonly mark approximation, and DMs such as *or* and *well* often mark reformulation, but *like* alone can function as a verb in quotative examples. For the purpose of this thesis, I will only be considering *like* DMs that mark importance, looseness, and reformulation, because these are the roles that fit with the majority of criteria proposed by different scholars.

Now that we have established what constitutes *like* as a DM, we can consider how *like* compares to other similar DMs. In their study, Jones et al. specifically investigated *like* usage in autistic versus non-autistic children. Previous literature had suggested that autistic individuals use fewer DMs compared to non-autistic peers, meaning that they are less likely to fill their verbal pauses (Lake et al., 2011). However, Jones hypothesized that *like* functions differently from DMs such as *um* and *uh*, suggesting that while *um* and *uh* seem to be primarily about letting the speaker collect their thoughts, *like* usage is inextricably linked to social elements and how the speaker is trying to be perceived by the listener. Jones found that there was no significant difference in *like* frequencies between autistic and non-autistic children, neither in the total number of *likes* nor in any of the individual categories of *like*. Based on this finding, Jones proposed that *like* plays a large role in how people fit in. *Like* creates in-groups (people who use similar frequencies of *like* as each other) and out-groups (people who use different frequencies). Using the same rate of *like* may help autistic children establish connections with their peers, which is something that is not observed for *um* and *uh* (McGregor & Hadden, 2020). Therefore, *like* seems to be somewhat unique in the way it takes into account the listener rather than being solely used to help the speaker through a verbal stumble. This leaves us with the question: if *like* seems to be more directly linked to the listener than other DMs, does *like* actually benefit the listener's comprehension in any significant way?

2.3. Contributors to Comprehension

There have been many studies on what contributes to listener comprehension (Fong & Ho, 2017; Fung & Macaro, 2021; Shang, 2008). It is generally agreed upon that listening comprehension requires working memory, foundational language skills (i.e., does the listener understand all of the words?), and higher-order cognitive skills, which Fong & Ho (2017) call the “comprehension monitoring” system (i.e., can the listener think about and make sense of what they just heard?). These studies largely focus on comprehension from a psycholinguistic perspective, using both recall tasks on sequences of numbers and single sentences as well as comprehension-inference tasks on short stories in order to model how humans process spoken language. However, a limitation is that they do not take into account the context, formality, or casualness of the situation, and they do not take into account DMs.

There are a number of studies that explicitly look at the impact of DMs. These studies fall into two major categories: DMs and credibility, and DMs and comprehension. In both categories, there is drastic disagreement and conflicting data on whether DMs have a positive, negative, or neutral impact. Conrad et al. (2013) found that telemarketer DM rates impacted the likelihood of the listener to actually sign up for the survey. Specifically, they found that when the telemarketer used zero DMs, only about 3% of the listeners signed up for the survey. By contrast, telemarketers who used $0 <$ DMs per 1000 words ≤ 12.8 had the highest success rate of 36%. This percentage steadily decreased as the frequency of DMs increased, petering out at 12% signing up when telemarketers used > 3.49 DMs per 1000 words. Therefore, it appears that 1) DMs have a significant impact on speaker persuasiveness and credibility, and 2) there is an optimal rate of DMs for certain goals.

On the comprehension side, DMs have been found to both improve and impair understandability of verbal communication. Arnold et al. (2004) used an eye tracking study to follow how the DM *uh* impacts where the listener's attention is directed. Specifically, they found that in sentences without DMs, the listener was biased in favor of looking at the object that had previously been described. However, the presence of a DM biased the listener towards looking at an object that had not previously been mentioned, providing psycholinguistic evidence that DMs can function to prepare the listener for new information. Fox Tree (2001) drew a similar conclusion, finding that *uh* in English and Dutch spoken language has a beneficial effect on the listener's ability to recognize the upcoming word. She also found that *um* had neither a beneficial nor a detrimental effect, supporting the claims that 1) DMs can improve listener comprehension by preparing them for novel information, and 2) different DMs serve different structural roles in the sentence and therefore should be studied independently in order to get a more nuanced understanding of each DM.

In this thesis, I examine how different frequencies of *like* impact listener performance on a comprehension quiz. I combine the methods seen in previous DM studies, crafting an environment for *like* that is less conversational than Conrad et al.'s study on telemarketers, and more organic than Arnold et al. and Fox Tree's word lists. Specifically, this thesis tests the impact of *like* as a topic marker and reformulation marker and asks: if *like* does not change the meaning of a given sentence, how (and when) does it impact listener comprehension of verbal scientific communication?

3 Methods

The data for this study came from a Qualtrics survey made possible by the Swarthmore College Linguistics Department. The survey was limited to 18-25 year olds who self-identify as being comfortable listening to and understanding spoken English. The survey collected no other demographic information. This study was approved by Swarthmore College Linguistics Department's ethics committee, and consent was received from all participants. All responses were anonymous and analyzed in bulk.

Participants were split into three equal groups before taking the survey. All participants were first asked to listen to a 6-minute audio recording, which was in the style of a scientific lecture. Each of the three groups received slightly different audio stimuli, which are described below. Second, participants were asked to provide metacognitive free responses to the following questions: "What are some things you noticed about the audio recording you just listened to? What made the content easy to understand? What made it hard to understand?" and "What does effective science communication sound like?" These free-response questions were included as a filler section so that the participants had a moment between listening to the audio and applying their knowledge. Finally, participants were asked to answer twelve multiple choice questions about the content they had just listened to.

Each audio recording was made of seven sections, with alternating control (zero DMs) and experimental (high, medium, or low rates of DMs) sections (**Figure 2**). The underlying script was constant between the three audio recordings. Specifically, the script described the astrophysics of polycyclic aromatic hydrocarbons, which is a niche scientific concept that was chosen in order to ensure that participants did not have background exposure to the content. All information about polycyclic aromatic hydrocarbons came from an astrophysics PhD student.

The three experimental DMs rates were 10 *like*s per 1000 words, 50 *like*s per 1000 words, and 100 *like*s per 1000 words. These rates were chosen in accordance with Crible's (2017) dissertation, which showed that casual conversations contain roughly 50 DMs per 1000 words. This became the middle DM rate, with additional experimental rates both higher and lower. The order of these three experimental rates varied from recording to recording: audio stimulus A had sections low, then high, then middle, audio stimulus B had sections middle, then low, then high, and audio stimulus C had sections high, then middle, then low.

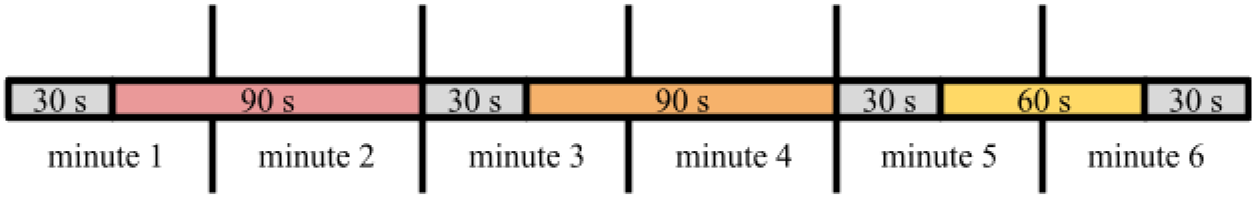

Figure 2. A timeline schematic of audio recordings, with control segments (zero DMs) marked in gray and experimental segments (high, medium, or low rates of DMs) marked in red, orange, and yellow. Each of the three audio stimuli used different orders of the three experimental DM rates.

All *like*s added into the script were topic marker, reformulation, or pause-filling DMs (see Appendix). They are all removable, as evidenced by the fact that different DMs appear in different scripts and the script remains grammatical with zero *like*s. *Like* DMs were added into DM-less scripts in grammatical locations, which were determined by 1) comparing script *like* locations to *like* locations in informal recorded explanations from the astrophysics consultant, and 2) getting casual grammaticality judgements from peers. For each experimental section, the "middle" *like* rate contained *like*s in all the same positions as the "low" rate as well as additional *like*s, and the "high" *like* rate contained *like*s in all the same positions as the "middle" rate as well as additional *like*s. Full transcripts of each script can be found in the Appendix.

Audio stimuli were recorded by two actors from Swarthmore College's Theater Department. One actor recorded audio stimulus A, and the other recorded audio stimuli B and C. To control for speaking speed, a digital teleprompter set at 160 words per minute was used. This ensured that all three recordings were within 9 seconds in length. It also ensured that the actors did not speed up or pause during sections with high frequencies of *like*, which could have been a compounding effect on listener comprehension.

The twelve comprehension questions at the end of the survey each came from a particular part of the audio recording. Specifically, the answer to each question appeared only one time in the audio recording, which allows me to divide up the listener's comprehension for each section individually. The survey included a mix of application questions (e.g., "Suppose you find a PAH with 50 carbon atoms in it. What do you think of its size?") and direct recall questions (e.g., "What do astronomical units measure?").

To analyze these data, I calculated the % correct value for each question for each of the three stimuli. I then separated each stimulus into sections corresponding to zero, low, medium, and high rates of *like*, which I used to analyze how the specific frequency of *like* impacts participant performance on the comprehension task. T-tests were used to determine the statistical significance of comparing % correct values. Detailed descriptions of each analytical step are described in Chapter 4: Results.

Because this study is focused on the impact of *like* on comprehension rather than the perception of *like*, I did not conduct a qualitative analysis on the metacognitive free-response questions. These questions were solely used as filler sections to ensure that the listeners had a moment of pause between listening to the audio stimulus and proceeding into the quiz section. As previously described, DMs including *like* tend to be met with strong, sometimes prescriptivist reactions; the positive, negative, or neutral opinions of the participants with respect to *like* are not of interest so much as the impact of *like* on their quiz performance.

4 Results

4.1. Like Frequency Impacts Performance on Comprehension Task

I received a total of 57 responses, including 18 responses on Stimulus A, 17 responses on Stimulus B, and 22 responses on Stimulus C. Of these responses, 3 responses from Stimulus A and 3 responses from Stimulus C were discarded because they did not complete the study, leaving 51 usable responses. For each question, I averaged the % correct across all responses from the same stimulus, culminating in a value for the % correct for that question for the corresponding DM rate (low, medium, or high). Additional analyses are described below.

Figure 3 shows the % correct for each question, broken down by stimulus (A, B, or C). Questions 1, 2, 6, and 10 contained zero *likes* in any of the audio stimuli. For the other eight questions, each stimulus (A, B, and C) contained a different rate of *like* at the time when the answer to a given question appeared in the audio. A challenge with comprehension-style studies is that there are multiple variables at play. My experimental variable is the changing rate of *like* during different sections of audio in otherwise equivalent audio recordings. This makes % correct values analogous when looking across the three audio recordings for a particular question. However, when comparing trends for % correct across multiple different questions, it is possible that question difficulty plays a role in how people respond to the question: if the question was universally considered too easy or too challenging, then it is possible that the content of the question made participants uniformly get the question correct or incorrect, regardless of the *like* frequency. Therefore, my first step in the analytical process was to remove questions that were not balanced for difficulty. I defined this lack of balance as questions that had ≥90% correct or ≤10% correct for *all three* audio stimuli.

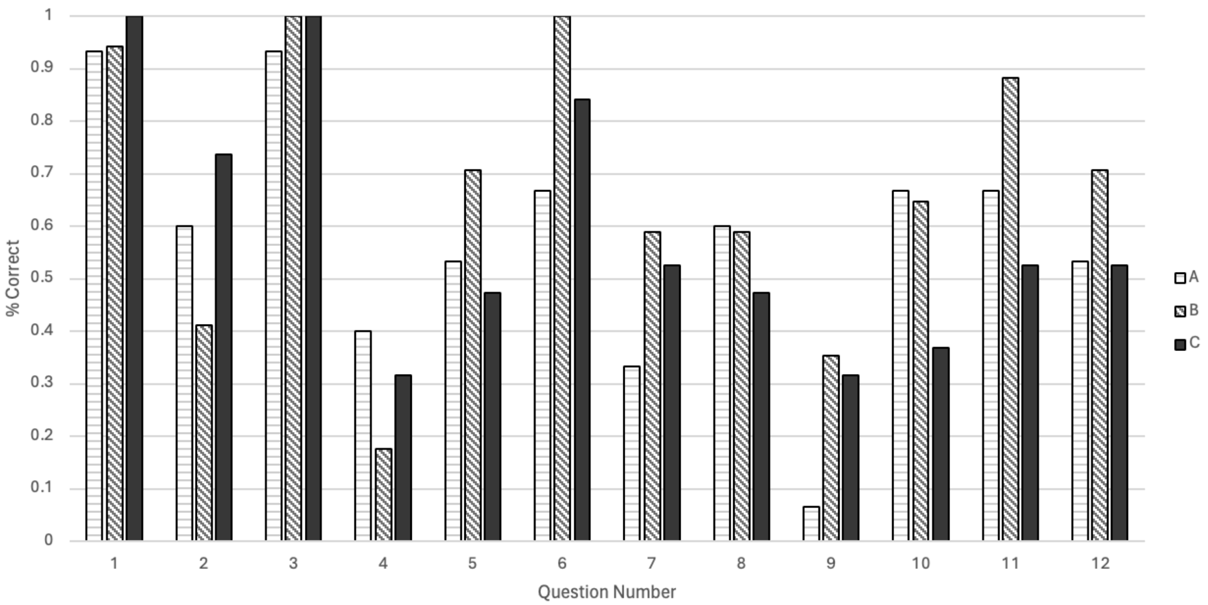

Figure 3. Distribution of % correct for twelve experimental questions across three audio stimuli. Bars of the same color come from the same audio stimulus.

I found that questions 1 and 3 were the only questions that showed a consistent % correct unbalance, and both questions showed overwhelmingly correct answers. Questions 1 and 3 were originally intended to be “sanity check” questions demonstrating that the participants listened to the audio recordings at all, asking “What discipline is this for?” (which should be apparent throughout the whole audio recording), and “What does PAH stand for?” (which was the central subject matter for the audio recording). Therefore, the fact that these questions were universally answered correctly indicates that participants actually did listen and pay attention to the audio stimuli enough to comprehend the core content. Having served their diagnostic role, questions 1 and 3 were omitted from further analyses. All of the other questions showed between 20% and 90% correct, making them of interest for further analysis.

Additionally, we can see in **Figure 3** that although different questions showed different levels of % correct and different variation between the three stimuli for a given question, there is no overarching trend in % correct over *time*. If there were a recency effect, with answers coming from the end of the recording being fresher in the listener's mind than answers from the beginning of the recording, then we would expect to find an upward slope in % correct from question 1 to question 12, regardless of which audio recording it came from. Likewise, if participants consistently listened to only the beginning of the recording before tuning out, then we would expect to find a downward slope in % correct from question 1 to question 12. We find neither trend in this data. Specifically, a linear regression on the average % correct values for each question shows no significant correlation between % correct and the time during the recording at which the answer to the question appeared (**Figure 4**, $R^2 < 0.5$).

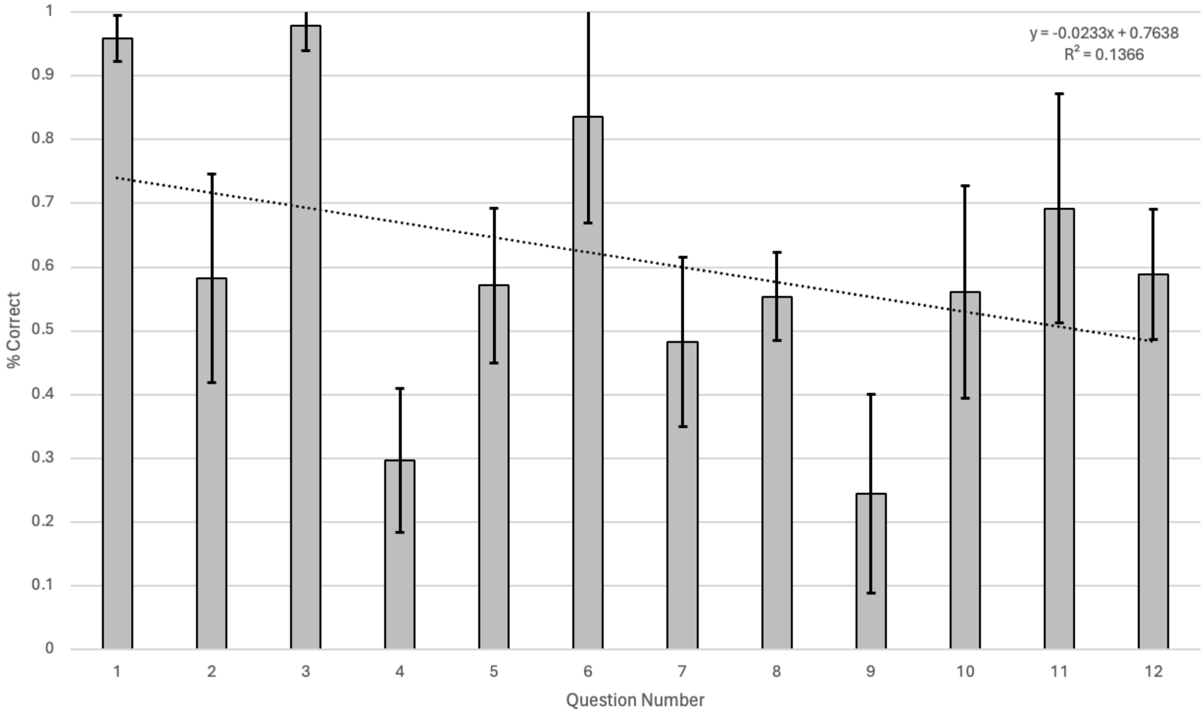

Figure 4. No significant trend exists for average % correct over the recording time ($R^2 < 0.5$). Average % correct values were calculated by averaging the % correct from Stimuli A, B, and C, and were fitted with a linear regression trend line. The answers to the questions appear in order in the audio recordings, with the answer to question 1 appearing before the answer to question 2 and so on.

Next, we can begin to investigate the impact of *like* frequency on % correct. **Figure 5** shows the % correct trends for each *like* rate (zero, low, medium, and high) for each audio stimulus (A, B, and C). It is important to first examine each recording holistically. Each participant is going to have a different approach to their audio stimulus and is going to have a different experience completing the comprehension task. By first comparing % correct for the different frequency regions within the same audio recording, we can see whether the same *people* are getting more questions right or wrong in a given section. We can see that within all three audio stimuli, the % correct for the different *like* frequencies are *not* all identical. Therefore, we can disprove our null hypothesis: there is evidence to support the fact that *like* frequency *does* have an impact on % correct. However, we can see that the magnitude and direction of the impact of different *like* frequencies is not consistent across the three audio stimuli, requiring a more granular approach to analysis.

The study design was such that each experimental (i.e., non-zero *like*) question is posed in a low, a medium, and a high *like* environment across the three audio stimuli. I hypothesized that there is a frequency of *like* such that the % correct will be higher for that frequency, regardless of what question is being asked. In other words, I hypothesized that at some "optimal" *like* rate, participants will pay closer attention to the audio recording and will get more of the questions correct, whether this "optimal" frequency comes at the beginning of the recording, or the middle, or the end, or at a slightly more challenging question, or at a slightly easier question. Therefore, I continued my analysis by asking: if the only variable that matters is the rate of *like* rather than which stimulus or part of the stimulus it came from, then can we see differences in the % correct between these different *like* rates?

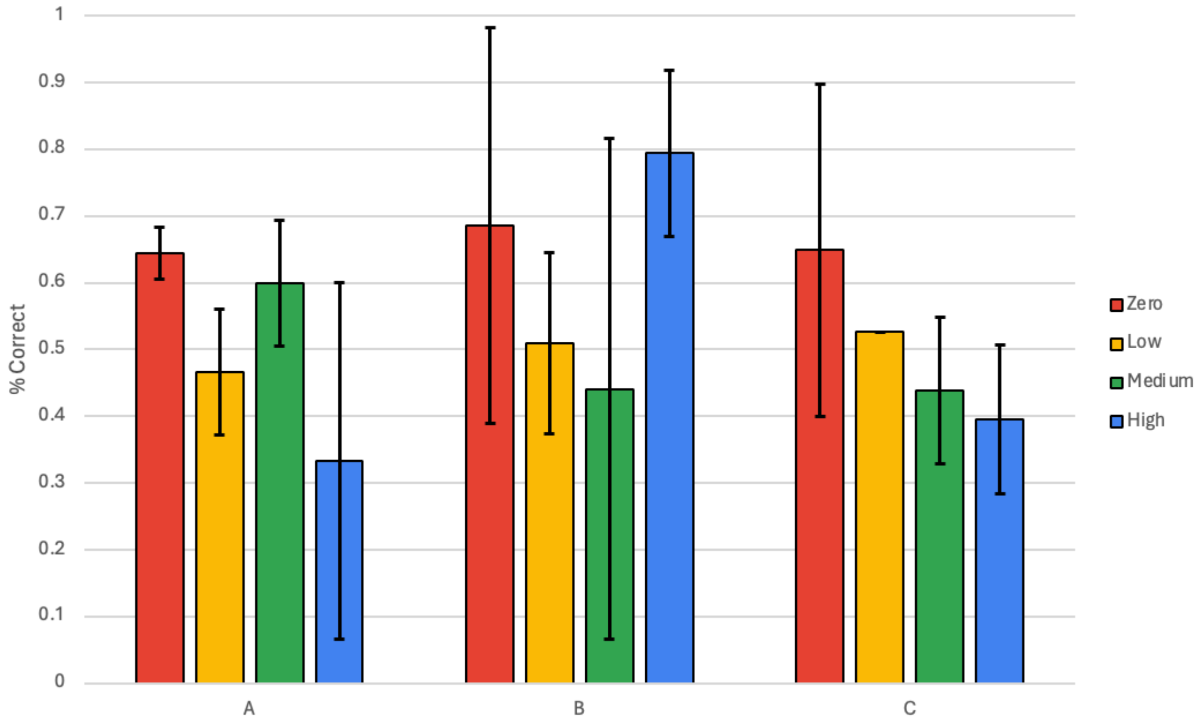

Figure 5. Distribution of % correct for each of the three audio stimuli at each *like* frequency. Each audio stimulus contained the same regions with zero *like*s, and distinct regions that contained each of the three experimental *like* frequencies. Breakdowns of exactly which questions correspond to which *like* frequency for a given audio stimulus can be found in the Appendix. Error bars represent the standard deviations across the averaged questions.

The answer requires a critical interpretation of the data. There is no statistically significant difference in the % correct between zero *like*s (averaged across stimuli A, B, and C) and the high *like* frequency (averaged across stimuli A, B, and C) (unpaired two-tailed t-test, p = 0.3523, **Figure 6**). However, there are statistically significant differences in % correct between zero *like*s and the low frequency (p = 0.0020, **Figure 6**), and between zero *like*s and the medium frequency (p = 0.0387, **Figure 6**), with improved accuracy for the zero *like* frequency. Based simply on these statistical tests, it appears that the zero frequency and the high frequency are equally beneficial for helping participants retain information from the audio recording.

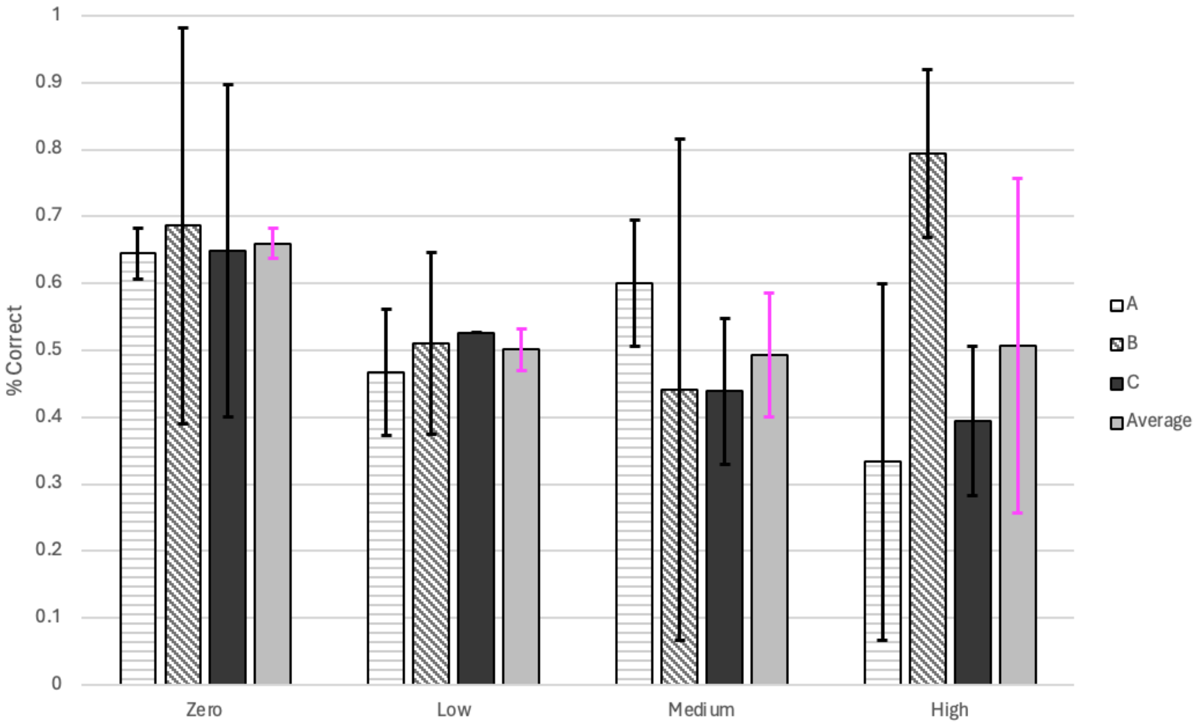

Figure 6. Distribution of % correct at each *like* frequency for each of the three audio stimuli. Error bars for each audio stimulus represent the standard deviations across the averaged questions. Error bars for the average values (shown in pink) represent the standard deviations across the three previous bars for the same *like* frequency.

More insights can be gleaned by examining the standard deviations for each of the *like* frequencies, shown in the pink error bars in **Figure 6**. Specifically, the standard deviation for the medium *like* frequency is nearly ten times larger than the standard deviations for the zero and low *like* frequencies, and the standard deviation for the high *like* frequency is nearly three times larger than that for the medium *like* frequency. Thus, there seems to be more consensus for how participants respond to the zero and low *like* frequencies as opposed to the medium and high *like* frequencies.

One possible interpretation is that participants respond more consistently to *like* frequencies that they are more accustomed to hearing, especially frequencies that they are more accustomed to hearing in academic settings. Ludivine Crible's 2017 dissertation provides evidence that English DMs appear an average of 55 times per thousand words in casual conversations, which is the same as the frequency observed in classroom settings (Crible, 2017). It follows that participants may be less surprised to hear this frequency and therefore have more consistent responses to this frequency of *like*. Fifty-five DMs per thousand words closely aligns with the medium *like* frequency of 50 *like*s per thousand words used in this study. However, it is worth noting that Crible's dissertation did not distinguish between different DMs. Therefore, it is possible that there is actually a slightly lower observed rate of specifically *like*, perhaps corresponding to a frequency in between low and medium. It follows that participants may be accustomed to hearing *like* frequencies that are similar to those found in the low and medium frequency sections, and therefore there is a more predictable response to these frequencies. Scripted speech, on the other hand, typically contains no *like*s, especially scripted speech that is meant to sound professional. The format of a pre-recorded podcast-like audio stimulus may have prejudiced the participants towards expecting zero *like*s, which explains the very low standard deviation for zero *like*s: the participants were hearing the frequency of *like* that they were expecting.

The high *like* frequency is double the average rate of DMs in casual conversations, making it a rate that is out of the range of what most participants likely hear on a regular basis. The large standard deviation for the high *like* frequency demonstrates that participants have varying responses to this frequency, with some participants getting many more questions correct and some participants getting many fewer questions correct. One possible explanation is that this high frequency of *like* causes participants to pay closer attention to the audio recording because they are hearing something out of the ordinary. This closer attention may be paid to the content of the audio recording, getting participants to re-focus on what is otherwise a long and technical audio recording, or it may be paid to the *like*s themselves, serving to distract the listener from the content and cause them to focus on the form.

It is noteworthy that this high *like* frequency is not universally detrimental, as the anti-DM stigma might have predicted. Rather, it seems more accurate to say that lower *like* frequencies cause more predictable effects while higher *like* frequencies cause more variable effects.

4.2. Like Frequency Does Not Cause Significant Differences in Recall Questions

As described in Chapter 2: Methods, I included both recall and application questions in this study. Recall questions are the subset of questions that require solely factual recall of a fact presented in the audio recording. Often these questions use some of the same phrasings as how the information originally appeared in the body of the recording. Application questions require some amount of synthesis of information. Their answers still come from a specific part of the audio recording, but the questions use different phrasing and require the participant to decode which part of the audio recording is most helpful to answer the question. There were six recall questions in this study (shown below), plus the two recall questions that were excluded from analysis as explained in Section 4.1.

Question 2: What year did Cecilia Payne first discover the chemical makeup of stars?

- a) 1842 (definitely before the US Civil War)
- b) 1896 (after the Civil War but before cars were popular)
- **c) 1925 (pretty sure it was during the roaring '20s)**
- d) 1948 (World War 2 was over but we hadn't quite entered the domesticity of the 1950s)

Question 6: How are emission lines measured?

- a) Using the Spitzer Space Telescope, which shows how the light from an Earth-bound telescope interacts with the light emitted from PAHs.
- **b) Using the Spitzer Space Telescope, which measures how much light is emitted by PAHs at different wavelengths.**

c) Using an optical vibrating sensor at Harvard, which shows how the light from an Earth-bound telescope interacts with the light emitted from PAHs.
d) Using an optical vibrating sensor at Harvard, which measures how much light is emitted by PAHs at different wavelengths.

Question 8: How many times bigger is the Milky Way compared to the sun?

a) 10^4 times bigger (the sun is a grain of sand, the diameter of Milky Way is the length of a canoe)
b) 10^8 (the sun is a grain of sand, the diameter of the Milky Way is the width of Rhode Island)
c) 10^{12} times bigger (the sun is a grain of sand, the diameter of the Milky Way is the distance from Earth to the moon)
d) 10^{16} times bigger (the sun is a grain of sand, the diameter of the Milky Way is the distance from Earth to Pluto)

Question 9: What would you expect to find in a protoplanetary disc?

a) Asteroids
b) Planets
c) Stars
d) Empty space, it's between planets

Question 10: What do astronomical units measure?

a) Distance
b) Time
c) Frequency
d) Energy

Question 12: In low metallicity galaxies, what is the ratio of heavy elements to hydrogen & helium?

a) 1:100
b) 1:1,000
c) 1:10,000
d) $1{:}10^{12}$

Figure 7 shows the % correct values for recall questions only. Because this analysis is only looking at a subset of the questions, each stimulus (A, B, and C) only covers three of the four *like* frequencies examined in this study. For example, stimulus A contained recall questions in zero, high, and medium *like* environments, while stimulus B contained recall questions in zero, high, and low *like* frequencies. Cumulatively, all experimental frequencies can be accounted for when looking at all of the data as a whole. As such, data is reported as an aggregate average of all questions using a given *like* frequency.

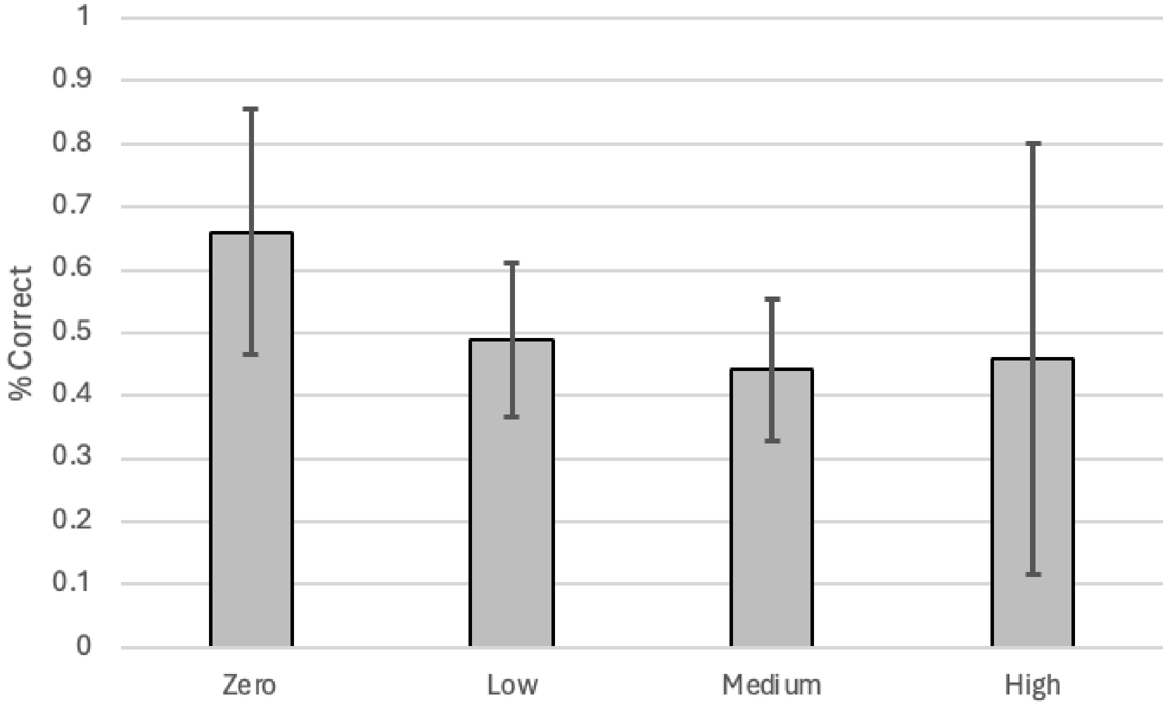

Figure 7. Distribution of % correct for recall questions at each *like* frequency, averaged across all three audio stimuli. Error bars for each audio stimulus represent the standard deviations across the averaged questions.

There are no significant differences in % correct across the different *like* frequencies. Similar to the analysis of all of the questions in section 4.1, we can see that the high frequency has the largest standard deviation that is roughly double the size of the others. Notably, this is a much smaller difference in standard deviation compared to the difference observed in Section 4.1, which showed a ten-fold increase in standard deviation for the high frequency when looking across all types of questions. Therefore, recall questions seem to experience more uniform variability across different *like* frequencies.

Looking specifically at the larger standard deviation for the high frequency, this standard deviation comes from one outlier question in particular. For questions 8 and 12, participants who heard the high frequency at that section got the answer correct 60.0% (stimulus A) and 70.5% (stimulus B) of the time, respectively. On the other hand, for question 9, participants who heard the high frequency (stimulus A) got the question correct only 6.67% of the time.

One possible explanation is that question 9 may be more challenging than the other questions and therefore the sharp decrease in % correct may be due to the difficulty of the question rather than the linguistic environment. However, question 9 reported 35.3% correct at the low *like* frequency and 31.6% correct at the medium *like* frequency, which is still lower than many of the other questions but is significantly different from the 6.67% correct at the high frequency. For each of the other recall questions, the differences between the low, medium, and high frequencies is never more than 18% different, whereas for question 9 there is a difference of 29%. The exact cause of this discrepancy for question 9 is not clear — it is possible that the particular order of the *like* frequencies caused participants for stimulus A to become fatigued right around question 9 while the order of frequencies for stimuli B and C did not experience this fatigue. Regardless, we can see an increased diversity in how participants respond to the high frequency of *like* compared to the lower frequencies, although the increase is not as pronounced as when examining all of the questions as a whole.

4.3. Like Frequency Does Not Cause Significant Differences in Application Questions

Finally, we can consider the impact of *like* frequency on application questions (shown below).

Question 4: Suppose you find a PAH with 50 carbon atoms in it. What do you think of its size?

a) That’s physically impossible, PAHs need to have more carbon atoms than that.
b) It's pretty small, but within the range of typical PAHs.
c) That's average, there are lots of PAHs bigger but also lots of PAHs smaller than that.
d) It’s pretty big, but within the range of typical PAHs.

Question 5: Which of the following is *not* a reason why PAHs are useful to study?

a) They can be used to explain the Bohr model of an atom.
b) PAHs are easy to observe.
c) Their bonds have lots of vibrational frequencies.
d) They can change in size, which changes their properties.

Question 7: Emission lines can tell us about the ionization of PAHs (whether the PAH is missing any electrons), and the size of PAHs (how many rings it has). Which of the following would be a logical conclusion based on the emission lines?

a) PAH #1 is more ionized than PAH #2, which means that PAH #1 must be in a lower energy environment than PAH #2.
b) PAH #1 is more ionized than PAH #2, which means PAH #1 must be in a bigger galaxy than PAH #2.
c) PAH #1 is more ionized than PAH #2, which means PAH #1 is smaller than PAH #2.
d) PAH #1 is more ionized than PAH #2, which means PAH #1 is around more stars than PAH #2.

Question 11: Which of the following compositions of galaxies would you expect to have the *fewest* PAHs?

a) Almost entirely hydrogen and helium
b) A whole lot of hydrogen and helium, some oxygen
c) A whole lot of hydrogen and helium, some oxygen and carbon and lithium
d) A whole lot of hydrogen and helium (but the least amount of hydrogen and helium out of these options), some oxygen, carbon, lithium, nitrogen, iron, and other elements

Figure 8 shows the % correct distributions for application questions only. Similar to recall questions, since we are looking at only a small subset of the data, it is more fruitful to examine averages across all three stimuli rather than first separating by stimulus. There were no application questions that came from a zero *like* section.

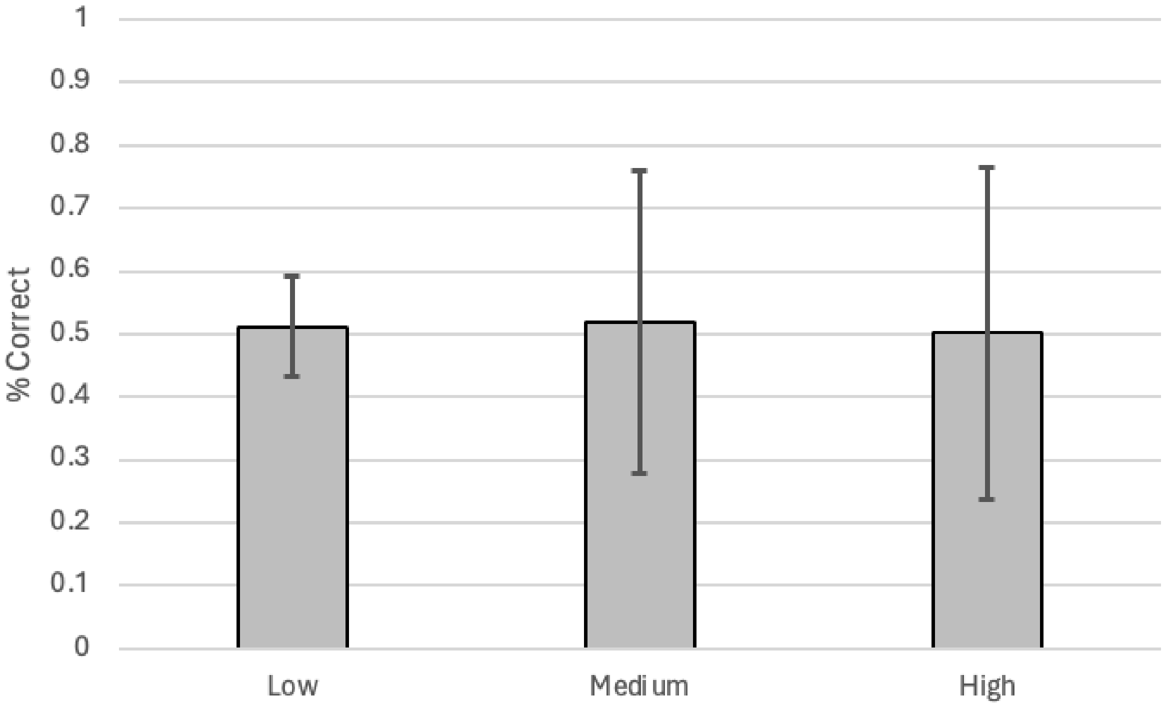

Figure 8. Distribution of % correct for application questions at each *like* frequency, averaged across all three audio stimuli. Error bars for each audio stimulus represent the standard deviations across the averaged questions.

There are no significant differences in the % correct between low, medium, and high *like* frequencies. Additionally, medium and high frequencies have nearly identical standard deviations, each about three times larger than the standard deviation for the low frequency. This finding corroborates our previous interpretation that lower *like* frequencies elicit more standardized responses from listeners.

5 Conclusions and Future Directions

Perceptions of discourse markers, including *like,* tend to be contentious in academic or other formal spaces. In this study, I examined the impact of different rates of *like* on the accuracy of participant comprehension of spoken content. I found that participants on average performed slightly better on questions coming from zero and high *like* frequency sections compared to the low and medium *like* frequency sections. When looking just at recall questions or just at application questions, there were no significant differences between the performance of participants at the different *like* frequencies. Therefore, it appears that on average, *like* frequency has only a minimal effect on the ability of a listener to understand the auditory science communication.

Studying average scores is helpful because averages allow us to see general trends across a task that might be extremely individual-specific. If no significant differences were found across any form of analysis, then it might be said that there is no universal response to *like*s and that there is no way to generalize how *like* impacts listener comprehension. However, even across all of the individual experiences of the participants, there were still significant, consistent trends in the standard deviations for accuracies at each of the experimental *like* frequencies. Specifically, increasing *like* frequencies (high) showed larger standard deviations on average than lower *like* frequencies (zero, low). Thus, the data suggest that there is a more uniform response to lower *like* rates compared to higher *like* rates, even though the averaged accuracies are nearly identical.

In this thesis, I propose that these differences in standard deviations can be attributed to familiar and unfamiliar *like* rates. It might be expected that scripted audio media contain zero *like*s, which accustoms listeners to hearing the zero *like* frequency. Likewise, it has been shown that casual English conversations contain a rate of *like*s that is close to the low and medium frequencies, which accustom listeners to these other lower rates. On the other hand, the high frequency is much higher than one would expect to find in a casual conversation or other everyday setting, causing listeners to pay extra attention to the high frequency audio segment, with either positive or negative effect. Therefore, rather than having a consistent impact on the accuracy of the listener, different rates of *like* seem to have different levels of consistent versus variable effects on listeners. This was also the case when looking at only recall questions or only application questions.

There are challenges with conducting quantitative analyses on such contentious and individual-dependent topics. One challenge is with sample size. For some of the smaller data subsets, including just recall questions or just application questions, each *like* frequency contained only three or four data points, giving each question considerable weight in calculating the standard deviation. To a certain extent, this problem could be mitigated by asking more questions in the comprehension task. Currently one question is posed based on every 30 seconds of audio. To get more questions, a future study could increase the length of the stimulus audio recording or increase the density of questions, posing one question based on each 10 or 20 seconds of audio instead. However, it is possible that recency effects may be more present for longer audio recordings, which would need to be accounted for in the analysis process. Another solution would be to include more participants, which would help generalize the trends.

Finally, it is worth considering to what extent these observed trends are due to *like* compared to other DMs or even other repeated sounds. McGregor & Hadden (2020) found that *like* functions differently than *um* when studying DMs with autistic children. Therefore, I hypothesize that *like* has a different impact on listener comprehension in casual academic spaces compared to other DMs. In addition to the linguistic differences described by McGregor &

Hadden, I also propose that *like* functions differently because it is so socially charged. While linguistically *like* seems to be used to accommodate the audience more than other DMs, which may cause listener comprehension to improve in some settings, *like* is also highly stigmatized and weaponized, which may socially cause listeners to tune out. Future studies should repeat these same methods but exchange the *like*s for other DMs such as *um*, or even for non-DMs such as throat clearing or lip smacking. If we can compare the results of identical scientific scripts with these different experimental variables, we will be able to draw deeper conclusions about the role of *like* in science communication as compared to other forms of repetitive speech behaviors. How much of *like*'s impact comes from its linguistic role as a marker of importance? How much of *like*'s impact comes from its repetition? And how much of *like*'s impact comes from the social stigma that surrounds specifically *like* as opposed to other similar DMs?

Acknowledgements

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Appendix

SCRIPT			QUESTIONS
Picture yourself in the 17th century. You're looking up at the night sky. It's dark outside, there are no city lights, maybe there's a breeze coming through the trees. You might see the moon, or a comet, or a constellation — it's the 17th century, you know what constellations are. But you don't know what stars are made of, or even really what a galaxy is. In 1925 a PhD student at Harvard named Cecilia Payne first discovered the chemical makeup of stars. Since then, astrophysics research has exploded.			1) What discipline is this for? **a) Astrophysics** b) Biology c) Chemistry d) Poetry 2) What year did Cecilia Payne first discover the chemical makeup of stars? a) 1842 (definitely before the US Civil War) b) 1896 (after the Civil War but before cars were popular) **c) 1925 (pretty sure it was during the roaring '20s)** d) 1948 (World War 2 was over but we hadn't quite entered the domesticity of the 1950s)
A *10/1000 → 2 LIKES* What *I* do is I study the relationship between polycyclic aromatic hydrocarbons and metallicity in nearby dwarf galaxies. What does this mean? Well poly means multiple, and cyclic means cycles, or **LIKE** circles. So it's multiple rings within one molecule. Hydrocarbons are molecules that only contain carbon and hydrogen atoms, so you have rings of carbon	B *50/1000 → 12 LIKES* What *I* do is **LIKE** I study the relationship between polycyclic aromatic hydrocarbons and metallicity in nearby dwarf galaxies. What does this mean? Well poly means multiple, and cyclic means cycles, or **LIKE** circles. So it's **LIKE** multiple rings within one molecule. Hydrocarbons are molecules that only contain carbon and hydrogen atoms, so **LIKE** you have rings of carbon	C *100/1000 → 25 LIKES* What *I* do is **LIKE** I study the relationship between polycyclic aromatic hydrocarbons and metallicity in nearby dwarf galaxies. What does this **LIKE** mean? Well poly means **LIKE** multiple, and cyclic means cycles, or **LIKE** circles. So it's **LIKE** multiple rings within **LIKE** one molecule. Hydrocarbons are molecules that only contain carbon and	3) What does PAH stand for? a) Polymer Allosteric Hyperbola b) Powerfully Analogous Hoop c) Pseudo- Absolute Hydrogen **d) Polycyclic Aromatic Hydrocarbon** 4) Suppose you find a PAH with 50 carbon

atoms linked together. Aromatic means that there are alternating double and single bonds in the ring. This is what polycyclic aromatic hydrocarbons are, what PAHs are. There can be anywhere from 50 to 500 carbon atoms in a PAH. We choose to study PAHs for three main reasons. They can change in size. They're easy to observe. They also have lots of vibrational lines. The baseline concept in quantum physics is that the world exists in quantized amounts. If you think about **LIKE** the Bohr model of an atom, you have your nucleus in the middle and your electrons going around like planets. This isn't the best model, but it shows how electrons can be in one energy level or the next energy level, but not in between. This is what quantized means. And this is true for vibrations as well. So in a hydrocarbon ring of a PAH, the bonds between the carbons act as springs, and their vibrational frequencies are quantized, so you can have this frequency or that frequency but not in the middle. Some of the PAH vibrational features occur at 3.3, 7.7, and 11.3 microns.	atoms linked together. Aromatic means that there are alternating double and single bonds in the ring. This is what polycyclic aromatic hydrocarbons are, **LIKE** what PAHs are. There can be anywhere from 50 to **LIKE** 500 carbon atoms in a PAH. We choose to study PAHs for three main reasons. They can change in size. They're easy to **LIKE** observe. They also have lots of vibrational lines. The baseline concept in quantum physics is that the world exists in quantized amounts. **LIKE** If you think about the Bohr model of an atom, you have your nucleus in the middle and your **LIKE** electrons going around like planets. This isn't the best model, but it shows how electrons can be in one energy level or the next energy level, but not **LIKE** in between. This is what quantized means. And this is true for vibrations as well. So **LIKE** in a hydrocarbon ring of a PAH, the bonds between the carbons act as springs, and their vibrational frequencies are quantized, so **LIKE** you can have this frequency or that frequency but not in the middle. Some of the PAH vibrational features occur at 3.3, 7.7, and 11.3 microns.	hydrogen atoms, so **LIKE** you have rings of **LIKE** carbon atoms linked together. Aromatic means that there are **LIKE** alternating double and single bonds in the ring. This is what polycyclic aromatic hydrocarbons are, **LIKE** what PAHs are. There can be anywhere from 50 to **LIKE** 500 carbon atoms in a PAH. We choose to study PAHs for **LIKE** three main reasons. They can change in size. They're easy to **LIKE** observe. They also have lots of **LIKE** vibrational lines. The **LIKE** baseline concept in quantum physics is that the world exists in quantized amounts. **LIKE** If you think about the Bohr model of an atom, you have your **LIKE** nucleus in the middle and your **LIKE** electrons going around like planets. This isn't **LIKE** the best model, but it shows how electrons can be in one energy level or **LIKE** the next energy level, but not **LIKE** in between. This is what quantized means. And this is true for vibrations as well. So **LIKE** in a hydrocarbon ring of a PAH, the bonds between the carbons act as **LIKE** springs, and their vibrational frequencies are quantized, so **LIKE** you can have this frequency or that frequency but not in the middle. Some of the PAH vibrational **LIKE** features occur at 3.3, 7.7, and 11.3 microns.	atoms in it. What do you think of its size? a) That's physically impossible, PAHs need to have more carbon atoms than that. **b) It's pretty small, but within the range of typical PAHs.** c) That's average, there are lots of PAHs bigger but also lots of PAHs smaller than that. d) It's pretty big, but within the range of typical PAHs. 5) Which of the following is *not* a reason why PAHs are useful to study? **a) They can be used to explain the Bohr model of an atom.** b) PAHs are easy to observe. c) Their bonds have lots of vibrational frequencies. d) They can change in size, which changes their properties.

<table>
<tr>
<td colspan="3">When the bonds vibrate, this releases energy and corresponds to light. We know that PAHs can only vibrate at very specific frequencies, and since frequency corresponds to wavelength, that means PAHs can only release light at very specific wavelengths. So, we can use spectroscopy to measure how much light is being emitted at each wavelength, which can tell us about how those PAHs are vibrating. In this case, we use a spectrograph on the Spitzer Space Telescope to measure how much light is emitted at the different wavelengths, revealing what are called emission lines.</td>
<td>6) How are emission lines measured?

a) Using the Spitzer Space Telescope, which shows how the light from an Earth-bound telescope interacts with the light emitted from PAHs.
b) Using the Spitzer Space Telescope, which measures how much light is emitted by PAHs at different wavelengths.
c) Using an optical vibrating sensor at Harvard, which shows how the light from an Earth-bound telescope interacts with the light emitted from PAHs.
d) Using an optical vibrating sensor at Harvard, which measures how much light is emitted by PAHs at different wavelengths.</td>
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<td>A
<i>100/1000 → 21 LIKES</i>
Just like how the wavelength of light corresponds to LIKE how fast the PAHs are vibrating, emission lines can LIKE tell us about two main properties of PAHs. First is the ionization of the PAHs, which tells us LIKE whether the PAH is missing electrons. The second property is the size of the PAH, LIKE how many rings it has. These two properties can tell us LIKE a lot about the environment that the PAHs LIKE live in. For example LIKE if you have more ionized PAHs than unionized PAHs, that means you're in LIKE a high energy place because to get ionized you LIKE</td>
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<td>C
<i>50/1000 → 10 LIKES</i>
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<td>7) Emission lines can tell us about the ionization of PAHs (whether the PAH is missing any electrons), and the size of PAHs (how many rings it has). Which of the following would be a logical conclusion based on the emission lines?

a) PAH #1 is more ionized than PAH #2, which means that PAH #1 must be in a lower energy environment than PAH #2.
b) PAH #1 is more ionized than PAH #2, which means PAH #1 must be in a bigger galaxy than PAH #2.
c) PAH #1 is more ionized than PAH #2, which means PAH #1 is smaller than PAH #2.
d) PAH #1 is more</td>
</tr>
</table>

need energy to come in and knock the electrons out, so if you have **LIKE** a lot of ionized PAHs, it's probably because you're around a lot of stars and it's **LIKE** a very energetic area in a galaxy. Galaxies are huge. The Milky Way is **LIKE** ten to the twelfth times more massive than **LIKE** the sun, and some galaxies can be up to **LIKE** thirty times more massive than that. PAHs can be **LIKE** pretty much anywhere, so **LIKE** knowing about the conditions of the environment can actually **LIKE** help us map out space. PAHs are in between stars, they're **LIKE** near stars, they're far away from stars, they're in **LIKE** protoplanetary discs which are **LIKE** the discs around stars that make planets. They're **LIKE** everywhere.	ionized PAHs, it's probably because you're around a lot of stars and it's a very energetic area in a galaxy. Galaxies are huge. The Milky Way is ten to the twelfth times more massive than the sun, and some galaxies can be up to thirty times more massive than that. PAHs can be pretty much anywhere, so knowing about the conditions of the environment can actually **LIKE** help us map out space. PAHs are in between stars, they're near stars, they're far away from stars, they're in protoplanetary discs which are the discs around stars that make planets. They're everywhere.	knock the electrons out, so if you have **LIKE** a lot of ionized PAHs, it's probably because you're around a lot of stars and it's a very energetic area in a galaxy. Galaxies are huge. The Milky Way is **LIKE** ten to the twelfth times more massive than the sun, and some galaxies can be up to **LIKE** thirty times more massive than that. PAHs can be pretty much anywhere, so knowing about the conditions of the environment can actually **LIKE** help us map out space. PAHs are in between stars, they're near stars, they're far away from stars, they're in **LIKE** protoplanetary discs which are **LIKE** the discs around stars that make planets. They're everywhere.	**ionized than PAH #2, which means PAH #1 is around more stars than PAH #2.** 8) How many times bigger is the Milky Way compared to the sun? a) 10^4 times bigger (the sun is a grain of sand, the diameter of Milky Way is the length of a canoe) b) 10^8 (the sun is a grain of sand, the diameter of the Milky Way is the width of Rhode Island) **c) 10^{12} times bigger (the sun is a grain of sand, the diameter of the Milky Way is the distance from Earth to the moon)** d) 10^{16} times bigger (the sun is a grain of sand, the diameter of the Milky Way is the distance from Earth to Pluto) 9) What would you expect to find in a protoplanetary disc? a) Asteroids **b) Planets** c) Stars d) Empty space, it's between planets
And we know a lot about PAHs. We know PAHs are really good at cooling things down because there are lots of places where electrons can get caught and then break off, which releases heat. We know that in order for a star to form you need to take a bunch of super hot dust and gas and cool it off enough for gravity to take over so it can actually collapse into a star. Once the diameter is about 10,000 astronomical units, or about 1 trillion miles, the star starts forming. So we can hypothesize that if there are more PAHs around, more stars will likely form there.			10) What do astronomical units measure? **a) Distance** b) Time c) Frequency d) Energy
A *50/1000 → 8 LIKES* One major thing we **LIKE** *don't* know is how PAHs are created and destroyed in the first	B *100/1000 → 16 LIKES* One major thing we **LIKE** *don't* know is how PAHs are created and destroyed in the first place. We've	C *10/1000 → 2 LIKES* One major thing we **LIKE** *don't* know is how PAHs are created and destroyed in the first	11) Which of the following compositions of galaxies would you expect to have the *fewest* PAHs?

place. We've noticed that PAHs aren't really in low metallicity galaxies, which is unexpected because **LIKE** they can be pretty much anywhere. In astrophysics, a metal is **LIKE** anything heavier than helium, so hydrogen and helium are not metals and then **LIKE** everything else counts as a metal, so low metallicity galaxies are galaxies that contain very few heavy elements or more than **LIKE** 10,000 times more hydrogen and helium than metals. And we see that PAHs tend to scale with metallicity, so **LIKE** when there's higher metallicity there are more PAHs, and when there's lower metallicity there are fewer PAHs. And there are **LIKE** a bunch of possible explanations for this. One thought is that maybe PAHs aren't really formed in the first place, because **LIKE** if these galaxies are mostly hydrogen and helium, maybe there's not enough carbon to make these carbonaceous molecules.	noticed that **LIKE** PAHs aren't really in low metallicity galaxies, which is unexpected because **LIKE** they can be pretty much anywhere. In astrophysics, a metal is **LIKE** anything heavier than helium, so **LIKE** hydrogen and helium are not metals and then **LIKE** everything else counts as a metal, so **LIKE** low metallicity galaxies are galaxies that contain very few heavy elements or **LIKE** more than 10,000 times more hydrogen and helium than metals. And **LIKE** we see that PAHs tend to scale with metallicity, so **LIKE** when there's higher metallicity there are **LIKE** more PAHs, and when there's lower metallicity there are fewer PAHs. And there are **LIKE** a bunch of possible explanations for this. **LIKE** One thought is that maybe PAHs aren't really formed in the first place, because **LIKE** if these galaxies are mostly hydrogen and helium, maybe there's **LIKE** not enough carbon to make these **LIKE** carbonaceous molecules.	place. We've noticed that PAHs aren't really in low metallicity galaxies, which is unexpected because they can be pretty much anywhere. In astrophysics, a metal is anything heavier than helium, so hydrogen and helium are not metals and then everything else counts as a metal, so low metallicity galaxies are galaxies that contain very few heavy elements or more than 10,000 times more hydrogen and helium than metals. And we see that PAHs tend to scale with metallicity, so when there's higher metallicity there are more PAHs, and when there's lower metallicity there are fewer PAHs. And there are a bunch of possible explanations for this. One thought is that maybe PAHs aren't really formed in the first place, because **LIKE** if these galaxies are mostly hydrogen and helium, maybe there's not enough carbon to make these carbonaceous molecules.	**a) Almost entirely hydrogen and helium** b) A whole lot of hydrogen and helium, some oxygen c) A whole lot of hydrogen and helium, some oxygen and carbon and lithium d) A whole lot of hydrogen and helium (but the least amount of hydrogen and helium out of these options), some oxygen, carbon, lithium, nitrogen, iron, and other elements 12) In low metallicity galaxies, what is the ratio of heavy elements to hydrogen & helium? a) 1:100 b) 1:1,000 **c) 1:10,000** d) $1:10^{12}$
Or, it's possible that PAHs are still formed, but then they're broken down really quickly. Low metallicity environments tend to have a lot of new stars, and new stars tend to be more energetic than old stars, so maybe all this energy is just breaking down the PAHs as soon as they're formed. There's a lot that we still don't know about PAHs. There's a lot that we still don't know about *space*. But at least we're narrowing in on what questions to ask next.			

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